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# Hay conditioners in the northeastern United States

A. D. Longhouse

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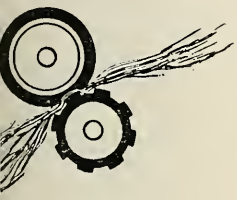
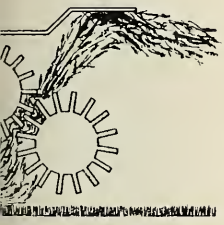
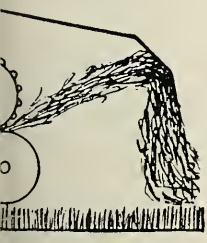
# HAY CONDITIONERS In the Northeastern United States







WEST VIRGINIA UNIVERSITY
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# Contents


Summary ..... 4

Introduction ..... 5

Effect of Crushing and Crimping on the Field Drying Rate ..... 7

Power Requirements of Two Types of Conditioners ..... 12

Effects of Roll Pressures on Drying Rate ..... 15

Effect of Fluffing on Drying Rate ..... 17

Effect of Conditioning Methods on Field Losses ..... 24

Drying Rate of Flail-cut Forage ..... 24

Effects of Tedding on Drying Rate ..... 25

Effects of Windrowing and Crushing on Drying Rate ..... 25

Factors to Consider When Planning to Condition Hay ..... 30

Conclusions ..... 31

Nomenclature ..... 32

# Summary*

DETERIORATION of quality while hay is drying in the field and loss of foliage during handling have been problems for many years. Hay that is artifically dried often escapes exposure to bleaching by the sun and possible rain. Leaf shatter also may be reduced. However, regardless of whether hay is completely field cured or artificially dried, the period it has to remain in the field must be minimized if it is to retain top quality.

Leaves of grasses and legumes dry considerably faster than the stems. Therefore, if the drying rate of the stems could be increased, the average drying rate of the whole plant would increase. Hay conditioning machines have been introduced to crack stems of forage to promote faster drying. Basically, hay conditioning machines differ in roll design—smooth rolls of either steel or rubber are called crushers, and rolls which flute or project are called crimpers.

All tests have shown that both crushers and crimpers will increase the drying rate, and most tests have also shown that the crusher holds some advantage over the crimper. Conditioned stems will dry nearly as fast as leaves. The effectiveness of both the crusher and crimper are more pronounced in legumes than in grasses. Conditioned hay will pick up more moisture during the night than unconditioned hay, but it will lose it faster the following day.

The crusher requires about twice as much power as the crimper. Horsepower to operate the crusher depends upon the pressure between the rolls. This pressure can be adjusted to give varying degrees of stem cracking which in turn affects drying rate. The effect of stem cracking on drying is more pronounced in legumes than in grasses. Varying crimping pressures had negligible effects on the rate of drying and power requirements.

The effect on the drying rate of hay by conditioning with the flail harvester appears greater than that of the crusher and crimper.This improvement of the drying rate is due to laceration of the hay. Some of the hay conditioned by flail harvesters is chopped relatively fine. Thus the pick-up losses may be more than those encountered from crushing or crimping. The stubble losses due to improper machine adjustment may be greater than for the standard mower.

Forage that passes through a conditioner may be left in the swath in a fluffed condition. The degree of fluffiness depends upon the position of the deflector. Fluffing had negligible effects on the rate of drying of timothy, but some slight effects were realized in legumes.

*Moisture content is calculated on wet weight basis.

# HAY CONDITIONERS
# In the Northeastern United States

## Introduction

DRYING of forage in the swath with minimum loss of foliage and deterioration in quality is a problem which faces farmers. Field curing hay to 20 per cent moisture may require two to four days depending upon the weather.

Unfavorable weather during the harvesting season causes large quantities of forage to spoil or deteriorate in quality. Rain during this season increases the risk of damage. The reduction in quality is due to leaching of the nutrients, the bleaching action of the sun, and the leaf shattering due to extra handling and uneven drying.

Any process or operation which will reduce the period the forage has to remain in the field is of importance to the farmer. Hay that is conditioned will dry faster in the field and also faster on the hay finisher in the barn. Figure 1 shows the amount of moisture which must be removed to produce one ton of 20 per cent moisture hay.

The leaves of hay dry more rapidly than the stems; thus by the time the stems reach a moisture level sufficient for storage, the leaves are overdry. The excessive drying of the leaves only serves to increase shattering. In legumes, 30 to 40 per cent of the weight and more than 50 per cent of the nutrients are in the leaves.

Much progress has been made in recent years in the development of hay conditioners. These machines crack the stems, thereby accelerating the drying rate of forage crops.

The present commercial conditioners may be put into two general classifications—crusher and crimper. The fluted-roll machine is commonly referred to as a crimper and the smooth-roll machine is called a crusher. Both will pick up a swath and pass it beween their rolls cracking the stems in the process. Many machines also provide some means of adjusting the pressure exerted on the hay by the roll. The crimper cracks the stem at regular intervals, whereas the smooth roll crushes the stem along its entire length.

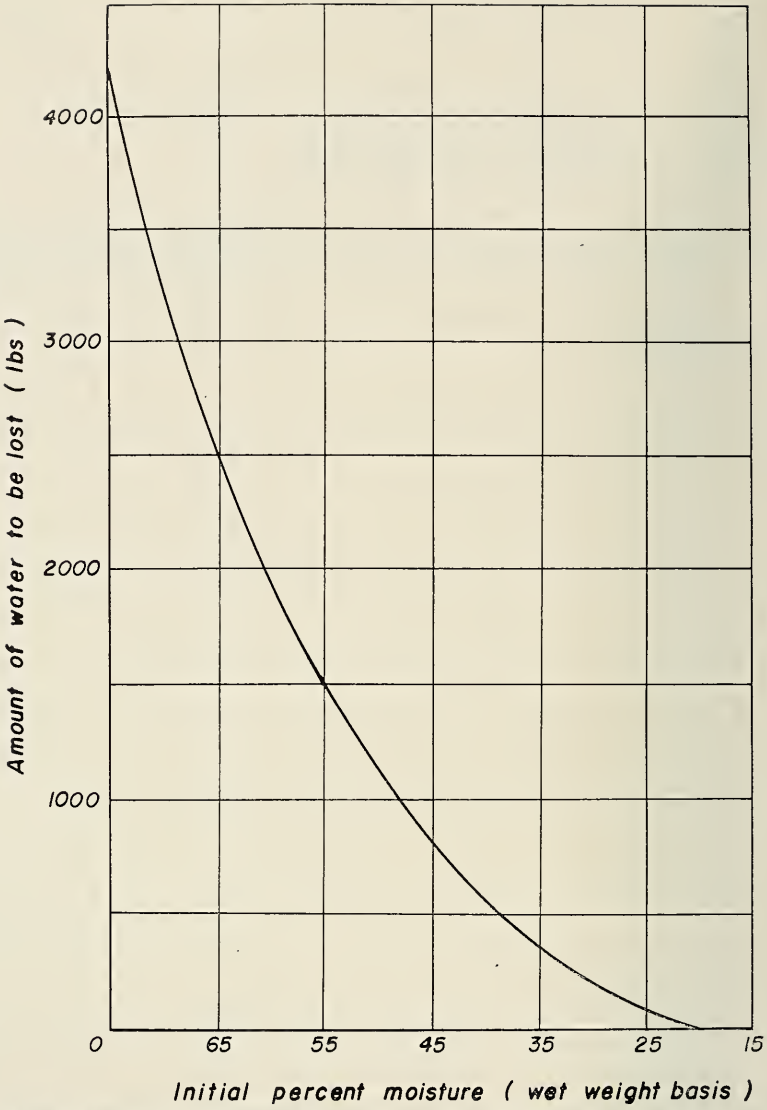


FIGURE 1. Amount of moisture which must be removed from hay to produce one ton of 20 per cent moisture hay.

In addition to the more common hay conditioners, some interest is developing in the use of the flail forage harvester in hay operations.[1] This machine, though it cuts a narrower swath than conventional mowers, appears advantageous from the standpoint of effectively

[1]See Nomenclature (page 32) for definition.

combining the mowing and conditioning in one operation, thus reducing the operational time and speeding the drying rate.

The manufacturers of self-propelled windrowers have recently included conditioning rolls as an integral part of the machine in an effort to realize a market for the windrower-conditioner as a haymaking tool. Several features of these machines appeal to farmers. Among these are maneuverability and time-saving because of extra width of cut and of eliminating separate operations of conditioning and raking. The fact that the machine can be used for haymaking, grass silage, and stubble clipping following combining will also favor its acceptance.

## Effect of Crushing and Crimping on the Field Drying Rate

The purpose of conditioning, whether by smooth or fluted roller, is to accelerate the field drying of forage. Cracking of the stems promotes drying. Leaves have a high rate of drying when compared with stems. Even when the leaves become dry and brittle the stems will contain a high percentage of moisture. Crushed stems dry nearly as fast as leaves (Figure 2). Moisture determinations of soybean leaves and stems, field cured over the same period of time, are shown in Table 1.

