

July 21, 1959

To the Graduate Council:

I am submitting herewith a thesis written by Joshua Joseph Fenn entitled "The Use of a Flail-Type Forage Harvester as a Hay Conditioner." I recommend that it be accepted for eighteen quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

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THE USE OF A FLAIL TYPE FORAGE HARVESTER
AS A HAY CONDITIONER

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Joshua Joseph Fenn

August 1959

28
33

ACKNOWLEDGEMENT

The author wishes to express his deep appreciation to Dr. Clarence W. Bockhop for his help and guidance in conducting this research work and in getting it written in its final form.

The author also wishes to express his appreciation to Mr. Houston Luttrell for the valuable help he rendered without which the work would have been much more difficult to carry out.

Thanks are due to Mrs. Adina Smith for her patience in reading the manuscript and for the trouble she took in typing the thesis.

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CHAPTER I

INTRODUCTION

Haymaking

Hay is the most important harvested roughage for livestock throughout the world. Heavy losses of feeding value in hay occur every year due to improper curing or storing. According to Morrison¹ these losses are far greater than those in any other agricultural crop. These losses can be prevented to a great extent by efficient methods of haymaking.

The importance of the hay crop in the United States is shown by the fact that over 100,000,000 tons of hay are made a year from an average of about 73,800,000 acres. This annual hay crop has a farm value of nearly two billion dollars.²

What makes high quality hay?

To be of high quality, hay should be made from plants cut at a sufficiently early stage of maturity. It should be cured and handled so that it is leafy and green in color. The stems should be soft and pliable. Such hay is more nutritious and palatable and has a much higher feeding value per ton. In fact, there may be far more difference in actual value per ton between good and poor hay of any particular kind than there is between the different kinds of hay made from the various common hay crops.³

¹Frank B. Morrison, Feeds and Feeding (22nd. ed.; Ithaca, New York: The Morrison Publishing Company, 1957), p. 253.

²Loc. cit.

³Loc. cit.

The federal hay grades, by which hay is sold on the larger markets in the United States, are based on the qualities which good hay should have. A three-year study was made by the New Jersey Station and a two-year study by the New York Station, to secure information on the grades of hay actually produced in north-eastern farms. In these studies 2,567 samples of hay, mostly first cutting were secured from farmers' barns during the winter feeding season and graded according to the official United States hay grades. On the average, 20 per cent of the lots of hay graded No. 1 (excellent hay); 45 per cent, No. 2 (fairly good hay); 19 per cent, No. 3 (rather poor hay); and 16 per cent, Sample grade.⁴

These and other studies show the need for improvement in haymaking, in order to secure the maximum feeding value from this important crop. Proper curing to retain leafiness and green color, and storing only when the moisture has been reduced to a safe level are among the chief factors for producing high quality hay.⁵

The great difference in feeding value between good hay and poor hay was shown in experiments by the United States Department of Agriculture with dairy heifers. During two winters one group of heifers was fed on good alfalfa hay, U. S. No. 1 or 2, containing 23 to 27 per cent fiber. Another group was fed poor alfalfa hay, U. S. No. 3, having 33 to 34 per cent fiber. The heifers fed on the good hay gained 28 per cent more and required 12 per cent less hay per 100 pounds gain than those

⁴Loc. cit.

⁵Ibid., p. 254.

fed on the poor hay.⁶

Good and poor hay were also compared in a trial by the Ohio Station with steers full-fed on corn-and-cob meal plus 1.5 pounds of soybean oil meal per head daily. Though these cattle, liberally fed on concentrates, did not eat an average of more than two pounds of hay a day, nevertheless the quality of the hay made a difference of 0.3 pound in the average daily gain. The difference in actual feeding value between the good and the poor hay was far greater than the \$7.50 per ton difference in cost.⁷

The percentage of protein, the digestibility, and the content of minerals and vitamins all decrease decidedly as hay crops advance in stage of growth.⁸ When one has a large acreage of hay, it is necessary to start haying early enough to finish it before the last of the crop gets too mature. This calls for an efficient and rapid method of haymaking.

Field curing of hay

The primary object in haymaking is to dry the green plants enough so that the hay can be safely stored without heating unduly or becoming moldy. The water content must be reduced to not more than 25 per cent for hay to keep safely in barn or stack. If the hay is baled at the time of storage, the moisture content should not be over 22 per cent. Hay containing too much moisture when stored, will undergo pronounced fermentation and become very hot. The value may be greatly decreased because

⁶Loc. cit.

⁷Loc. cit.

⁸Loc. cit.

of mold or the losses of nutrients which occur in the extensive fermentations. There is also the danger of spontaneous combustion when hay is stored with too much moisture.⁹

A practical method used by farmers to find out when hay is cured sufficiently for storage is to twist a wisp of it in the hands. If the stems are slightly brittle and there is no evidence of moisture when the stems are twisted, the hay is ready to be stored. In excellent curing weather the hay may appear drier than it actually is, especially if cured chiefly in the swath.¹⁰ Testing by this method requires a lot of experience and under different weather conditions it may not be possible to predict the moisture content with sufficient accuracy.

Losses of nutrients

The losses that occur in haymaking are:

- (1) losses of leaves and other finer parts by shattering
- (2) losses by fermentation and bleaching; and
- (3) losses of soluble nutrients by leaching, in case of heavy rains.¹¹

✓ The leaves of legume hay dry out much faster than the stems, and if they become dry and brittle they shatter badly when the hay is raked or otherwise handled. This loss of leaves is serious, for the leaves contain two to three times as much protein as do the stems. They also

⁹Ibid., p. 255.

¹⁰Loc. cit.

¹¹Ibid., p. 256.

contain most of the carotene and other vitamins, are much richer in minerals, and have much less fiber. The proportion of leaves, therefore, is one of the most important factors in determining the feeding value of any particular lot of hay.¹²

If the hay does not dry fast enough and has to be left longer, fermentations take place in which some of the organic nutrients, especially the sugars and starch, are oxidized to carbon dioxide and water, and thus lost. Fermentation has also a very destructive effect on the carotene in the hay.¹³

Long exposure to the sun will badly bleach the hay resulting in nearly all the carotene being lost. In general, the amount of carotene in hay is proportional to the greenness in color.¹⁴

The losses by fermentation do not cease when hay is stored in the barn. If the hay is well dried and does not heat unduly in the mow, the loss of dry matter in barn storage for six months will usually not exceed 5 to 7 per cent. When hay is under-cured and molding or severe heating occurs the loss is much greater.¹⁵

The total loss of nutrients in hay during field curing and subsequent storage will vary widely. In fairly good haymaking weather and with proper methods, the total loss of dry matter from the green crop

¹²Loc. cit.

¹³Loc. cit.

¹⁴Ibid., p. 257.

¹⁵Loc. cit.

to the manger should not exceed 20 to 30 per cent for legume hay and 10 to 15 per cent for grass hay.¹⁶

Hay conditioners

✓ To reduce field losses to a minimum it is necessary to dry the hay as fast as possible without spoiling its quality. It is also important that both the leaves and stem dry at the same rate, so that at the time of baling they have the same moisture content and the leaves do not shatter. It takes two to four days to dry hay to 20 per cent moisture by merely leaving it mowed on the field, depending upon the nature of the forage and the weather.¹⁷ If a sufficient time is given for the stems to be dry enough for the storage, half or more of the leaves can be lost by shattering. Leaves contain two to three times as much protein as the stems and also most of the carotene and other vitamins and minerals.¹⁸

Unfavorable weather during the forage harvesting season causes large quantities of forage to spoil or deteriorate in quality. The frequency of rain during this season increases the risk of spoilage. Any process or operation which would reduce the period the forage has to be cured in the field is of importance to the farmer.

Considerable progress has been made during the last few years in

¹⁶Ibid., p. 257.

¹⁷P. John Zachariah, K. C. Elliot and R. A. Phillips, Performance of Forage Crushers, (Bulletin 418, West Virginia University Agricultural Experiment Station, Morgantown, June 1958).

¹⁸Frank B. Morrison, op. cit., p. 256.

developing hay conditioners which speed up the field drying rate of forages. According to Allan Keith Lawrence,¹⁹ before 1930 the Cushman Engineering Company, Riverside, California, developed the idea of crushing the stems of hay to reduce the field curing time. A power mower-and-crusher was designed and constructed by Mr. E. B. Cushman, in cooperation with the Food Machinery Corporation of San Jose, California. It was tested by the California Agricultural Experiment Station at Davis, California.²⁰ In 1932 the Agricultural Engineering Department of the Mississippi Experiment Station started building a crusher and completed it in 1933.²¹ An improved crusher was constructed by the same station in 1940.²² Experimental and development work with various crushers continued and led to the production of the present commercial models.

A hay conditioner cracks, partially breaks, or kinks the stems, opening up the moist inner parts of the stems so that they will come in direct contact with the air. As a result, the stems dry rapidly at almost the same rate as the leaves. This speeds up the haying operation by shortening the field curing period which decreases weather hazard, helps to conserve the feeding value, retains better color, and in general makes for better hay. More leaves and branch stems are saved because the stems dry before the leaves dry to the shattering point.

¹⁹Allan Keith Lawrence: Some Engineering Investigations on the Crushing and Field Curing of Hay (Master's thesis, Rutgers University, New Brunswick, New Jersey, January 1952).

²⁰Loc. cit.

²¹Loc. cit.

²²Loc. cit.

Most farm trials, as well as those at experiment stations, show that the hay conditioner will reduce field drying time by around 50 per cent in good haying weather.²³ The principle of the several machines now on the market is simple. The hay is picked up, passed through a pair of rollers which may be smooth or corrugated, and dropped back on the stubble, with the stem tissue cracked or crimped just enough to let moisture within the stem evaporate quickly. The sap will not flow out if the machine rollers are properly adjusted; thus, no nutrients are lost. With the inner parts of the stem exposed to the air, they dry more nearly at the same time as the leaves, which normally dry far ahead of the stems in uncrushed hay.²⁴

Commercial hay conditioners may be divided into two general groups - the smooth roller and the fluted roller. The smooth roller crushes and cracks the stems while the fluted roller crimps the stems. The corrugated rollers mesh together like gear teeth.

The hay conditioner is a pto powered implement and is hitched on to the drawbar and employs the hydraulic system of the tractor for the control of the conditioner. A two-plow tractor will easily handle the hay conditioner at good mowing speeds of five to seven miles per hour. As the conditioner passes over the mowed hay, a floating rotary pick-up feeds the hay into two steel rolls that crush the stems. The hay is slightly fluffed by the operation and dropped back loosely on the ground to provide ventilation for fast drying. The rollers have an

²³"Hay Equipment," American Agricultural Reports (File: 20.66).

²⁴Loc. cit.

adjustable pressure tension screw to permit adjustment of the roller tension to accommodate different crops.

The crushing action of the two types of rollers is slightly different. The smooth roller machine crushes the stems uniformly throughout their length while the fluted roller crimps the stems at 0.5 to 2 inch intervals. The increased rate of moisture removal in the latter case is accomplished by moisture travelling along the lengths of the unbroken stems to these ruptures.

Experiments show²⁵ that both types of conditioners work best when crushing is done shortly after mowing. It has also been shown that the quality of crushed hay is better than uncrushed hay. More nearly uniform drying of stems and leaves reduces the loss of leaves by shattering during raking and baling operations. Carotene content in crushed hay at the time of baling and after five months of storage was reported to be 20 to 50 per cent higher than uncrushed hay which was field cured to the same moisture level.²⁶ Crushing of the thick and woody stems makes the hay more palatable. Two years' observations on the palatability of crushed and uncrushed hays showed a preference for the crushed hay by milking cows and a significant advantage in consumption of the crushed hay by dairy heifers.²⁷

Dairymen who have hay conditioners agree that they are important

²⁵P. John Zachariah, K. C. Elliot, and R. A. Phillips, op. cit.

²⁶Loc. cit.

²⁷Allan Keith Lawrence, op. cit.

machines in making high-quality hay. Over a period of years they could easily pay for themselves through saving the protein in high-quality hay that would otherwise have to be purchased.²⁸

Purpose of this study

A new type of machine, the flail-type forage harvester has recently appeared in the farm implement trade. This has been evolved out of the need for a lower cost forage-harvesting machine that will produce an ensilage or grass product that is comparable to that provided by conventional forage harvesters. The initial cost, about 60 to 80 per cent of the initial cost of conventional harvesters, plus the versatility of the unit, resulting in potentially more annual use, places it in an attractive lower-cost-per-acre category.²⁹ The flail-type forage harvester is an outgrowth of a type of stalk shredder and all present machines of such a type can be used for shredding stalks as well as for the production of ensilage.³⁰

The shredding action of this machine leaves the stems in hay in a crushed state, similar to the state in which hay is left after it has been passed through a crusher. It seems possible that if this machine can be used as a conditioner, it would bring down the cost of hay making by reducing the number of machines necessary and the labor required.

²⁸Kenneth K. Barnes and Robert C. Fincham, "Yes, Hay Crushers Can Cut Field Rushes." Iowa Farm Science (Vol. 12, No. 11) p. 7.

²⁹Clarence W. Bockhop, Power Distribution and Requirements of a Flail Type Forage Harvester (Master's thesis, Iowa State College, 1955) p. 2.

³⁰Ibid., p. 3.

At the present time we go over the field too often and handle the hay too much - once to cut it, once to crush it or crimp it, once to rake it, once to bale it and once to pick up the bales. One or more men are involved in each operation. This considerably increases the cost of hay-making.

The purpose of this study was to find out whether the flail-type forage harvester can be used as a hay conditioner. If it can be, then the mower and, with suitable modifications, the rake can be eliminated for the hay making process. Also, this machine can be used for the production of ensilage, thus eliminating the need for a separate chopper or forage blower on the farm. In this study the performance of the flail-type forage harvester as a hay conditioner was compared with the performances of the smooth roller and fluted roller hay conditioners.

CHAPTER II

MATERIALS AND METHODS

Location of Experiments

The experiments were conducted under field conditions on the Cherokee farm of the University of Tennessee in Knoxville, Tennessee. The farm is located on the banks of the Loudon Lake, across from the Agricultural College campus.

Hay Studied

The crop used for making the hay was alfalfa. The fields had a well established stand of alfalfa growing more or less uniform. The field was well drained and, without any trees, well exposed to the sun and the prevailing winds. Experiments were made on the first cutting and the second cutting on adjacent fields.

Machines Used

The following machines were used in these experiments to make a comparative study of their effect on the drying rate of alfalfa hay.

1. International Harvester No. 2. Hay Conditioner with rubber roller crushers (Fig. 1). This had two cylindrical rubber rollers both of which had helical grooves and rough exteriors to pick up the hay and pass it between the cylinders (Fig. 3) to crush it.
2. New Holland Hay Conditioner with fluted roller crushers to crimp the hay (Fig. 2). This had two fluted rollers, the lower one of which had a smaller diameter. This would pick up the hay and pass it between the rollers to crimp it (Fig. 4).



Figure 1

International Harvester No. 2 Hay Conditioner with
Rubber Roller Crushers



Figure 2

New Holland Hay Conditioner with
Fluted Roller Crushers

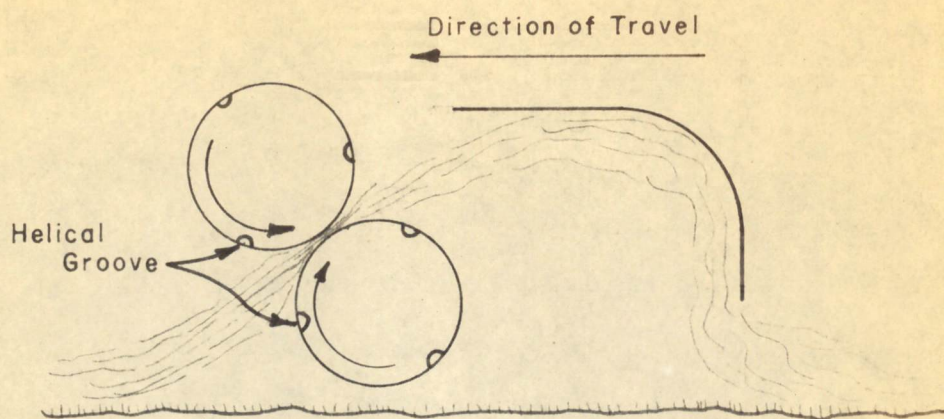


Figure 3

Flow Pattern of Hay Conditioner with
Rubber Roller Crushers

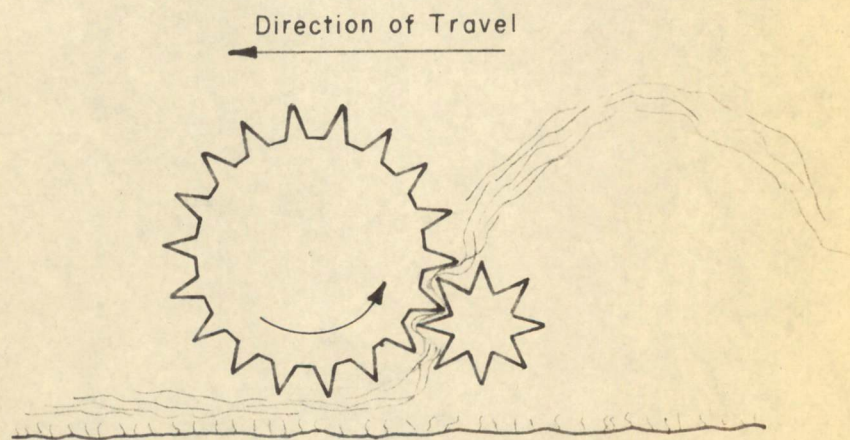


Figure 4

Flow Pattern of Hay Conditioner with
Fluted Roller Crushers

3. New Holland Hay Conditioner with smooth steel roller crushers (Fig. 5). Since the crushing cylinders are smooth they cannot pick up the hay and so a slatted pickup cylinder is used in addition (Fig. 8).
4. John Deere No. 15 Flail-type Forage Harvester (Fig. 6). This employs loose hanging knives (Fig. 7) to shear the crop. The crop is cut by the impact of the swinging knives and carried up and back over the cutter shaft where an auger feeds it to the blower (Fig. 9).
5. Two-plow tractors.