The beneficial effects of conditioning are more pronounced in legume than in grass crops. Soybeans, red clover, and alfalfa respond favorably to conditioning. Results show that during favorable

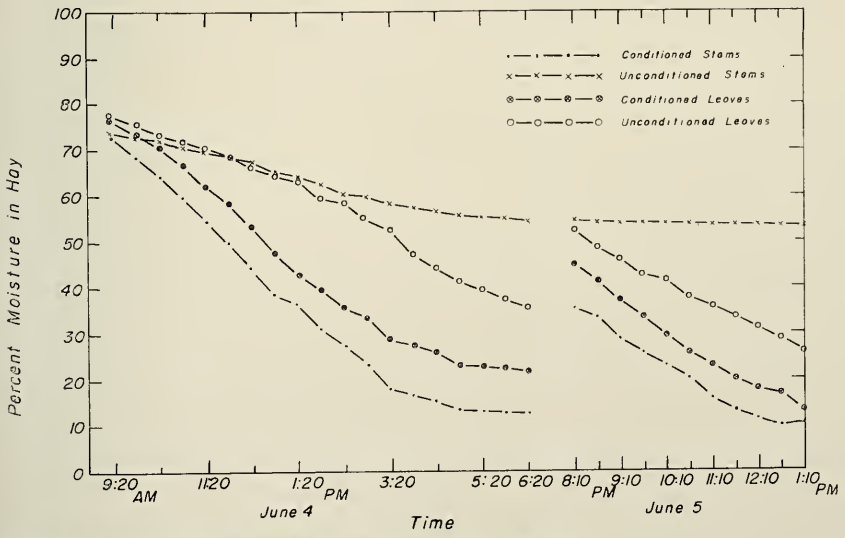


**FIGURE 2. Drying characteristics of pre-bloom alfalfa.**

TABLE 1. Moisture in Stems and Leaves of Soybeans

| Treatment | Per Cent Moisture | |
|---|---|---|
| | Stems | Leaves |
| At the time of cutting | 70 | 74 |
| After field curing | | |
| crushed | 42 | 33 |
| Trial I crimped | 43 | 31 |
| none (mowed only) | 54 | 29 |
| crushed | 32 | 21 |
| Trial II crimped | 29 | 19 |
| none (mowed only) | 46 | 20 |

weather, forage of 65 to 70 per cent initial moisture (mowed and conditioned in the morning) dried to 18 to 25 per cent moisture by late afternoon. However, if the initial moisture content of the crop was more than 75 per cent, or if the yield was more than 10 tons per acre (wet weight), the forage had to be left in the field overnight. Table 2 and Figures 3, 4, 5, and 6, show the field drying rate of unconditioned (mowed only), crimped, and crushed red clover, clover-timothy mixture, timothy, soybeans, and alfalfa. The data in Table 2 indicate that in favorable drying weather, conditioned timothy and clover-timothy mixture will dry to 25 per cent moisture or less in 7 to 9 hours.

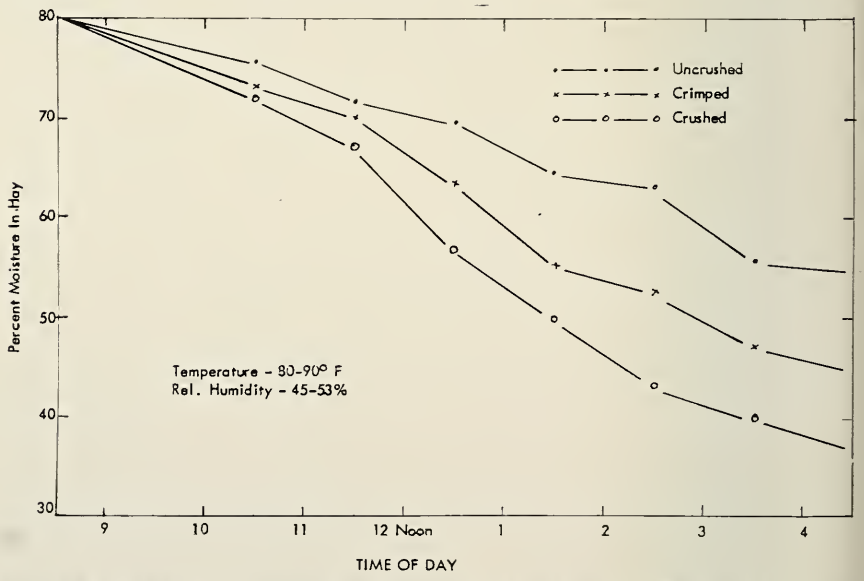


FIGURE 3. Effect of crimping and crushing on the drying rate of red clover.

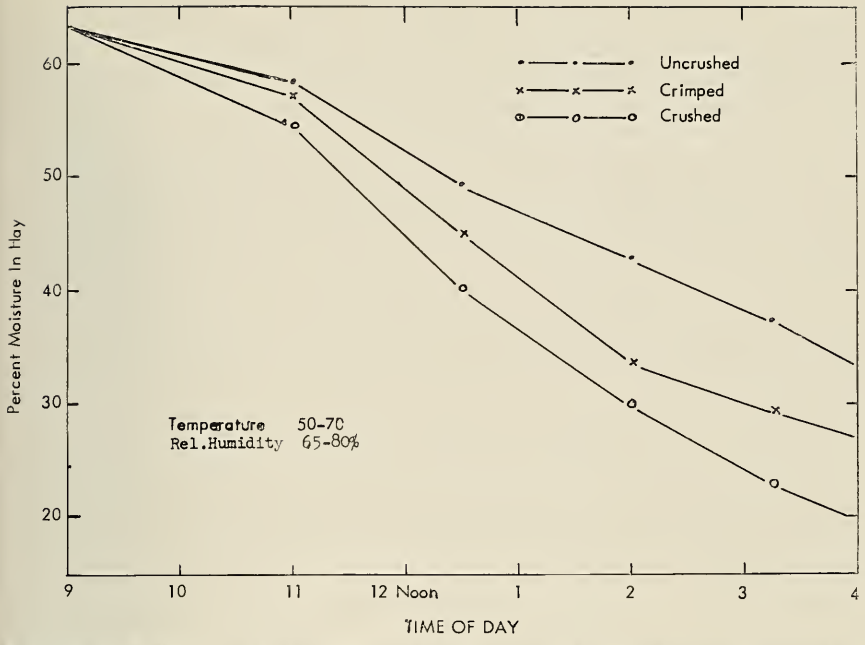


**FIGURE 4. Field drying rate of uncrushed, crimped, and crushed clover-timothy mixture.**

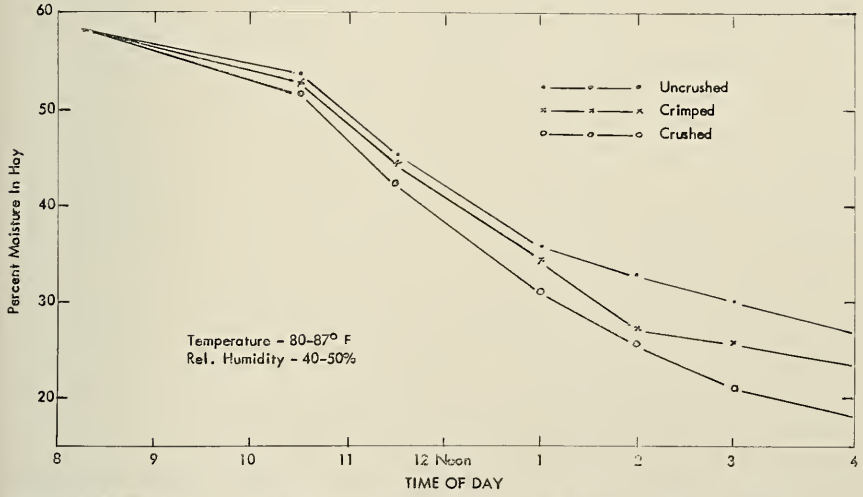


**FIGURE 5. Field drying rate of uncrushed, crimped, and crushed timothy.**

When moisture content in conditioned timothy, timothy-clover, and brome grass forages reached approximately 25 per cent, moisture in unconditioned forage cured over the same period was about 33 to

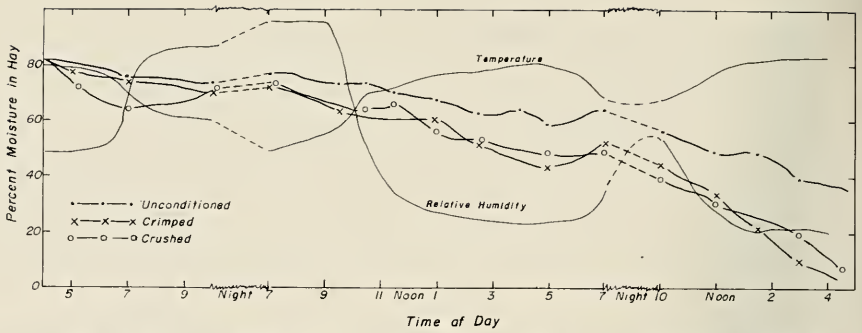


**FIGURE 6. Drying rates of unconditioned, crimped, and crushed soybeans.**

40 per cent. In soybeans, red clover, and alfalfa the difference ranged from 15 to 23 per cent. Most of the tests showed that crushing was more effective than crimping. However, there were occasions when the crimper proved more effective, Figure 10, and there was no appreciable difference in the drying rate of crimped or crushed soybeans, Figure 6. Rain following conditioning tends to reduce the effect of conditioning.

Some parts of the Northeast Region, particularly those areas centering around the District of Columbia, Rhode Island, Southeastern New York, Eastern Shore of Maryland, and parts of Delaware, have climatic conditions (frequent rains and extremely high relative humidity) which often make it impossible to cure hay in one day. Here, it is not unusual to require two to four days to reduce the moisture content to 40 per cent. However, conditioning, regardless of the type of machine used, did increase the rate of drying, as shown in Figure 8. The drying period required three days, from September 30 through October 3, for alfalfa which had been conditioned by a combination crusher and crimper, regular crimper, and a crusher. Figure 7 shows that the unconditioned hay had the slowest drying rate. On October 1, 0.95 inches of rain fell. The mean temperature was 54° F. and the mean relative humidity was 93 per cent. At the end of the first test day the hay, regardless of type of conditioning, was not dry enough to bale without heat drying.