Instrumentation

1. The flail-type forage harvester.

The flail-type forage harvester used for the experiments was not adapted for laying the cut hay gently on the stubbles in a swath. It was, therefore, necessary to modify the spout on the machine. A pipe eighteen inches in diameter and eight feet long was made from 28 guage galvanized sheet metal. One end of the pipe was securely bolted to the spout on the machine so that the hay could drop down through it on to the stubbles in a swath. The pipe was hung vertically from the spout with the lower end about three inches above the ground - the height of the stubbles. The main problem was to fix the pipe in such a way that the cut hay would rest on the stubbles loosely enabling proper air circulation to speed up drying. No special attachments were made for this purpose in this experiment. It was assumed that the pipe would break the force of the cut hay coming from the blower and let it down

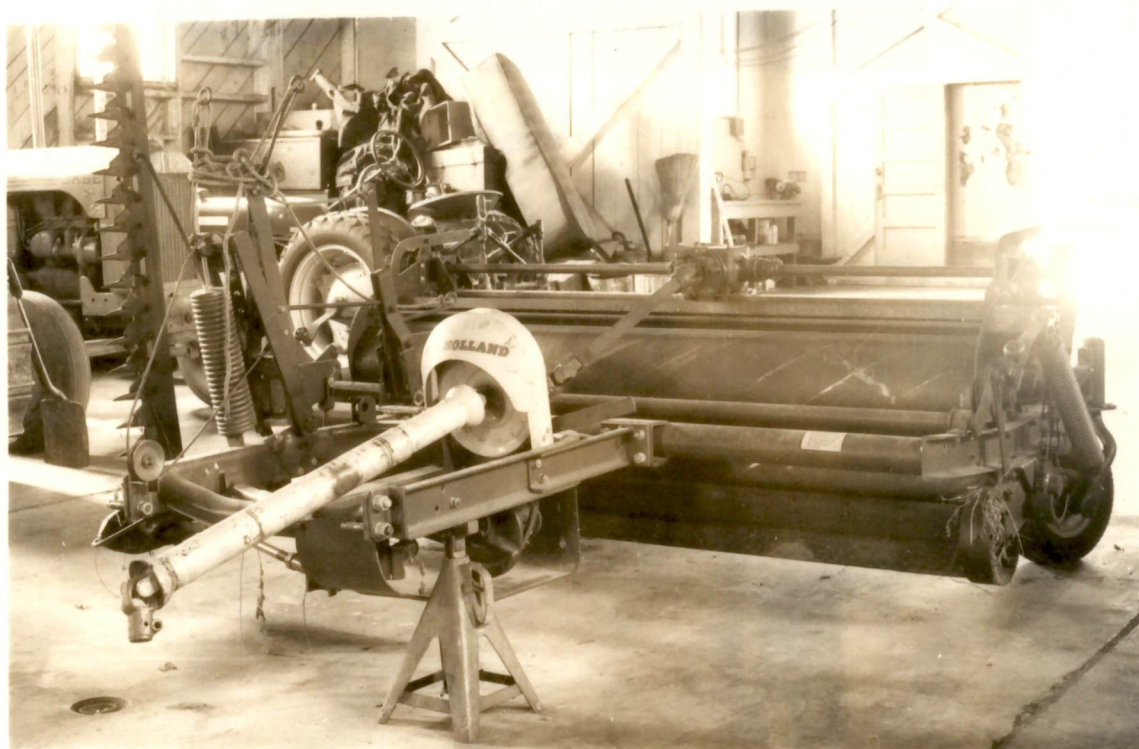


Figure 5

New Holland Hay Conditioner with
Smooth Steel Roller Crushers

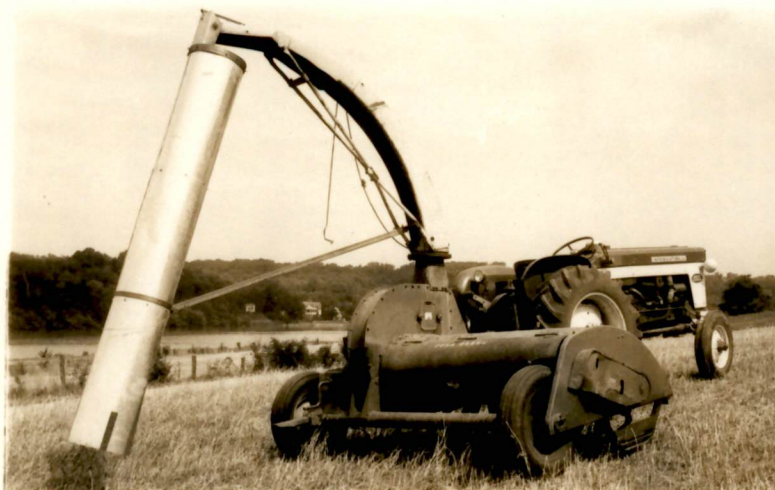


Figure 6

John Deere No. 15 Flail-Type
Forage Harvester



Figure 7

A View of the Hanging Knives of the John Deere
Flail-Type Forage Harvester

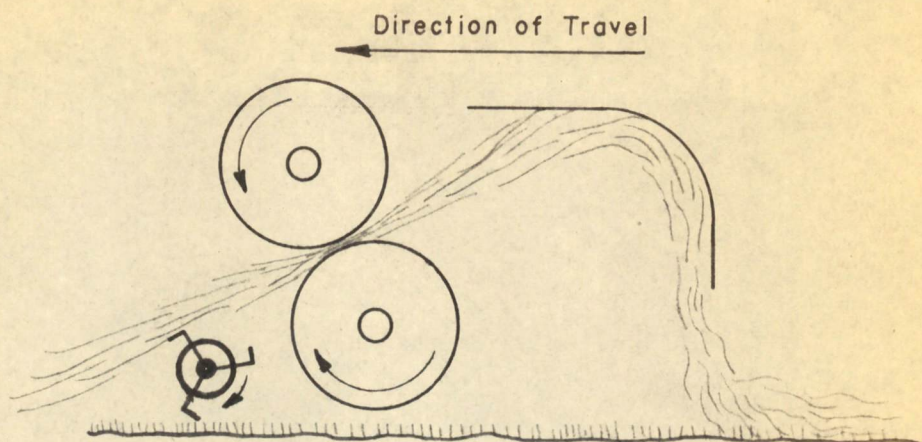


Figure 8

Flow Pattern of Hay Conditioner with
Smooth Steel Roller Crushers

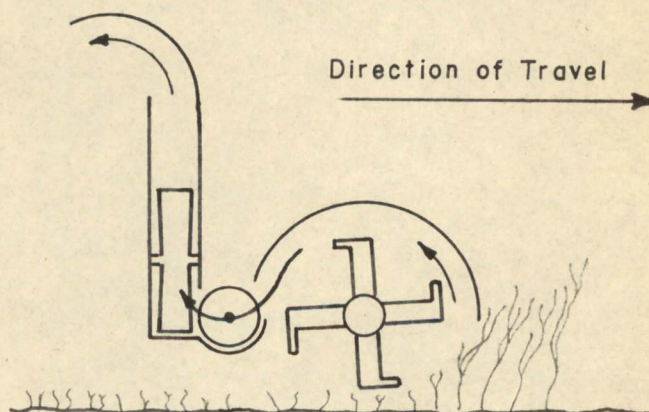


Figure 9

Flow Pattern of the Flail-Type
Forage Harvester

gently enough to rest on the stubbles. Another problem was to get all the hay coming from the spout to fall into the pipe. It was for this purpose that the pipe was made with a larger diameter than that of the spout.

2. A moisture-testing apparatus.

An inexpensive method of sufficient accuracy and speed for finding out the moisture content of hay at any particular time on the field is not available now. With increased mechanization of the harvesting and conditioning operations, there is less time for hay to lose moisture in the field. It is important that the hay be baled when it has reached the correct moisture content. Either an excess or a shortage of moisture content will result in poor quality hay which will continue to deteriorate in quality in storage. It is, therefore, important that equipment be made available for determining the moisture content of hay for finding out the time of cutting and the time of baling. Equipment for precise moisture measurement is not usually necessary. Moisture content determination within 1 per cent is sufficient. Considerable money is lost each year because of overdrying.¹

In most cases the farmer relies upon his experience to estimate the moisture content to determine the time of baling. Guessing the moisture content is usually not accurate enough. The oil-distillation method offers a possible solution. It is inexpensive, simple, and sufficiently rapid and accurate. The test takes about twenty minutes

¹C. W. Hall, Drying Farm Crops (Reynoldsburg, Ohio: Agricultural Consulting Associates, Inc., Engineering Specialists, 1957), p. 73.

and helps to determine whether the hay is sufficiently dry to be taken from the field.²

A simple, portable apparatus for determining the moisture content of hay by the oil-distillation method was designed and made (Fig. 10). A rectangular box, twenty-two inches long, sixteen inches wide and eight inches high was made from half-inch five-ply wood. The top and front lids were made of three-eighths inch five-ply wood. The lids were hinged so they could be opened and laid back. The box was provided with two handles for handling ease.