On occasions forage was cut and harvested the same day. This was particularly true when the temperature was relatively high, the humidity low, and the sky clear with some wind movement. If the hay was field cured to 45 per cent and baled, it could then be placed on a heated air drier for finishing. With good weather conditions and heated-air drying, hay could frequently be removed from the field the same day it was cut.

TABLE 2. Field Drying Rates of Mowed, Crimped, and Crushed Hay

| Time Cut | Temperature °F | Relative Humidity (Per Cent) | Per Cent Moisture | | Time Samples Taken | Per Cent Moisture Treatment After Mowing | | |
|---|---|---|---|---|---|---|---|---|
| | | | Forage | Soil | | None | Crimped | Crushed |
| June 18, 1957 Clover-Timothy 8:15 A.M | 85-90 | 60-70 | 75.5 | ** | 11:00 A.M. | 61.7 | 58.8 | 53.0 |
| | | | | | 2:15 P.M. | 42.2 | 30.0 | 22.0 |
| | | | | | 5:20 P.M. | 28.8 | 18.0 | 15.9 |
| July 2, 1957 Clover-Timothy 9:00 A.M. | 50-70 | 65-80 | 62.9 | 18.8 | 11:00 A.M. | 58.2 | 57.3 | 54.5 |
| | | | | | 12:30 P.M. | 49.3 | 45.0 | 40.0 |
| | | | | | 2:00 P.M. | 43.0 | 33.5 | 30.0 |
| | | | | | 3:15 P.M. | 37.4 | 29.5 | 23.0 |
| | | | | | 4:00 P.M. | 33.8 | 27.0 | 20.0 |
| July 3, 1957 Timothy 8:15 A.M. | 80-87 | 40-50 | 58.0 | 16.6 | 10:30 A.M. | 54.1 | 53.0 | 52.0 |
| | | | | | 11:30 A.M. | 45.6 | 45.0 | 42.5 |
| | | | | | 1:00 P.M. | 35.5 | 34.0 | 31.0 |
| | | | | | 2:00 P.M. | 33.2 | 27.0 | 26.0 |
| | | | | | 3:00 P.M. | 30.5 | 26.0 | 21.0 |
| | | | | | 4:15 P.M. | 27.3 | 23.0 | 17.5 |
| July 12, 1957 Clover 2nd Cut 8:30 A.M. | 80-90 | 45-53 | 80.0 | 20.4 | 10:30 A.M. | 75.4 | 73.0 | 72.0 |
| | | | | | 11:30 A.M. | 71.5 | 70.0 | 67.0 |
| | | | | | 12:30 P.M. | 69.4 | 63.5 | 57.0 |
| | | | | | 1:30 P.M. | 64.6 | 55.0 | 50.0 |
| | | | | | 2:30 P.M. | 63.0 | 53.0 | 43.0 |
| | | | | | 3:30 P.M. | 55.7 | 47.0 | 40.0 |
| | | | | | 4:30 P.M. | 54.5 | 45.0 | 37.0 |

*Data not available.

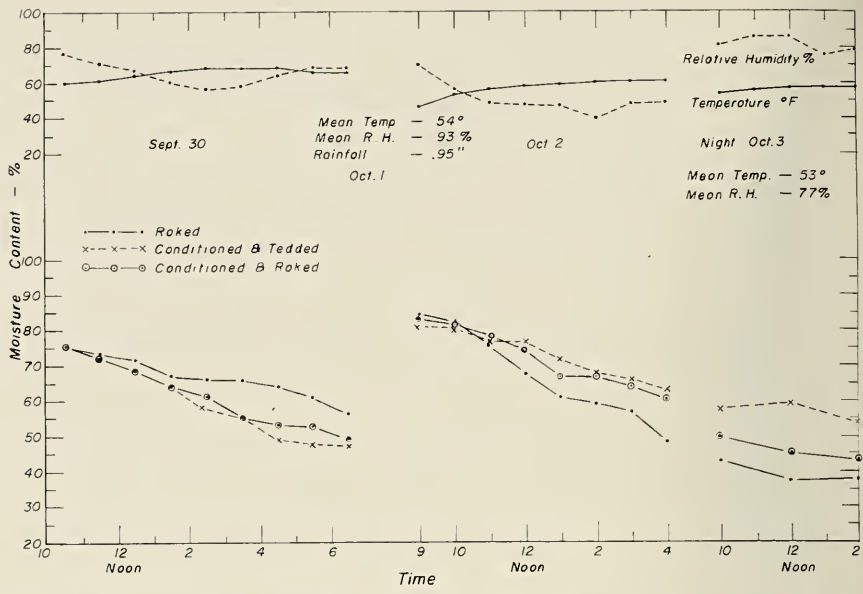


**FIGURE 7. Effects of tedding and raking on drying rate of conditioned alfalfa.**

Sometimes climatic conditions are not so favorable, thus requiring two or more days for curing—particularly heavy first-cutting crops. Figures 8, 9, and 10 show the moisture pickup during the night hours. Conditioned hay absorbed more moisture during the night hours than the unconditioned hay, but gave it up more readily the second day. Figures 8, 9, and 10 all compare a smooth-roll crusher with a crimper. Figures 8 and 9 show that crushed hay dried at a faster rate than the crimped hay. Figure 10 shows that crimped alfalfa dried faster than crushed alfalfa. Conditioning, either crimping or crushing, increased the drying rate.

## Power Requirements of Two Types of Conditioners

Laboratory tests showed that a crusher operating at different roller tensions required from 3.0 to 4.7 horsepower while running empty. Field testing for power used by the crusher and crimper was conducted while crushing alfalfa and soybeans. Measurements were made by a power take-off dynamometer, Figure 11. Test results in Table 3 show that the crusher at various roller pressures used 7.0 to 10.8 horsepower. During the power tests, the pickup cylinders were well above ground, but low enough to pick up all of the forage. The crimper required less than 4 horsepower.

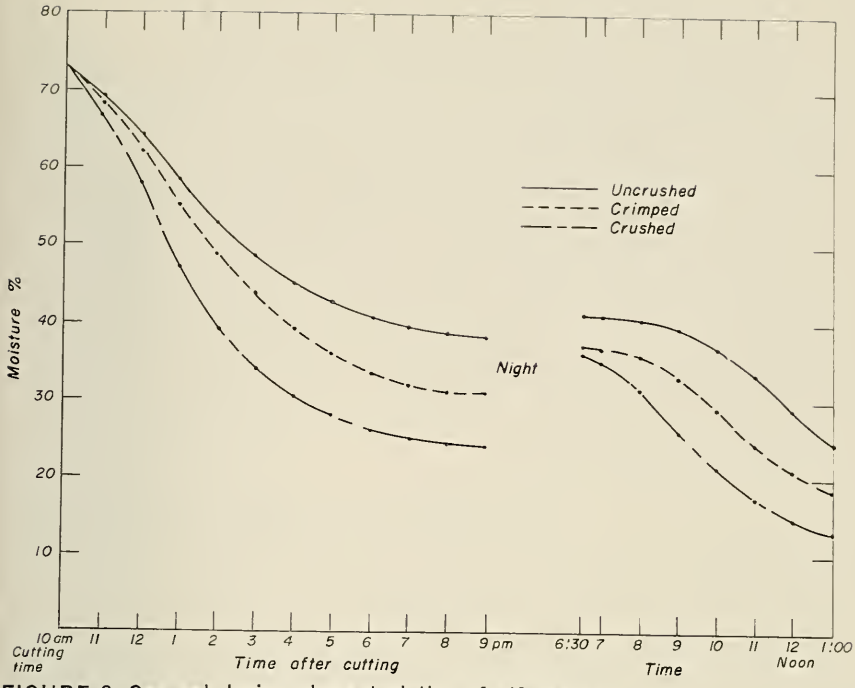


FIGURE 8. General drying characteristics of alfalfa hay.

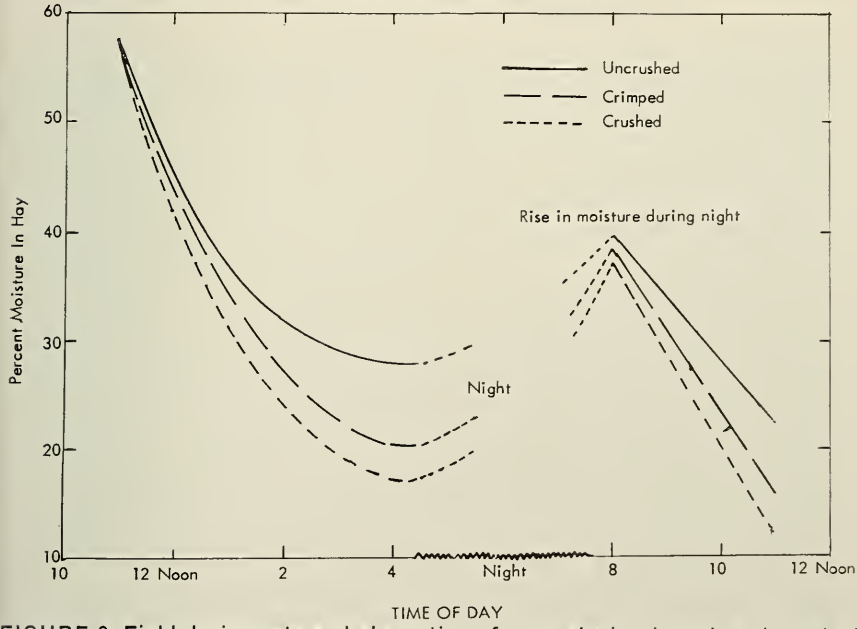


FIGURE 9. Field drying rate and absorption of uncrushed, crimped, and crushed timothy.

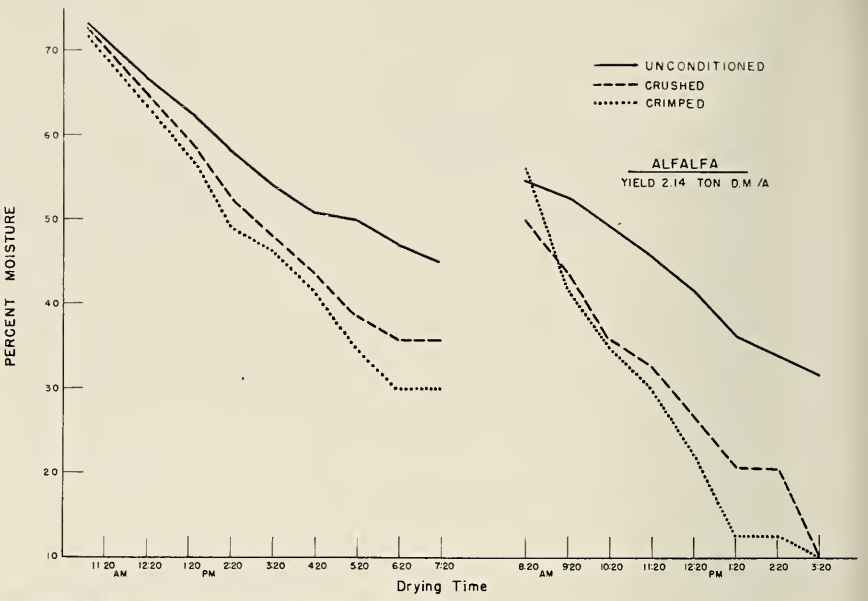


**FIGURE 10. Field drying rate test of alfalfa.**

Considering only power requirements, both the crimper and the mower crusher can be operated by a two-plow tractor. The mower-crusher combination weighed approximately 1,000 pounds at the

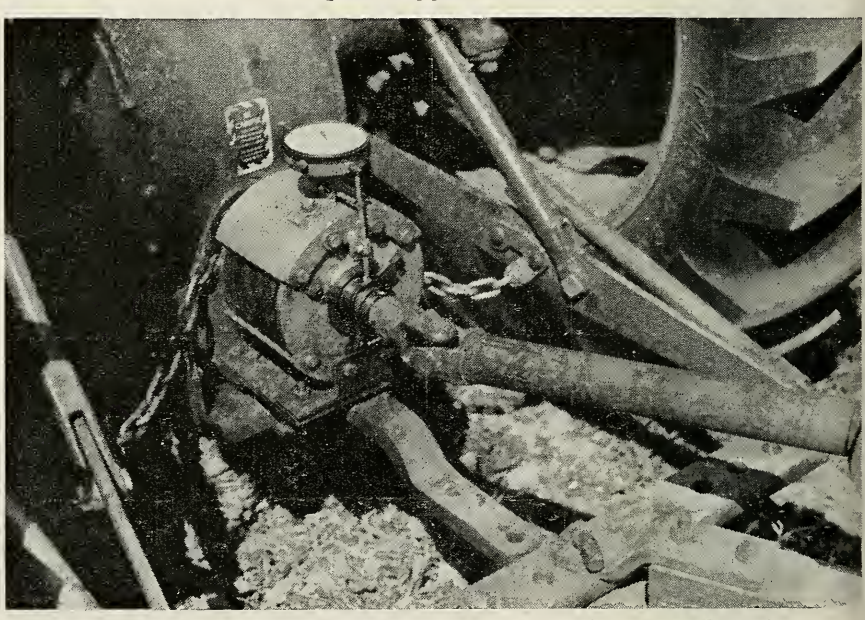

**FIGURE 11. PTO dynamometer measuring power requirements of crusher.**

TABLE 3. Power Required to Crush Alfalfa*

| Roller Tension in Pounds | Lbs/inch Roll Length | Power Take-off Shaft Speed | PTO Horsepower |
|---|---|---|---|
| 1882 | 13.0 | 530—550 | 7.0 |
| 2024 | 22.3 | 530—550 | 7.2 |
| 2568 | 28.2 | 530—550 | 8.8 |
| 3112 | 34.2 | 530—550 | 9.4 |
| 3656 | 40.1 | 530—550 | 10.8 |

*3.65 tons/acre with 74 per cent moisture.

hitch point to the tractor. Though the power requirement of the mower crusher is within the capacity of a two-plow tractor, a three-plow tractor is preferred.

## Effects of Roll Pressures on Drying Rate

The effects of roll pressures on the rate of moisture loss and the optimum roll pressure for different crops were determined by crushing or crimping forage at various pressures. An increase in the roll pressure of crushers, Figures 12, 13, and 14, tended to increase the

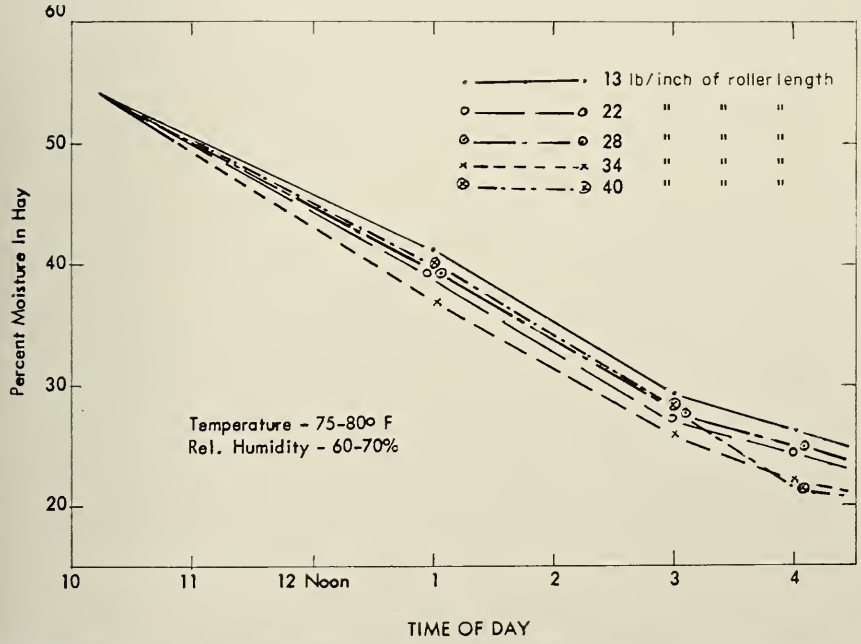


FIGURE 12. Effect of different crushing pressures on the field drying rate of timothy.

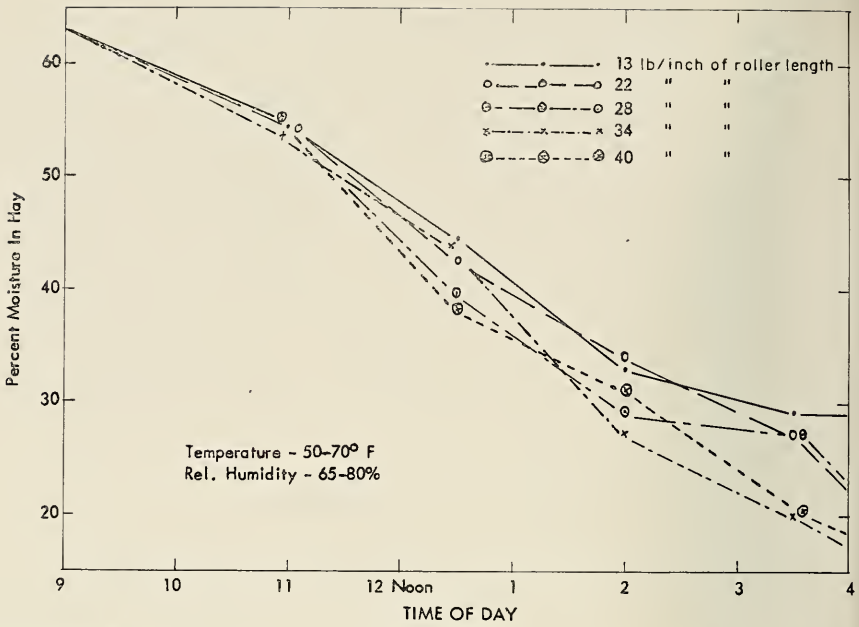


FIGURE 13. Effect of crushing pressures on the field drying rate of clover-timothy mixture.

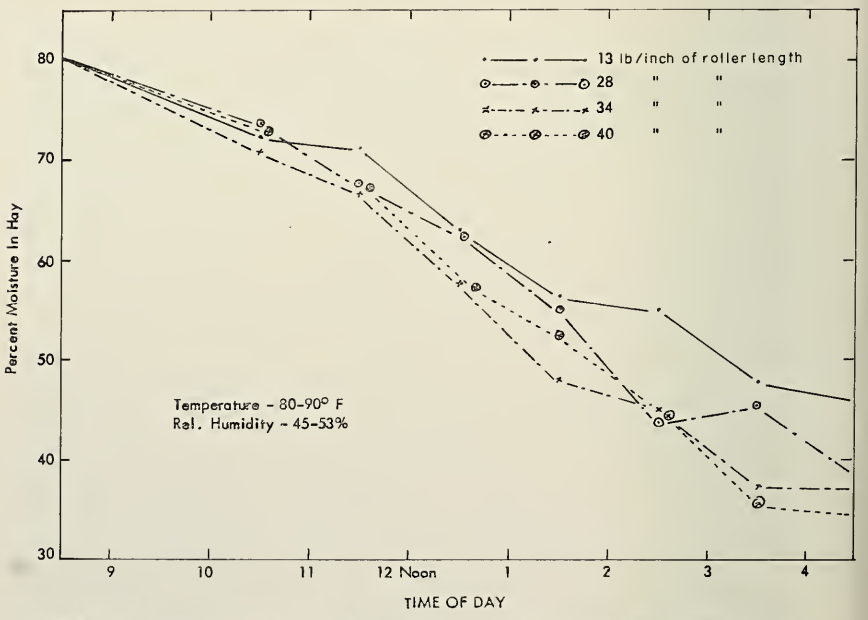


FIGURE 14. Effect of crushing pressures on the drying rate of red clover.

drying rate. The effect of increasing roll pressures on drying rate was more pronounced in red clover and alfalfa than in timothy and brome. Increasing the roll pressures beyond a certain value did not have any appreciable effect on the drying rate of timothy (see Table 4a). The clover-timothy mixture and pure red clover crushed at a higher pressure dried faster than hay crushed at lower pressures, Table 4b. During the various tests the minimum and maximum pressures used were 13 and 40 pounds per inch of roll length. A pressure of 13 pounds per inch tended to crush only the big stems, with negligible bruising of leaves, whereas a pressure of 40 pounds per inch of roller length gave uniform crushing, but 40 to 60 per cent of the leaves were bruised.