The box was equipped with the following:

1. Dietetic scale of 1000 gram capacity with one gram divisions.

It had a rotating dial, to simplify the weighing process.

2. Coleman LP gas picnic stove.
3. Thermometer capable of measuring temperatures up to 200° Centigrade.
4. Can of about one quart capacity and a piece of fly-screen wire cut to fit snugly into the can. The wire screen was provided with a hole to let the bulb of the thermometer pass through.
5. One-gallon tin of Wesson cooking oil.
6. Pair of shears for cutting hay sample into one-inch pieces.
7. Dwyer wind meter. This was about six inches long, one and one-half inches wide and one-half inch thick and was very easy to use.
8. Psychrometer, to determine relative humidity.

²W. F. Rissmiller, "A Moisture Test For Hay," Extension Leaflet 355, (Lafayette, Indiana: Purdue University, 1953).

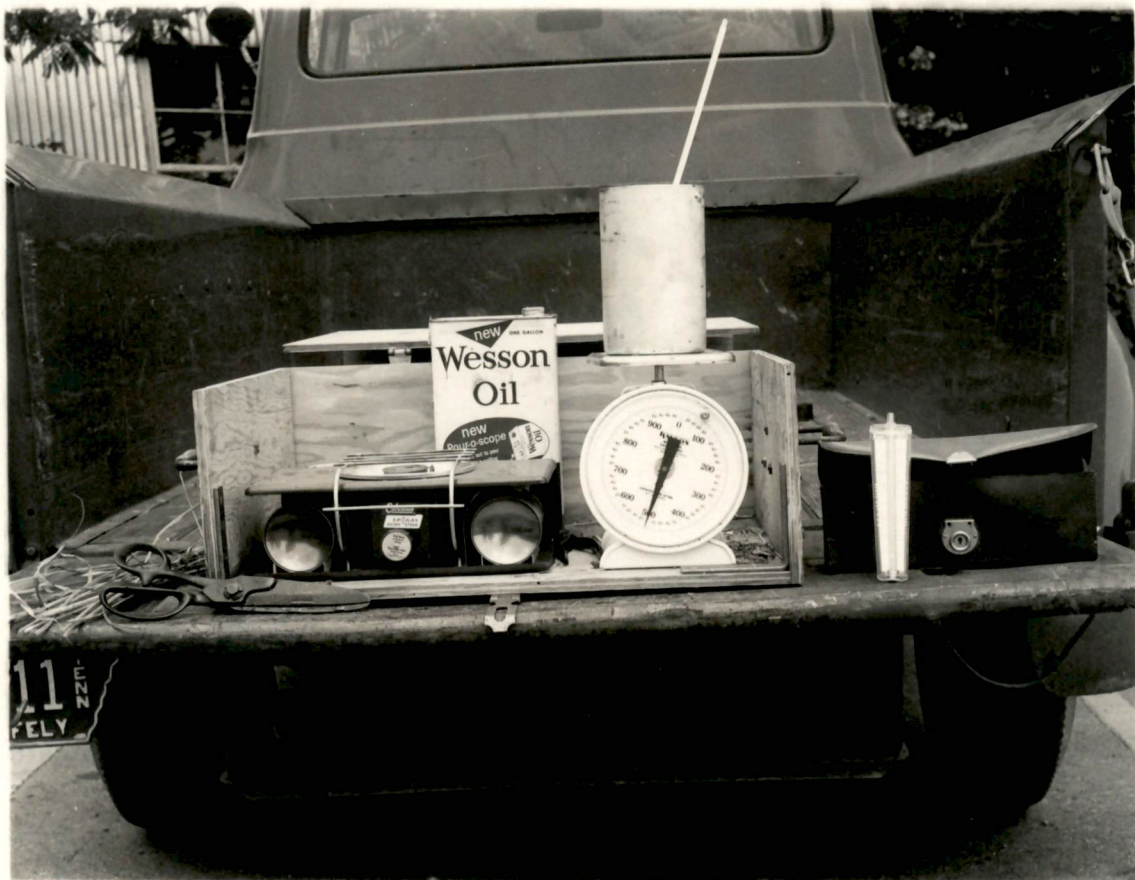


Figure 10

Field Moisture-Testing Apparatus

9. Data pad and pencil.

All this equipment was arranged and fixed in the box in such a way that it could be easily carried from place to place and set up for use with a minimum of time and work.

Procedure for Oil-distillation Method

This method was used to determine the moisture content of hay on the field at any time when it was necessary.

The sample of hay was cut into one-inch lengths with the shears and mixed thoroughly. This was done fast enough to prevent any loss of moisture by evaporation. The can was placed on the scale and the dial set to read zero. Then fifty grams of the cut sample of hay was placed in the can. This was done by adding hay in the can until the dial indicated fifty grams. The hay was then slightly compressed and covered with the fly-screen wire. Enough Wesson oil was poured into the can to cover the sample completely. The fly-screen wire kept the sample immersed in the oil. The thermometer was inserted through the hole in the wire and the can was again placed on the scale and the dial set to zero. The can was then transferred to the stove and slowly heated to 115° Centigrade. The temperature was held at 115° Centigrade by adjusting the flame and was not allowed to rise higher at any time. This was important as the oil does not evaporate appreciably within this range of temperature. But it was higher than the boiling point of water and so the moisture in the hay boiled away.

Heating was continued for twenty minutes by which time all the moisture in the sample had evaporated, as indicated by the absence of

any bubbles. The can was then weighed and the weight noted. As the dial had been set at zero with the can on the scale before it was heated, the amount of moisture lost could be noted directly from the scale. The weight of the sample taken was fifty grams. Therefore, the weight of moisture lost, in grams, multiplied by two gave the moisture content of the hay in percentage on a wet basis.

The oil was strained off for future use. The amount of oil lost for the experiment was negligible. No calculations were involved. Therefore this was both an inexpensive and simple method.

The accuracy of the method was tested by comparing the result to that obtained by the oven method by using the same sample of hay. The difference in moisture percentage determined by both the methods was less than 2 per cent.

A weighed quantity of Wesson oil was heated slowly up to 115° Centigrade, just as for the experiment, for a period of twenty minutes. It was then weighed. There was no change in weight indicating that no oil was lost by evaporation during the experiment.

Sampling

The experiment was done twice, each time on a different field and on a different cutting.

1. First Experiment

The plot selected for the first experiment was a long strip along the middle portion of the field. The field had an area of seven acres and a good stand of alfalfa. This was the first cutting.

The experiment was started on May 11, 1959. The alfalfa was

mowed at 10:00 a.m. The hay conditioners were used immediately afterwards. The flail-type forage harvester was used at 12:15 p.m.

The first two swaths were left just as they were mowed, to serve as check. The next two swaths were crushed by using the hay conditioner with the rubber roller crushers. The fifth and sixth swaths were crimped by the hay conditioner with the fluted rollers. These two operations were done immediately after mowing. The next two swaths were cut by the flail-type forage harvester at 12:15 p.m. The cut hay was allowed to drop on to the stubbles through the pipe which was attached to the spout on the machine. It was noticed that the hay was chopped up too short and that it was forming a rather compact mass on the swath, without being fluffy and with little possibility of proper aeration. This fine chopping up was done by the six knives on the fly wheel and blower of the machine. It was equipped with these knives as the machine was essentially a forage harvester and chopper. As the chopped hay coming down through the spout did not look good enough to get properly cured, two more swaths were made by opening the back of the machine (Fig. 11) and allowing the hay to drop down on to the stubbles without letting it pass through the blower and the knives.

The long strip of field was divided into four plots crosswise and representative samples were collected from each plot at the same time. Samples of uncut alfalfa were taken at 10:30 a.m., just before it was mowed. All samples were collected in cans with tight lids to prevent loss of moisture during transportation to the laboratory. Each time when samples were collected, the humidity, wind speed and cloud cover were also recorded. The humidity was determined by a psychrometer