The recommended roll pressures for crushing different crops of 4 to 8 tons fresh cut per acre are:*

| | |
|---|---|
| Timothy and brome | 23 to 28 lb/in. of roller length |
| Clover-timothy mixture | 25 to 30 lb/in. of roller length |
| Alfalfa, red clover, and soybeans | 28 to 33 lb/in. of roller length |

Increasing or decreasing roll pressures of a crimper had negligible effect on the rate of drying.

## Effect of Fluffing on Drying Rate

For the purpose of studying the effect of fluffing on the drying rate, a crimper was modified to obtain maximum possible fluffing. Forage conditioned by another crimper having normal action was used to serve as a basis of comparison between fluffed and unfluffed forage. Observations of humidity above and below the forage, as well as temperatures on top and under the forage, are given in Tables 5a and 5b. These observations were made during the field drying rate tests conducted on alfalfa and soybeans. Table 5 shows that during the drying period the relative humidity of air below the forage is higher than that of the atmosphere. Data in the tables also show that the air temperature at the top surface of the forage is higher than that of atmospheric temperature, with the difference reaching as much as 21° F.

Results of fluffing, given in Table 6, show that there were negligible differences between the moisture of fluffed and unfluffed timothy dried over the same period, while some beneficial effects from fluffing were obtained in the clover-timothy mixture, Figure 15. Fluffing without conditioning does not increase the drying rate, Figure 16.

*The pressure is inadequate if portions of the stems are uncrushed (not split). Excessive pressure crushes both leaves and stems causing the leaves to dry more rapidly than the stems, thus defeating the purpose for crushing.

TABLE 4a. Effect of Smooth-Roll Crushing Pressure on the Drying Rate of a Timothy-Brome Mixture

| Date | Time Crop Was Mowed and Crushed | Per Cent Moisture at Time of Cutting | Time of Day Samples Taken | Per Cent Moisture of Differently Treated Forage Crushed at Roll Pressures of: | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Mowed Only | Lb/Inch Length of Roll | | | | |
| | | | | | 13 | 22 | 28 | 34 | 40 |
| June 10, 1957 | 1:00 P.M. | 62.1 | 2:30 P.M. | 57.0 | 45.7 | 50.2 | 43.0 | 48.0 | 53.4 |
| | | | 3:50 P.M. | 48.9 | 38.1 | 36.6 | 38.0 | 37.0 | 35.3 |
| | | | 5:30 P.M. | 39.6 | 33.4 | 28.5 | 25.8 | 22.8 | 25.8 |
| June 17, 1957 | 9:15 A.M. | 63.2 | 11:45 A.M. | 43.2 | 40.0 | 40.2 | 34.6 | 38.2 | 34.8 |
| | | | 2:15 P.M. | 27.3 | 23.2 | 25.2 | 17.7 | 19.1 | 19.7 |
| | | | 4:15 P.M. | 22.0 | 16.8 | 15.5 | 15.2 | 10.5 | 11.7 |
| July 1, 1957 | 10:15 A.M. | 54.2 | 1:00 P.M. | 41.2 | 41.1 | 39.4 | 38.9 | 36.4 | 39.4 |
| | | | 3:00 P.M. | 36.4 | 29.4 | 26.9 | 27.5 | 25.3 | 28.4 |
| | | | 4:00 P.M. | 34.7 | 26.3 | 24.4 | 24.9 | 22.2 | 21.4 |
| July 2, 1957 | | | 10:30 A.M. | 28.5 | 22.7 | 20.6 | * | 19.5 | 20.4 |
| | | | 1:00 P.M. | 23.4 | 15.1 | 12.9 | 14.4 | 13.7 | 13.4 |
| July 3, 1957 | 8:15 A.M. | 58.0 | 10:30 A.M. | 54.1 | * | 53.2 | 51.4 | 52.0 | 52.8 |
| | | | 11:30 A.M. | 45.6 | 41.5 | 42.1 | 42.5 | 41.2 | 43.9 |
| | | | 1:00 P.M. | 35.5 | 33.3 | 31.0 | 30.9 | 26.6 | 33.3 |
| | | | 2:00 P.M. | 33.2 | 26.6 | 29.0 | * | 26.0 | 24.0 |
| | | | 3:00 P.M. | 30.5 | 25.5 | 28.6 | * | 22.1 | 19.5 |
| | | | 4:45 P.M. | 27.3 | 18.2 | 19.6 | 17.9 | 15.6 | 14.6 |

*Data not available.

TABLE 4b. Effect of Smooth-roll Crushing Pressure on the Drying Rate of Clover and a Clover-Timothy Mixture

| Date | Time Crop Was Mowed and Crushed | Per Cent Moisture at Time of Cutting | Time of Day Samples Taken | Per Cent Moisture of Differently Treated Forage Crushed at Roll Pressures of: | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Mowed Only | Lb/Inch Length of Roll | | | | |
| | | | | | 13 | 22 | 28 | 34 | 40 |
| July 2, 1957 | 9:00 A.M. | 62.9 | 11:00 A.M. | 58.2 | 54.6 | 54.0 | * | 54.2 | 55.8 |
| | | | 12:30 P.M. | 49.3 | 44.6 | 42.5 | 39.8 | 44.0 | 37.6 |
| | | | 2:00 P.M. | 43.0 | 32.8 | 39.3 | 29.4 | 27.3 | 31.6 |
| | | | 3:15 P.M. | 37.4 | 28.8 | 27.0 | 27.7 | 20.1 | 20.3 |
| | | | 4:00 P.M. | 33.8 | 30.4 | 21.9 | 21.4 | 17.0 | 18.7 |
| July 12, 1957 | 8:15 A.M. | 80.0 | 10:30 A.M. | 75.4 | 72.1 | 66.2 | 73.6 | 70.6 | 72.7 |
| | | | 11:30 A.M. | 71.5 | 71.2 | 66.4 | 67.9 | 66.6 | 67.0 |
| | | | 12:30 P.M. | 69.4 | 62.9 | 57.7 | 63.0 | 55.5 | 57.2 |
| | | | 1:30 P.M. | 64.6 | 56.1 | 48.5 | 54.9 | 48.0 | 52.8 |
| | | | 2:30 P.M. | 63.0 | 55.0 | 41.1 | 43.7 | 44.9 | 44.6 |
| | | | 3:30 P.M. | 55.7 | 47.6 | 42.2 | 46.8 | 37.4 | 35.5 |
| | | | 4:30 P.M. | 54.5 | 46.5 | 38.5 | 38.2 | 37.7 | * |

*Data not available.

TABLE 5a. Temperature and Relative Humidity in the Vicinity of Alfalfa During Field Drying

| Day and Time | Sky Condition | Moisture in Hay (Alfalfa) (Per Cent) | Relative Humidity (Per Cent) | | Temperature °F | | |
|---|---|---|---|---|---|---|---|
| | | | Atmospheric | On Soil Surface and Below Forage | Atmospheric | On Top of Forage | On Soil Surface and Below Forage |
| August 7 | | | | | | | |
| 11:00 A.M. | Bright | 66 | 57 | 66 | * | * | * |
| 12:00 A.M. | Bright | 62 | 53 | 68 | 81 | 90 | 81 |
| 12:00 P.M. | Bright | 57 | 50 | 70 | 85 | 106 | 80 |
| 1:45 P.M. | Cloudy | 45 | 51 | 70 | 80 | 85 | 80 |
| 3:00 P.M. | Bright | 37 | 48 | 58 | 80 | 85 | 80 |
| 4:00 P.M. | Cloudy | 33 | 43 | 62 | 85 | 86 | 76 |
| 5:00 P.M. | Bright | 30 | 47 | 69 | 87 | 90 | 73 |
| August 8 | | | | | | | |
| 7:30 A.M. | Cloudy | 52 | 96 | 95 | 55 | 55 | 61 |
| 8:30 A.M. | Cloudy | * | 83 | 82 | 72 | 69 | 68 |
| 9:30 A.M. | | 35 | 63 | 89 | 72 | 78 | 69 |
| 10:30 A.M. | Slight Overcast | 24 | 45 | 76 | 84 | 88 | 76 |
| 11:30 A.M. | Bright | * | 42 | 61 | 90 | 102 | 72 |
| 12:00 A.M. | Cloudy | 21 | 40 | 44 | 88 | 89 | 76 |

*Data not available.