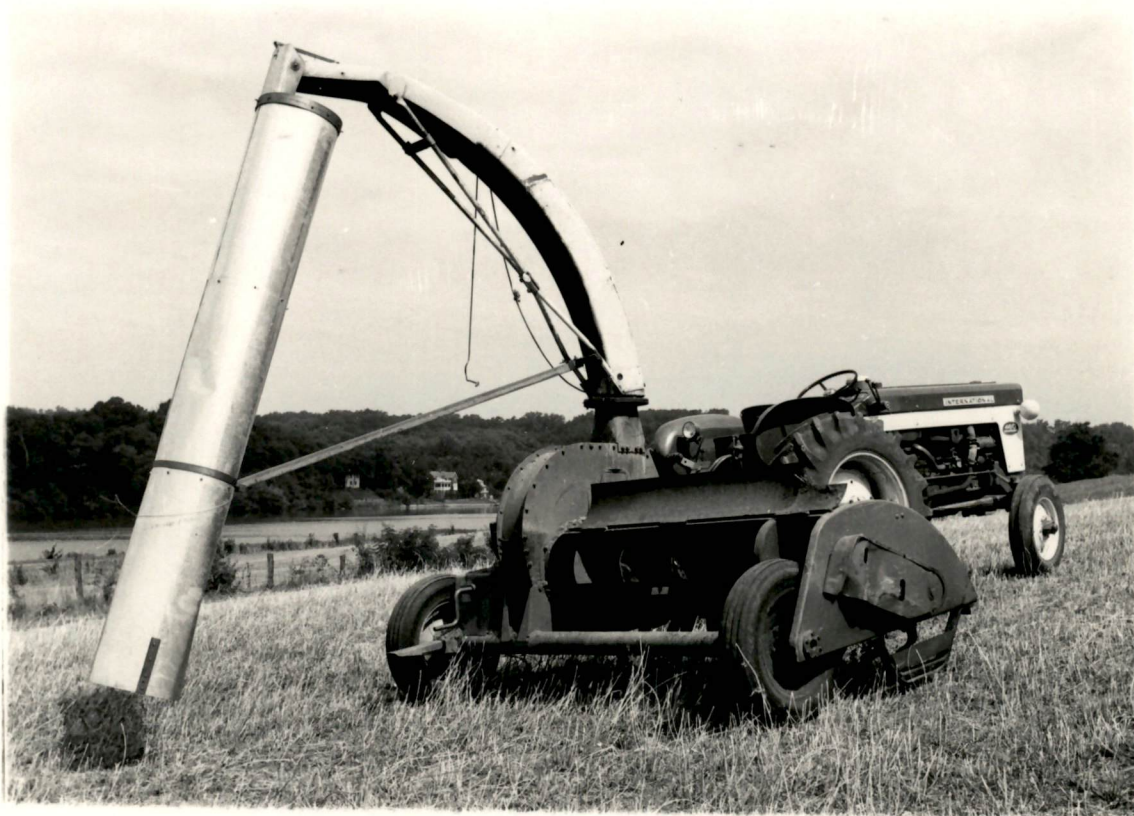


Figure 11

John Deere No. 15 Flail-Type Forage Harvester
With the Back Open

and the wind speed by a wind meter.

The first samples were collected from the four plots at 12:30 p.m. These were from the unconditioned check swaths, the rubber roller crushed swaths and, the fluted roller crimped swaths. The samples were collected in cans each of which was immediately tightly closed. Then the treatment, plot number, time of collection and date were marked on each can. These cans had been previously numbered and weighed. The number and weight were stamped on each can.

The cans with the samples were then transported to the laboratory and each carefully weighed. The plot number, can number, time of sampling, relative humidity, wind speed, percentage of cloud cover, weight of empty can, weight of can with hay sample and the treatment of the sample were noted down on data sheets. The samples were then kept in an electric oven to dry at 160° Fahrenheit.

The next set of samples were collected at 2:30 p.m. These included the first set of samples from the swaths cut by the flail-type forage harvester. The cans were marked as before, weighed and all data entered on the data sheets. They were then left in the oven to dry at 160° Fahrenheit.

Samples were again collected at 4:00 p.m. and at 6:00 p.m. the same day. No samples were taken during the night. The next set of samples was collected at 9:15 a.m. the next day, May 12, 1959. This was followed by samples at 10:30 a.m. and 12:00 noon. All data were recorded as before and the samples left in the oven.

The last samples were collected at the raking time of each swath. This was at 2:45 p.m. for the unconditioned check, 2:50 p.m. for the

flailed swath both with and without knives, 3:15 p.m. for the rubber roller crushed swath and 3:30 p.m. for the crimped swath. Weights and data were recorded as before and the samples left in the oven to dry.

All the samples were allowed to dry in the oven at 160° Fahrenheit for a minimum period of forty-eight hours. They were then weighed and the weights recorded.

The moisture content of the samples was calculated as follows:

Moisture content in percentage - $\frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$

2. Second Experiment

The second experiment was made on the second cutting in an eight acre alfalfa field adjoining the first one. The experiment was started on June 15, 1959. This was also an open field without any trees, well drained and well exposed to the sun and the prevailing winds. This time one more type of conditioner was used for the comparison study in addition to the ones used for the first experiment - the New Holland conditioner with smooth steel roller crushers (Fig. 5).

A slight modification was made in the attachment for the flail-type forage harvester. The eighteen-inch diameter, eight-foot long pipe fixed to the spout was hung at an angle of about 60 degrees to the horizontal, slanting backwards (Fig. 6). A metal deflector on wooden runners was attached to the lower end of this pipe to receive the falling hay and gently slide it on to the stubbles. This was made to pivot so that it could swing back in case it hit an obstacle on the field. All the six knives were removed from the blower.

When the hay was allowed to come down through the spout and the

pipe, two difficulties were encountered:

1. The throat of the spout just above the blower was clogged up by the hay.
2. The hay tended to heap on the deflector at the lower end of the pipe resulting in clogging up the whole pipe.

This indicated that a larger throat and modification of the deflector were needed. As this entailed a lot more work, the back of the machine was opened as in the first experiment and the hay allowed to fall directly on to the swath.

The plot chosen was a long strip in the middle portion of the field but along a side. Two swaths were left unconditioned just as they were mowed, to serve as check. Then two swaths each were made by using the following:

1. New Holland Hay Conditioner with smooth steel roller crushers.
2. New Holland Hay Conditioner with fluted roller crushers.
3. International Harvester No. 2 Hay Conditioner with rubber roller crushers and
4. John Deere No. 15 Flail-Type Forage Harvester.

Samples were collected as before. The mowing of alfalfa started at 2:45 p.m. on June 15, 1959, and the conditioners were used even as the mowing was going on. Swaths were made by the flail-type forage harvester also at the same time. Samples were collected at 4:45 p.m. and 6:00 p.m. the same day. The next day, June 16, samples were collected at 9:00 a.m., 10:00 a.m., 11:00 a.m., 12:00 noon, 1:00 p.m. and 2:00 p.m. Each time the samples were collected, the relative humidity, wind speed and percentage of cloud cover were also recorded.

After weighing and recording all data as in the first experiment, the samples were left to dry in the oven at 160° Fahrenheit. They were allowed to dry for more than forty-eight hours. They were then weighed and the moisture content calculated as before.

CHAPTER III

RESULTS AND DISCUSSION

Weather

1. First Experiment. The weather was fair during the first experiment on the day the hay was cut, May 11, 1959. The day was slightly cloudy and there was an almost continuous wind the speed of which varied from six to eight miles per hour. The wind dropped and the air became still by the time the last sample was collected at 6:00 p.m. The humidity was a more or less uniform 41 per cent which rose to 54 per cent by 6:00 p.m. At 10:30 a.m. when the hay was cut the temperature was 82.0° Fahrenheit. This gradually rose and the maximum temperature of 88.5° Fahrenheit was recorded at 2:30 p.m. When the last samples for the day were collected at 6:00 p.m. the temperature was 84.5° Fahrenheit.

The weather was more or less the same during the second and final day of the experiment. The wind blew in gusts with the speed varying from zero to seven miles per hour. The humidity was a fairly uniform 50 per cent. In the afternoon the sky became overcast. When the first samples were collected at 9:15 a.m. the temperature was 81° Fahrenheit. This rose to a maximum of 86° Fahrenheit at 2:30 p.m. and dropped to 83° Fahrenheit by 3:30 p.m. when raking was done and baling started. As soon as baling was completed, at 5:30 p.m., there was a burst of heavy rainfall.

Details of weather are shown in Table I on page 31.

2. Second Experiment. The second experiment was carried out under ideal haymaking weather. This was on June 15 and 16, 1959. The

TABLE I

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

EXPERIMENT I

Date and Time of Day	Check	Crimped	Rubber Rolled	Flailed Without Knives	Flailed With Knives	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
May 11, 1959									
12:30 p.m.	65.0	62.3	60.7	----	----	87.5	40	8.0	25
2:30 p.m.	57.4	52.0	48.2	61.1	67.1	88.5	41	6.0	50
4:00 p.m.	53.7	42.7	36.1	48.3	64.7	86.0	41	6.0	40
6:00 p.m.	49.4	34.9	30.1	49.8	60.4	84.5	54	0.0	20
May 12, 1959									
9:15 a.m.	49.1	34.1	28.9	38.5	57.7	81.0	64	0 to 4	30
10:30 a.m.	43.5	27.0	22.6	32.6	59.4	83.2	58	0 to 6	40
12:00 noon	42.0	17.6	16.0	24.1	52.1	83.5	53	6 to 8	75
2:45 p.m.	*30.0	----	----	----	----	86.0	50	0 to 7	90
2:50 p.m.	----	----	----	*20.8	*50.9	86.0	50	0 to 7	90
3:15 p.m.	----	----	*11.5	----	----	86.0	50	0 to 7	90
3:30 p.m.	----	*13.0	----	----	----	86.0	50	0 to 7	90

Moisture content in uncut hay: 82.2 per cent
 Time of mowing and conditioning: 10:30 a.m., May 11, 1959
 Time of using flail: 12:15 p.m., May 11, 1959

*Moisture content at raking time.

sky was clear on the day the alfalfa was cut and conditioned, and continued to be clear on the next day when baling was done. The relative humidity was about 38 per cent from the time the hay was cut to the time the last sample was taken on the first day. The next day when the first samples were collected at 9:00 a.m. the humidity was 70 per cent. This dropped to 42 per cent at 10:00 a.m. and continued to drop until it was 25 per cent at 2:00 p.m. when the last samples were taken.

When the hay was cut the temperature was 84° Fahrenheit and this dropped to 82° Fahrenheit at 6:00 p.m. when the final sampling for the day was done. The temperature was 79° Fahrenheit at 9:00 a.m. the next day when the first samples were collected. This gradually rose to 87° Fahrenheit at 1:00 p.m. and stayed at that level till 2:00 p.m. when the final samples for the experiment were collected.

Table II shows details of the weather during the second experiment.

Moisture Content of Hay

The first experiment was carried out on the first cutting of alfalfa and the second experiment on the second cutting. The moisture content of the alfalfa just before the first cutting was 82.2 per cent and that before the second cutting was 76.4 per cent.

All moisture contents were determined as percentages, on a wet basis. The average percentage moisture contents of all samples for the first experiment are shown on Table I and those for the second experiment are shown on Table II.

It was not possible to determine the moisture content of the hay

TABLE II

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

EXPERIMENT 2

Date and Time of Day	Check	Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
June 15, 1959									
4:45 p.m.	70.6	62.2	58.8	63.1	67.8	84.0	37.5	0 to 5	2
6:00 p.m.	66.5	55.5	54.9	54.8	59.8	82.0	38.5	0 to 2	0
June 16, 1959									
9:00 a.m.	65.2	53.7	50.4	40.6	54.4	79.0	70.0	0	1
10:00 a.m.	60.7	45.8	43.4	41.1	45.3	80.0	42.0	0	1
11:00 a.m.	52.9	39.4	36.1	34.0	37.1	81.5	38.0	0 to 3	2
12:00 noon	46.5	28.3	30.9	25.3	33.4	84.0	29.0	6 to 8	0
1:00 p.m.	43.7	24.1	26.1	19.9	26.8	87.0	25.0	5 to 10	0
2:00 p.m.	40.6	19.6	21.0	22.4	23.9	87.0	25.0	0	0

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with

smooth steel roller crushers:

2:45 p.m., June 15, 1959

fluted roller crushers:

3:15 p.m., do

rubber roller crushers:

3:45 p.m., do

Time of using flail:

3:45 p.m., do

Time of mowing check swath:

4:00 p.m., do

samples in the field even as they were collected. The moisture-testing device which was designed during the course of this investigation was useful only for determining the time of baling by taking one representative sample. It was therefore necessary to transport all the samples to the laboratory where they could be carefully weighed and then heated in an oven at controlled temperature. The main problem was to prevent loss of moisture from the samples during the period between the time of collection and the time of keeping in the oven. Cans with tight lids were used for this purpose. They were sufficiently tight to prevent any appreciable loss of moisture.

All samples were left for a minimum of forty-eight hours in the oven at 160° Fahrenheit and were weighed as soon as they were taken out. This temperature and time were sufficient to drive out all the moisture.

For each experiment there were five treatments for the hay including the check. Each treatment was replicated in four plots. The results obtained from each plot are shown in the tables in Appendices A and B.

Due to mechanical errors in sampling the results were sometimes inconsistent. For example in Table III (Appendix A) the moisture content of the check swath was 38.2 per cent at 10:30 a.m. and 45.7 at 12:00 noon. But these mechanical errors in sampling more or less balanced and the loss of moisture showed normal trends when the averages for the four plots were taken for each experiment. Table I shows the averages for the four plots in the first experiment and Table II that of the four plots in the second experiment.

The graphs shown in Figure 12 for the first and Figure 13 for the

second experiments were based on Tables I and II respectively.

Comparison of Hay Under the Different Treatments

Tables I and II show the average moisture content for each treatment for the first and second experiment respectively. These are shown graphically in Figures 12 and 13.

Both the graphs indicate that the fastest drying rate was obtained when conditioning was done by the rubber roller crushers. The comparatively low drying rate when conditioned with smooth steel roller crushers might have been due to improper adjustments in the machine used for the experiment. It was a new machine and did not work very satisfactorily on the field. Various adjustments were tried and what was considered to be the best was used for the experiment.

The hay chopped with the knives on the blower of the flail-type forage harvester had a very slow drying rate, even lower than that of the untreated hay. This was because the hay was cut too short and the pieces rested on the ground surface instead of on the stubbles. Also, they formed a more or less compact mass without being fluffy. These two factors contributed to improper aeration with the result that the drying rate was very low.

The drying rate of flailed hay, without the use of knives in the blower was quite close to the drying rate of crimped hay. The curves for these two drying rates run close to each other (Figures 12 and 13), and the moisture content at raking time was almost the same for both. This showed that the flail-type forage harvester was as efficient as the fluted roller hay conditioner in conditioning hay. Also, this drying