TABLE 5b. Temperature and Relative Humidity in the Vicinity of Soybeans During Field Drying

| Day and Time | Sky Condition | Air Movement | Moisture in Hay (Soybeans) (Per Cent) | Relative Humidity (Per Cent) | | Temperature °F | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Atmospheric | On Soil Surface and Below Forage | Atmospheric | On Top of Forage | On Soil Surface and Below Forage |
| Sept. 5, 1957 | | | | | | | | |
| 7:00 A.M. | Foggy | Still | 68 | 97 | 97 | 52 | 52 | 54 |
| 9:30 A.M. | Foggy | Still | 65 | 96 | 94 | 56 | 60 | 59 |
| 10:30 A.M. | Bright | Slight Breeze | 62 | 70 | 62 | 50 | 72 | 68 |
| 11:30 A.M. | Bright | Slight Breeze | 57 | 39 | 72 | 69 | 74 | 66 |
| 1:00 P.M. | Bright | Slight Breeze | 54 | 29 | 72 | 72 | 83 | 42 |
| 2:00 P.M. | Bright | Slight Breeze | 51 | 27 | 73 | 75 | 92 | 72 |
| 2:30 P.M. | Bright | Slight Breeze | 48 | 24 | 75 | 77 | 96 | 72 |
| 3:30 P.M. | Bright | Slight Breeze | 46 | 23 | 42 | 79 | 91 | 73 |
| 5:00 P.M. | Bright | Slight Breeze | 44 | 23 | 55 | 83 | 84 | 70 |

TABLE 6. Effect of Fluted-Roller Pressure and Fluffing on the Drying Rate of Various Crushed Hays

| Date and Crop | Time Mowed | Moisture Content (Per Cent) | Time Samples Taken | Per Cent Moisture | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Crimped | | | Crimped and Fluffed | | |
| | | | | Low Crimping Pressure | Medium Crimping Pressure | High Crimping Pressure | Low Crimping Pressure | Medium Crimping Pressure | High Crimping Pressure |
| June 27, 1957 Timothy June 28, 1957 | 8:45 A.M. | 57.4 | 10:45 A.M. | 47.0 | * | 43.0 | 40.5 | 40.0 | 38.3 |
| | | | 1:15 P.M. | 27.6 | 29.7 | 27.1 | 24.6 | 24.7 | 30.4 |
| | | | 3:30 P.M. | 24.2 | 20.2 | 18.5 | 20.9 | 22.0 | 19.2 |
| | | | 9:00 A.M. | 26.1 | 25.6 | 25.3 | 25.4 | 25.7 | 23.8 |
| | | | 12:00 Noon | 18.0 | 15.8 | 15.6 | 20.7 | 16.6 | 14.6 |
| July 1, 1957 Timothy July 2, 1957 | 10:15 A.M. | 54.2 | 1:00 P.M. | 42.5 | 42.3 | 42.0 | 40.2 | 41.5 | 43.2 |
| | | | 3:00 P.M. | 33.8 | 33.0 | 32.4 | 33.0 | 31.6 | 33.2 |
| | | | 4:00 P.M. | 30.3 | 28.4 | 29.0 | 30.0 | 27.9 | 26.8 |
| | | | 10:30 A.M. | 24.1 | 23.4 | 23.3 | 24.6 | 23.3 | 25.2 |
| | | | 1:00 P.M. | 17.4 | 15.2 | 16.6 | 17.0 | 15.3 | 13.6 |
| July 3, 1957 Timothy | 8:15 A.M. | 58.6 | 10:30 A.M. | 52.0 | 54.6 | 52.1 | 54.8 | 52.0 | 48.8 |
| | | | 11:30 A.M. | 44.7 | 46.0 | 44.6 | 47.5 | 44.6 | 44.4 |
| | | | 1:00 P.M. | 35.7 | 34.3 | 32.0 | 41.5 | 39.6 | 33.8 |
| | | | 2:00 P.M. | 27.2 | 27.2 | * | * | 28.8 | 27.6 |
| | | | 3:00 P.M. | 26.7 | 25.7 | 25.8 | 29.4 | 24.7 | 23.6 |
| | | | 4:15 P.M. | 22.6 | 25.8 | 26.1 | 20.5 | * | * |
| July 2, 1957 Red Clover-Timothy Mixture | 9:00 A.M. | 62.9 | 11:00 A.M. | 57.8 | 58.2 | 56.3 | 56.2 | 53.5 | 56.0 |
| | | | 12:30 P.M. | 43.9 | 47.7 | 44.3 | 43.2 | 39.6 | 46.0 |
| | | | 2:00 P.M. | 30.0 | 34.2 | 35.8 | 36.8 | 33.7 | 36.2 |
| | | | 3:15 P.M. | 33.8 | 27.7 | 27.4 | 28.1 | 33.5 | 30.0 |
| | | | 4:00 P.M. | 28.9 | 26.1 | 25.6 | 24.5 | 24.8 | 20.0 |
| July 12, 1957 Red Clover 2nd Cut | 8:15 A.M. | 80.0 | 10:30 A.M. | 74.5 | 73.6 | 72.0 | | | |
| | | | 11:30 A.M. | 72.6 | 70.9 | 69.6 | | | |
| | | | 12:30 P.M. | 63.8 | 64.7 | 63.0 | | | |
| | | | 1:30 P.M. | 57.1 | 57.7 | 54.4 | | | |

*Data not available.

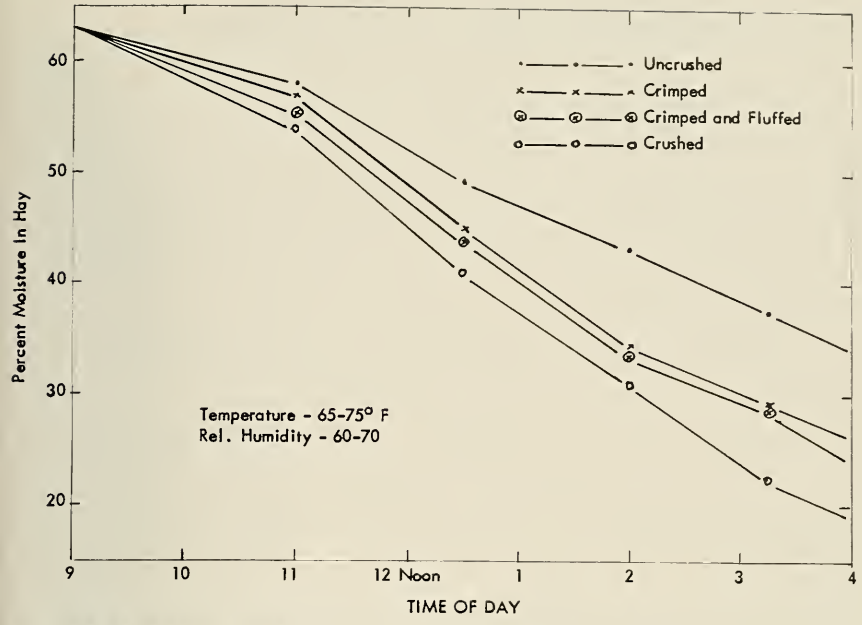


FIGURE 15. Effect of fluffing on the field drying rate of clover-timothy mixture.

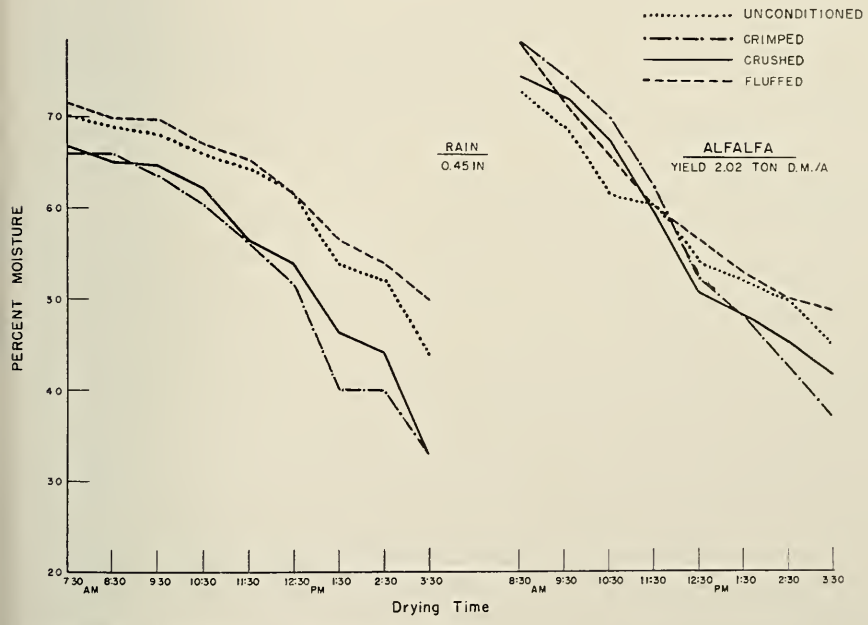


FIGURE 16. Field drying rate test of alfalfa.

## Effect of Conditioning Methods on Field Losses

A study on pick-up losses, which involve stems and leaves remaining on the ground after completion of the harvest, showed for both timothy-brome and alfalfa, losses approximately twice as large for flail-cut material as for unconditioned material, Table 7. This loss difference is attributable to the short-clipped material produced by the flail, coupled with its more severe beating action. This tendency to produce shorter lengths and greater shattering makes subsequent pick-up more difficult.

TABLE 7. Pick-Up Losses by Conditioning Method

| Treatment | Crop Loss | | | |
|---|---|---|---|---|
| | Alfalfa | | Timothy-Brome | |
| | Lbs/Acre | Per Cent Total Yield | Lbs/Acre | Per Cent Total Yield |
| Unconditioned | 159 | 6.88 | 191 | 5.52 |
| Crushed | 254 | 10.99 | 141 | 4.07 |
| Crimped | 257 | 11.33 | 192 | 5.55 |
| Flail-Cut | 327 | 14.16 | 365 | 10.55 |

Flail-harvesting compared with other conditioning methods in alfalfa shows more losses. The same comparison in the timothy-brome mixture shows a loss of nearly twice that of other conditioning methods. Because of leaf-shatter, any method of conditioning caused greater field losses in legumes than in grasses, when the hay was field cured and baled.

## Drying Rate of Flail-cut Forage

The advantages of forage conditioning are apparent from data presented in this bulletin. The flail-type forage harvester, though not specifically designed as a conditioner, has exhibited similar advantages. Test results show that this machine, slightly modified so as to allow it to deposit the cut swath back on the ground without windrowing, not only reduces curing time compared to that for unconditioned forage, but also requires less time than other conditioning methods. The machine has also been effective in reducing operational time by ¼ to ⅓ by combining mowing and conditioning in a single operation.

Figure 17 compares the drying rates of unconditioned, crimped, crushed and flail-cut timothy-brome forage. It shows that the flail-cut forage had the most rapid drying rate.

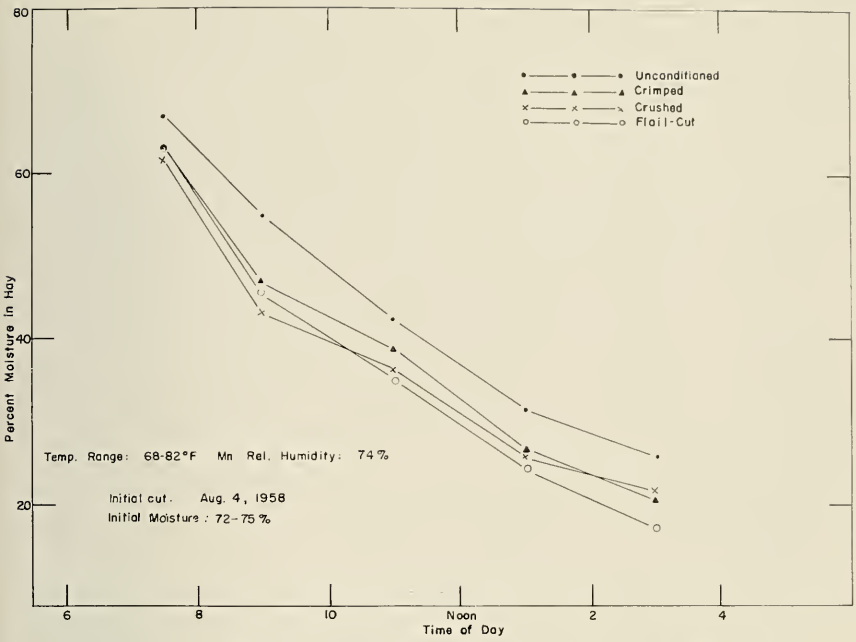


FIGURE 17. Drying rate of timothy-brome mixture (August 5, 1958).

## Effects of Tedding on Drying Rate

Tedding the forage one or more times has little or no influence on the drying rate (Tables 8 and 9), except where hay has been rained on before it is dry (Figures 7 and 18). Detailed measurement of wind movement within tedded and untedded forage clearly showed that tedding does not "rough up" the surface of the layer of hay sufficiently to cause any major change of air movement within the forage (Table 10). Wide changes in rate of crop displacement resulted in relatively small absolute changes in air movement within the undisturbed and tedded swaths. A difference in wind movement within the undisturbed and tedded swaths approached mathematical significance at the 5 per cent level, when all observations were combined. However, it is highly questionable if a small absolute difference of 0.06 miles per hour (about 5 ft/min.) is of any practical significance in terms of rate of drying.

## Effects of Windrowing and Crushing on Drying Rate

Observations of the self-propelled windrower, Figure 19, in operation showed that its cutting action was quite satisfactory. The reel was effective, especially in short material, in keeping the cut forage

TABLE 8. Effect of Tedding on Moisture Content of Unconditioned, Crimped, and Crushed Hay

| Test | Unconditioned | | Crimped | | Crushed | |
|---|---|---|---|---|---|---|
| | Not Tedded | Tedded | Not Tedded | Tedded | Not Tedded | Tedded |
| Experiment No. | Per Cent Moisture | Per Cent Moisture | Per Cent Moisture | Per Cent Moisture | Per Cent Moisture | Per Cent Moisture |
| 1 | 39.3 | 43.1 | 26.7 | 29.6 | 22.6 | 20.0 |
| 2 | 25.3 | 31.1 | 22.9 | 21.3 | 22.2 | 19.2 |
| 3 | 51.4 | 47.7 | 37.6 | 39.5 | 33.0 | 37.6 |
| 4 | 34.3 | 35.1 | 25.8 | 25.6 | 16.4 | 17.2 |
| 5 | 29.9 | 37.5 | 27.1 | 27.4 | 16.8 | 20.6 |
| 6 | 49.4 | 47.9 | 52.8 | 48.5 | 35.8 | 34.4 |
| 7 | 34.8 | | 25.3 | | | |
| Means—7 tests | 39.0 | | 31.5 | | 24.1 | |

Means—Not Tedded 6 Tests --31.6
Tedded ----------32.4

TABLE 9. Moisture Content of Untreated and Tedded Forage

| Treatment | Moisture Content at Different Sampling Times | | |
|---|---|---|---|
| | 1 % Moisture | 2 % Moisture | 3 % Moisture |
| 1. Untreated ---------- | 37 | 29 | 27 |
| 2. Tedded at time of cutting ---- | 40 | — | — |
| 3. Tedded with heavy wilt ------ | 37 | 28 | 31 |
| 4. Tedded with top leaves dry --- | — | 27 | 29 |
| 5. Tedded as in 2 and 3 ---------- | 41 | 29 | 34 |
| 6. Tedded as in 2 and 4 ---------- | | 30 | 28 |
| 7. Tedded as in 3 and 4 ---------- | | 28 | 32 |
| 8. Tedded as in 2, 3, and 4 ------ | | 33 | 34 |

TABLE 10. Influence of Rate of Wind Movement Five Feet Above Ground Upon Wind Movement Immediately Above and Within the Hay

| Condition | Rate of Wind Movement, Miles Per Hour | | | |
|---|---|---|---|---|
| | Height of 5 feet | Height of 8 inches | Within Tedded | Within Undisturbed Swath |
| Mean of 18 observations ------- | 6.5 | 2.8 | 0.60 | 0.54 |
| Maximum wind speed measured | 15.1 | 7.0 | 0.84 | 0.71 |
| Minimum wind speed measured | 1.8 | 1.0 | 0.41 | 0.40 |

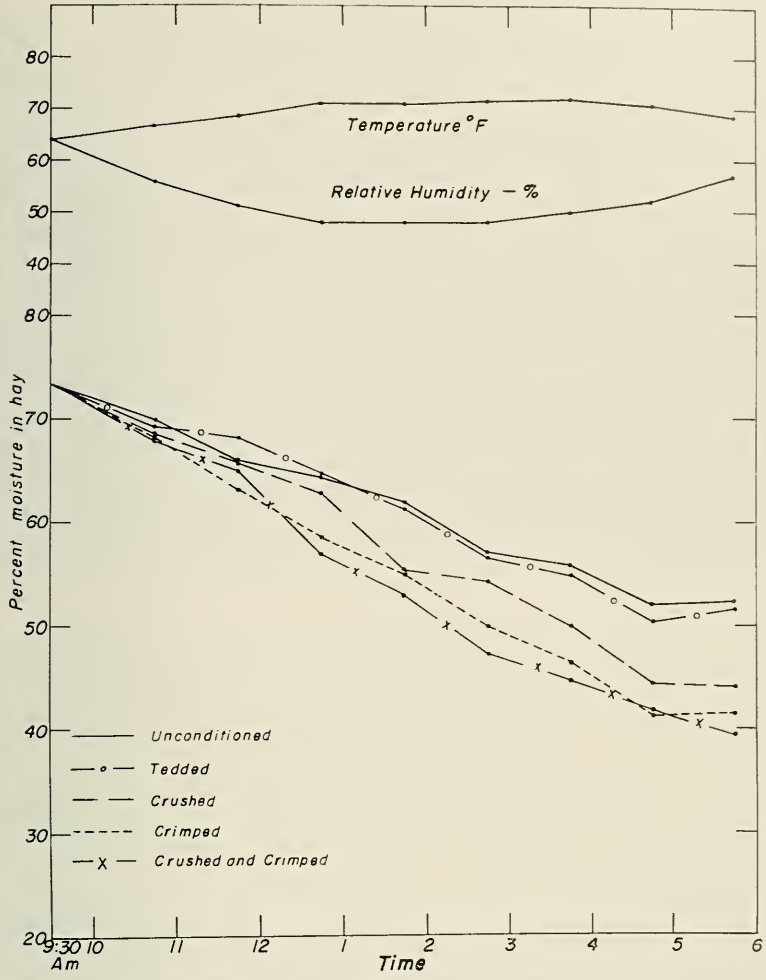


**FIGURE 18. Comparison of hay conditioners (alfalfa).**

moving back onto the aprons. Plugging of the sickle bar was not a problem.

The one factor which caused most loss of time was breakage of guards due to stones in the plots. Because of the weight of the header, its mounting arrangement, and its location directly in front of the heavy framework and propelling mechanism, the impact load which must be absorbed by the guards and other parts is much greater than that encountered by a conventional mowing machine with a relatively light cutting bar and cantilever mounting arrangement.