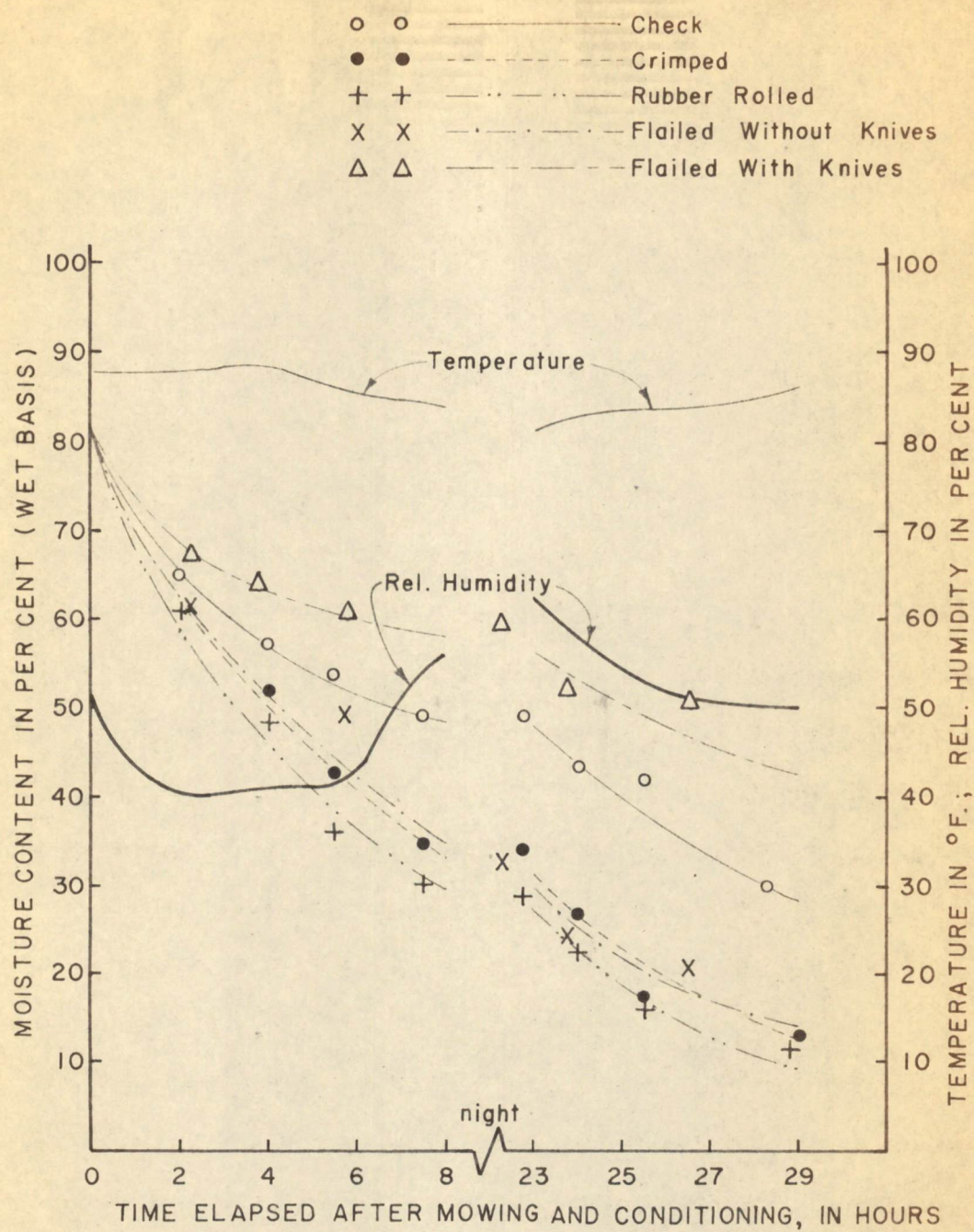


Figure 12

Drying Rate of Alfalfa Hay, Experiment 1

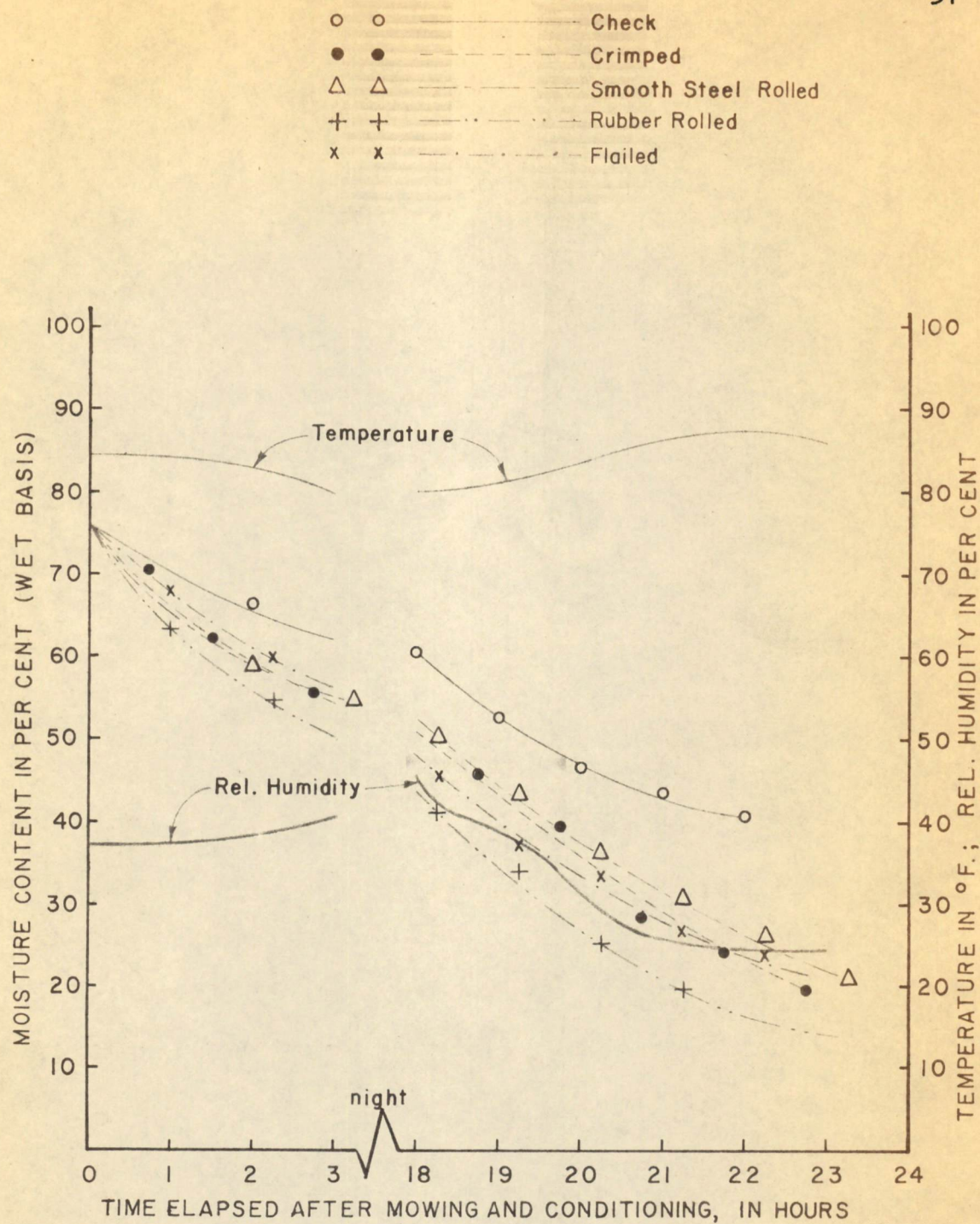


Figure 13

Drying Rate of Alfalfa Hay, Experiment 2

rate was close enough to that obtained with rubber roller crushers for all practical purposes. Therefore these experiments showed that the flail-type forage harvester was as efficient as the other machines for conditioning hay.

The Flail-Type Forage Harvester

Some difficulties were encountered when the flail-type forage harvester was used for these experiments. This machine was primarily a forage harvester and chopper and was designed to cut the crop into short pieces. This was detrimental to proper hay curing and baling. As was pointed out earlier the short pieces tended to fall directly on to the ground in a more or less compact mass lessening the possibility of proper aeration. This resulted in a very slow drying rate as shown in Figure 12. The short length of the pieces was the cause of another serious difficulty. The baler could not pick up the short hay.

Another difficulty encountered was the narrowness of the throat of the spout. When the knives were removed from the blower and the hay allowed to come through the spout, it clogged up the throat.

These difficulties were overcome in these experiments by opening the back of the machine and allowing the hay to fall on the ground without letting it pass through the blower. But this does not seem to be a good practice if this machine is to be used on the farm as a hay conditioner. Its effectiveness and efficiency can be greatly increased by the following modifications in the machine:

1. Arrangement for removing the blower knives easily.
2. Adjustable speed for the flails so that the hay can be cut

to the desired length.

3. Arrangement for laying two adjacent swaths in one windrow so as to eliminate the need for a rake and increase the efficiency of the baler.
4. A throat for the spout wide enough to prevent clogging.

If these modifications are brought about, the cost of haymaking on the farm will become considerably less by eliminating the need for a mower and a rake. This machine is a forage chopper also and this eliminates the need for another machine on the farm.

These experiments showed one distinct advantage for the flail-type forage harvester over the other conditioners. The lacerating action of the flails broke open and softened the stems of the hay more than the other machines did. This action probably increased the palatability of the hay.

There is need for future research on the following related aspects of this study.

1. Modifications on the flail-type forage harvester to make its use practicable on the farm as a hay conditioner in addition to its use as a forage harvester and chopper.
2. Comparison of the palatabilities of hay made with the different types of hay conditioners including the flail-type forage harvester.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the possibility of using the flail-type forage harvester as a hay conditioner. This machine was essentially designed as a low cost forage harvesting machine. The shredding action of this machine leaves the stems in hay in a crushed state, similar to the state in which hay is left after it has been passed through a crusher. It, therefore, seemed possible that this machine, with suitable modifications and adjustments could also be used for hay conditioning.

In this study the drying rates of alfalfa hay conditioned with rubber roller crushers, smooth steel roller crushers and fluted roller crushers were compared to the drying rate of hay conditioned with the flail-type forage harvester. Two experiments were carried out under field conditions, with each treatment replicated in four plots. Every effort was made to collect representative samples and gather accurate data. The data included the temperature, humidity, wind speed and cloud cover at the time each sample was taken. The weights of the hay samples as collected from the field were taken and then they were heated in an electric oven at 160° Fahrenheit for a minimum of forty-eight hours. They were weighed again and the moisture content of each sample calculated as a percentage on a wet basis. Graphs were then drawn to represent the drying rates of the hay under these various treatments.

These experiments showed that the flail-type forage harvester was as good as the other conditioners for conditioning hay. It also seemed possible that it improved the palatability of hay by lacerating the

stems and making them softer.

The use of a properly modified machine eliminates the need for a mower and a rake for haymaking, thus lowering the cost of hay. As this machine is a forage harvester and chopper also, the need of another machine for this purpose is also eliminated from the farm. These factors contribute to reducing the capital cost of machinery needed on a farm.

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APPENDIX A

Experiment 1

TABLE III

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 1

Date and Time of Day	Check	Crimped	Rubber Rolled	Flailed Without Knives	Flailed With Knives	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
May 11, 1959									
12:30 p.m.	61.1	55.8	57.1	----	----	87.5	40	8.0	25
2:30 p.m.	50.7	49.5	43.7	62.4	58.0	88.5	41	6.0	50
4:00 p.m.	57.3	40.0	28.8	47.5	63.1	86.0	41	6.0	40
6:00 p.m.	48.3	31.7	31.8	48.2	48.3	84.5	54	0.0	20
May 12, 1959									
9:15 a.m.	45.1	35.5	25.8	34.4	44.3	81.0	64	0 to 4	30
10:30 a.m.	38.2	27.0	18.3	28.9	59.6	83.0	58	0 to 6	40
12:00 noon	45.7	18.3	15.4	20.8	41.2	83.5	53	6 to 8	75
2:45 p.m.	*27.7	----	----	----	----	86.0	50	0 to 7	90
2:50 p.m.	----	----	----	*18.5	*61.0	86.0	50	0 to 7	90
3:15 p.m.	----	----	*13.0	----	----	86.0	50	0 to 7	90
3:30 p.m.	----	*11.5	----	----	----	86.0	50	0 to 7	90

Moisture content in uncut hay:

82.2 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of using flail:

12:15 p.m., May 11, 1959

*Moisture content at raking time.