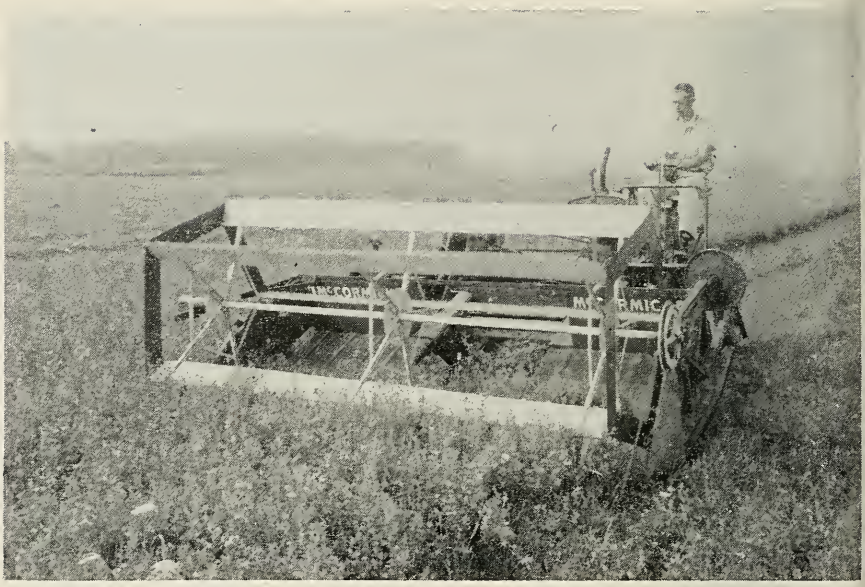

FIGURE 19. The reel keeps the cut forage flowing evenly back onto the aprons.

Examination of the stubble in the plots after mowing did not reveal any difference between the windrowed and conventionally mowed plots.

Table 11 shows the summary of moisture contents for all runs and treatments.

Statistical analysis of the moisture content of the samples showed that in all runs there was variation due to treatments and that no other effects caused significant variation.

Results of field tests of the windrower-conditioner indicated that the five treatments fell into three categories of drying rate. Beginning with the slowest drying rate and moving toward higher drying rates, the categories were:

1. Slow rate of field curing: Treatment C—Windrowed, not conditioned.
2. Medium field rate: Treatment E—windrowed, conditioned.
   Treatment A—mowed, not conditioned, and raked.
3. Fastest field curing rate: Treatment B—mowed, conditioned, and raked.
   Treatment D—mowed, conditioned, and left in swath.

TABLE 11. Mean Moisture Content of Samples Following Field Curing Period

| Treatment | Run 1 | Run 2 | Run 3 | Average of 3 runs |
|---|---|---|---|---|
| Windrowed, not conditioned ____ | 53.3 | 41.9 | 66.4 | 56.1 |
| Windrowed, conditioned ______ | 41.0 | 28.3 | 59.7 | 46.2 |
| Mowed, not conditioned, raked _ | 41.2 | 33.6 | 59.6 | 47.2 |
| Mowed, conditioned, raked ____ | 31.6 | 23.2 | 46.3 | 35.2 |
| Mowed, conditioned, left in swath | 25.4 | 23.8 | 45.2 | 33.0 |

Results of this experiment indicate that the self-propelled windrower with conditioning rolls does a satisfactory job of cutting second-cutting alfalfa and alfalfa-clover-grass mixtures in the encountered range of yield from 2,800 to 3,400 pounds of hay. The machine places the forage in a uniform windrow which is efficiently handled by the pick-up attachment of a baler or forage harvester, Figure 20.

While the conditioner rolls are effective in increasing the drying rate of windrowed material, nevertheless, the placing of the material

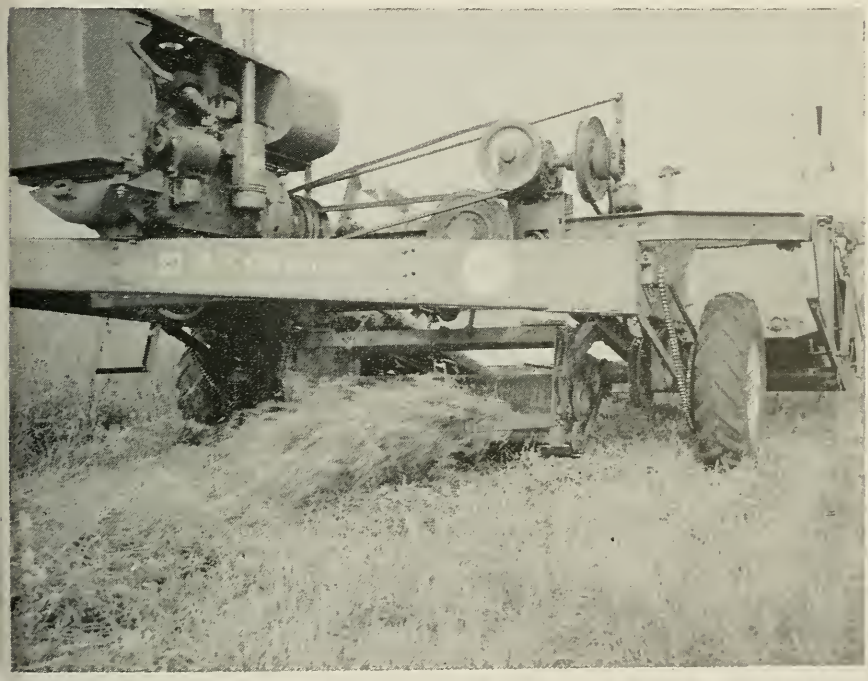

FIGURE 20. Conditioner rolls pick up forage behind header and deposit a ten-foot swath in a 30-inch windrow.

from a 10-foot width to dry in a windrow approximately 2½ to 3 feet in width decreases the drying rate so that the conditioned windrow offers no drying rate advantage over conventionally mowed, unconditioned material which is partially dried in the swath. The advantage gained by conditioning is offset by the disadvantage of windrow curing.

Windrowing of forage immediately after cutting is a disadvantage where the drying rate is concerned. The advantages of the self-propelled windrows as a haymaking tool come from its width of cut, maneuverability and elimination of separate operations of conditioning and raking.

## Factors to Consider When Planning to Condition Hay

Since it is essential to condition hay as soon after cutting as possible, it is desirable to operate both the mower and conditioner at the same time. If the mower and conditioner were separate units, it would be necessary to use two 2-plow tractors and two men for their operation. Therefore, it appears economical to attach the mower and conditioner so that one man and one tractor will be able to do the job. However, the mower-conditioner combinations are usually more expensive than a conditioner alone, assuming the availability of a mower, and they usually require a three-plow tractor for easy operation. It is often more economical to purchase the lower-cost item where small acreages are involved and when an extra tractor and operator are available. There is also the factor of reduced capacity of mower-crusher conditioners. Since the drying process does not begin until mowing is accomplished, any reduction in mowing capacity becomes a critical factor.

Since various crops require different crushing pressures, some means of adjusting roll clearance or pressure is absolutely necessary. As fluffing appears to have little effect on drying rates, adjustable deflectors, although desirable, are not necessary. Good pick-up characteristics are also important. It is necessary for the pick-up roll to be either slotted or fluted if it is not made of rubber. For this reason, where crushing is accomplished by two smooth rolls, a third fluted pick-up roll is required. Rapid attachment to the tractor, adjustments which can be made readily, and relative ease of operation are also desirable factors. For combined mower-conditioners, separate control of the mower and conditioner is especially useful when starting or finishing a field. This allows the conditioner to be disengaged for the first pass opening the field and the mower to be disengaged while

conditioning the last swath mowed. Of course, a machine such as the flail harvester self-propelled windrower is ideal from this standpoint, as the conditioner always works on the fresh-cut material

Although there are differences between types of machines, their over-all performances are comparable. Therefore there is no single machine best for all conditions. Selection must be based on several factors.

From a standpoint of machine performance no single hay conditioner excells under all operating conditions. Therefore machine selection may be finally based on factors remote from performance—cash, availability, parts, service, dealer, etc.

## Conclusions

The following conclusions have been drawn from the combined cooperative research of the several states in the Northeast.

1. Hay conditioning, whether through the use of a crusher, crimper, or flail harvester, can significantly reduce the required field drying time of forage crops, in some cases by 30 per cent or more. Indications are that conditioning may also reduce drying time in forced-air drying systems.
2. In general, uniform crushing will result in more rapid drying than will uniform crimping. This advantage may be partially or completely offset by the fact that it is considerably more difficult to crush hay uniformly than to crimp it uniformly.
3. Conditioning has a greater effect on legumes than on grasses; the thicker the stem, the greater the effect.
4. In the ordinary hay curing process, a tedder is of little or no value. It does help remove free water after a rain.
5. In grasses, fluffing is of no importance, but adequate fluffing is advantageous with legumes.
6. The lacerating action of a flail harvester, without windrowing, used for cutting forage for hay produces a more rapid drying rate than can be obtained by the other types of conditioners. Dry matter losses are also greater in some systems; tests have indicated losses to be in the range of ¼ to ⅓ greater than with crushers or crimpers, when used on legumes in a baled-hay system.
7. On the basis of tests with a self-propelled windrower it appears that although the machine may be desirable from the standpoint of increased operational efficiency, the windrowing of hay immediately after conditioning slows down the drying rate.
8. From a practical standpoint, the purpose of a hay conditioner is to reduce the amount of time hay must be left in the field. From

this standpoint there is little difference among the various types of conditioners; each will permit harvesting hay, as field cured hay, one day earlier than unconditioned hay, under average haymaking conditions throughout most of the Northeast. There are local areas or times of unusual conditions when this figure will not apply.

9. Field cured hay, conditioned or not, is still field cured hay. As such, it remains subject to the rather severe shattering losses to which completely field cured hay, especially of the legume varieties, is always susceptible.

## Nomenclature

HAY CONDITIONER—Field machine that either crushes, bruises, lacerates, or displaces mowed forage for the purpose of accelerating drying.

HAY CRUSHER—Hay conditioner where one or more of the processing rolls are smooth.

HAY CRIMPER—Hay conditioner where processing rolls are fluted or fitted with projections that intermesh during operation.

TEDDER—Machine for lifting (fluffing) and stirring hay in the swath or windrow.

FLAIL HARVESTER—A machine having pivoted flails on a horizontal shaft that cuts and chops forage.