TABLE IV

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 2

Date and Time of Day	Check	Crimped	Rubber Rolled	Flailed Without Knives	Flailed With Knives	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
May 11, 1959									
12:30 p.m.	67.0	67.8	63.2	-----	-----	87.5	40	8.0	25
2:30 p.m.	58.0	54.3	49.7	59.9	69.0	88.5	41	6.0	50
4:00 p.m.	48.7	44.0	27.0	49.8	67.7	86.0	41	6.0	40
6:00 p.m.	47.6	37.4	28.8	46.0	67.3	84.5	54	0.0	20
May 12, 1959									
9:15 a.m.	46.5	27.1	25.7	41.0	66.3	81.0	64	0 to 4	30
10:30 a.m.	48.6	26.3	28.9	29.9	64.6	83.0	58	0 to 6	40
12:00 noon	38.0	12.2	10.2	22.4	63.2	83.5	53	6 to 8	75
2:15 p.m.	*31.9	-----	-----	-----	-----	86.0	50	0 to 7	90
2:50 p.m.	-----	-----	-----	*24.3	*58.1	86.0	50	0 to 7	90
3:15 p.m.	-----	-----	*11.2	-----	-----	86.0	50	0 to 7	90
3:30 p.m.	-----	*13.7	-----	-----	-----	86.0	50	0 to 7	90

Moisture content in uncut hay: 82.2 per cent
 Time of mowing and conditioning: 10:30 a.m., May 11, 1959
 Time of using flail: 12:15 p.m., May 11, 1959

* Moisture content at raking time.

TABLE V

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 3

Date and Time of Day	Check	Crimped	Rubber Rolled	Flailed Without Knives	Flailed With Knives	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
May 11, 1959									
12:30 p.m.	64.9	62.4	61.0	----	----	87.5	40	8.0	25
2:30 p.m.	62.9	47.5	51.5	67.5	73.0	88.5	41	6.0	50
4:00 p.m.	57.0	42.5	43.6	42.8	65.8	86.0	41	6.0	40
6:00 p.m.	50.8	37.8	25.2	56.2	57.8	84.5	54	0.0	20
May 12, 1959									
9:15 a.m.	52.1	35.7	31.0	39.9	55.0	81.0	64	0 to 4	30
10:30 a.m.	40.3	25.3	23.0	41.3	54.2	83.0	58	0 to 6	40
12:00 noon	36.9	22.5	14.6	22.0	51.7	83.5	53	6 to 8	75
2:45 p.m.	*27.5	----	----	----	----	86.0	50	0 to 7	90
2:50 p.m.	----	----	----	*18.9	*39.3	86.0	50	0 to 7	90
3:15 p.m.	----	----	*11.0	----	----	86.0	50	0 to 7	90
3:30 p.m.	----	*12.2	----	----	----	86.0	50	0 to 7	90

Moisture content in uncut hay: 82.2 per cent
 Time of mowing and conditioning: 10:30 a.m., May 11, 1959
 Time of using flail: 12:15 p.m., May 11, 1959

* Moisture content at raking time.

TABLE VI

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 4

Date and Time of Day	Check	Crimped	Rubber Rolled	Flailed Without Knives	Flailed With Knives	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
May 11, 1959									
12:30 p.m.	66.8	63.1	61.4	-----	-----	87.5	40	8.0	25
2:30 p.m.	57.5	56.5	47.7	54.5	68.4	88.5	41	6.0	50
4:00 p.m.	51.8	44.2	45.1	53.2	62.0	86.0	41	6.0	40
6:00 p.m.	50.7	32.8	34.4	48.7	68.0	84.5	54	0.0	20
May 12, 1959									
9:15 a.m.	52.6	38.2	32.9	38.7	65.0	81.0	64	0 to 4	30
10:30 a.m.	47.0	29.4	20.0	30.2	59.1	83.0	58	0 to 6	40
12:00 noon	47.4	17.4	23.7	31.0	52.1	83.5	53	6 to 8	75
2:45 p.m.	*33.0	-----	-----	-----	-----	86.0	50	0 to 7	90
2:50 p.m.	-----	-----	-----	*21.6	*45.3	86.0	50	0 to 7	90
3:15 p.m.	-----	-----	*10.8	-----	-----	86.0	50	0 to 7	90
3:30 p.m.	-----	*14.5	-----	-----	-----	86.0	50	0 to 7	90

Moisture content in uncut hay:

82.2 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of using flail:

12:15 p.m., May 11, 1959

* Moisture content at raking time.



APPENDIX B

Experiment 2

TABLE VII

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 1

Date and Time of Day	Check	Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
June 15, 1959									
4:45 p.m.	70.6	67.5	58.6	65.8	68.3	84.0	37.5	0 to 5	2
6:00 p.m.	69.8	54.4	59.5	59.1	54.7	82.0	38.5	0 to 2	0
June 16, 1959									
9:00 a.m.	66.6	57.0	47.0	50.3	57.0	79.0	70.0	0	1
10:00 a.m.	56.9	45.2	42.7	38.3	45.2	80.0	42.0	0	1
11:00 a.m.	55.7	38.1	31.6	33.2	39.2	81.5	38.0	0 to 3	2
12:00 noon	48.3	34.8	27.5	26.0	35.0	84.0	29.0	6 to 8	0
1:00 p.m.	44.5	29.8	25.0	18.9	31.9	87.0	25.0	5 to 10	0
2:00 p.m.	40.6	16.7	19.6	21.7	21.7	87.0	25.0	0	0

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with

smooth steel roller crushers:

2:45 p.m., June 15, 1959

fluted roller crushers:

3:15 p.m., do

rubber roller crushers:

3:45 p.m., do

Time of using flail:

3:45 p.m., do

Time of mowing check swaths:

4:00 p.m., do

TABLE VIII

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 2

Date and Time of Day	Check	Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
June 15, 1959									
4:45 p.m.	71.5	57.0	58.7	67.3	66.8	84.0	37.5	0 to 5	2
6:00 p.m.	62.1	56.1	52.8	50.3	58.5	82.0	38.5	0 to 2	0
June 16, 1959									
9:00 a.m.	63.4	53.5	48.0	51.7	56.0	79.0	70.0	0	1
10:00 a.m.	62.5	47.2	39.5	40.4	45.7	80.0	42.0	0	1
11:00 a.m.	49.7	42.3	38.4	37.7	34.1	81.5	38.0	0 to 3	2
12:00 noon	38.4	21.3	36.8	24.5	36.8	84.0	29.0	6 to 8	0
1:00 p.m.	48.0	18.9	22.4	23.4	29.0	87.0	25.0	5 to 10	0
2:00 p.m.	36.9	21.5	18.1	20.4	22.9	87.0	25.0	0-	0

Moisture content in uncut hay: 76.4 per cent

Time of mowing and conditioning with

smooth steel roller crushers: 2:45 p.m., June 15, 1959

fluted roller crushers: 3:15 p.m., do

rubber roller crushers: 3:45 p.m., do

Time of using flail: 3:45 p.m., do

Time of mowing check swath: 4:00 p.m., do

TABLE IX

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 3

Date and Time of Day	Check	Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
June 15, 1959									
4:45 p.m.	69.7	62.1	54.3	58.5	66.6	84.0	37.5	0 to 5	2
6:00 p.m.	66.0	52.8	49.9	53.8	61.8	82.0	38.5	0 to 2	0
June 16, 1959									
9:00 a.m.	67.3	49.3	53.1	49.3	55.5	79.0	70.0	0	1
10:00 a.m.	63.8	40.5	43.5	45.5	40.6	80.0	42.0	0	1
11:00 a.m.	52.8	34.7	36.6	32.7	37.4	81.5	38.0	0 to 3	2
12:00 noon	49.3	30.3	28.5	28.5	29.8	84.0	29.0	6 to 8	0
1:00 p.m.	44.8	22.3	32.0	13.8	23.7	87.0	25.0	5 to 10	0
2:00 p.m.	43.3	24.5	22.9	22.2	28.9	87.0	25.0	0	0

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with smooth steel roller crushers:

2:45 p.m., June 15, 1959

fluted roller crushers:

3:15 p.m., do

rubber roller crushers:

3:45 p.m., do

Time of using flail:

3:45 p.m., do

Time of mowing swath:

4:00 p.m., do

TABLE X

DRYING RATE OF ALFALFA HAY
UNDER DIFFERENT TREATMENTS

PLOT 4

Date and Time of Day	Check	Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed	Temperature of	Rel. Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Moisture Percentage (Wet Basis)								
June 15, 1959									
4:45 p.m.	70.5	62.1	63.4	60.6	69.4	84.0	37.5	0 to 5	2
6:00 p.m.	68.0	58.6	57.5	56.0	64.0	82.0	38.5	0 to 2	0
June 16, 1959									
9:00 a.m.	63.6	54.9	53.6	51.1	49.0	79.0	70.0	0	1
10:00 a.m.	59.5	50.3	47.8	40.3	49.6	80.0	42.0	0	1
11:00 a.m.	53.3	42.5	37.8	32.5	37.6	81.5	38.0	0 to 3	2
12:00 noon	50.0	26.9	30.9	22.2	32.1	84.0	29.0	6 to 8	0
1:00 p.m.	37.4	25.2	25.0	23.6	22.5	87.0	25.0	5 to 10	0
2:00 p.m.	41.7	15.8	23.5	25.3	22.2	87.0	25.0	0	0

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with

smooth steel roller crushers:

2:45 p.m., June 15, 1959

fluted roller crushers:

3:15 p.m., do

rubber roller crushers:

3:45 p.m., do

Time of using flail:

3:45 p.m., do

Time of mowing check swaths:

4:00 p.m., do