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DRYING HAY IN THE BARN AND TESTING ITS FEEDING VALUE

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The Agricultural Building, containing the offices and laboratories of the Experiment Station, the College class rooms, and the headquarters of the Agricultural Extension Service, is located at the University Farm, on Kingston Pike, about one mile west of the main campus. Farmers are cordially invited to visit the building and the experimental grounds.

Bulletins of this Station will be mailed free to any farmer in the State. Write Agricultural Experiment Station, University of Tennessee, Knoxville, Tennessee.

FOREWORD

While the full possibilities of the method described in this bulletin for drying hay in the barn are undetermined, the results obtained so far indicate that in Tennessee the quality of hay thus dried is always better than similar hay dried in the field during the same period of time. The system is adaptable to practically any size of barn in which hay normally is stored, and utilizes all hay-making machinery in present use on the farm.

The principal responsibility for conducting the work has been carried jointly by the University of Tennessee, Department of Dairying; the West Tennessee Experiment Station; and the Tennessee Valley Authority, Department of Agricultural Industries.

The authors wish to express appreciation to the following persons who, assisting in various capacities, made possible the carrying out of the experiments reported in this bulletin: Mr. Ben P. Hazlewood, Mr. S. A. Hinton, Mr. G. A. Shuey, and Mr. W. A. Campbell, of the Tennessee Agricultural Experiment Station; Mr. George W. Kable, Mr. John A. Schaller, and Mr. H. E. Kiefer, of the Tennessee Valley Authority; Mr. E. H. Chambers, of the Alabama Agricultural Experiment Station; Dr. W. E. Krauss, of the Ohio Agricultural Experiment Station; Mr. W. A. Wheeler, of the U. S. Bureau of Agricultural Economics; Mr. R. F. Gaalaas, Jr., of the U. S. Dairy and Livestock Experiment Station, Lewisburg, Tennessee; and Mr. Alex Locker, Florence, Alabama.

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J. W. Weaver, Jr., and C. E. Wylie

INTRODUCTION

VALUE OF HAY

Hay is one of the three leading crops of the nation in farm value (13). It is not generally recognized as a cash crop because about 90 percent is consumed on the farm where it is produced. This is one of the reasons that hay has not been elevated to its proper place in agriculture along with cotton, wheat, tobacco, and other important cash crops.

The great soil-conservation program in the southern states is relying, to a large extent, upon the use of cover crops to provide humus and to prevent erosion and leaching of soils. The growth of leguminous crops to restore nitrogen to the soil is advocated universally by agricultural leaders. In keeping with good farm management, it is recommended that the increased amount of hay resulting from the soil-conservation practices be converted into meat and dairy products through the medium of livestock. This, in effect, will convert the hay into a cash crop, and in addition will provide manure for enrichment of the soil.

PRODUCTION

In 1934 the acreage of all hay and sorghums for forage in the United States was 6 percent larger than that reported in 1929 (15). The percentage expansion of hay in the eight southeastern states[1] equaled that in the nation as a whole. Annual legumes saved for hay made an acreage gain of 210 percent during the 5-year period, while sweet clover and lespedeza hays made a gain of 82 percent. More recent figures (3) show the 1938 production of alfalfa in Tennessee to be nearly three times that of the 1927-36 average, while the production for the southeastern states as a whole almost doubled during the same period.

NEED FOR QUALITY

It does not appear advisable to increase the hay acreage materially without giving consideration to a proportionate improvement of quality, in order to keep the demand for hay balanced with the supply. It is the belief of many agricultural authorities that one of the best approaches to the problem of lowering the cost of livestock feeding operations is through the improvement of the quality of home-grown forage.

[1]Kentucky, Virginia, North Carolina, South Carolina, Florida, Georgia, Alabama, and Mississippi.

Farmers are improving the quality and yield of hay each year by seed selection, fertilization, and grading; but little has been done to improve methods of harvesting and curing of hay. Tennessee has an average annual rainfall of about 50 inches, being one of several southern states with comparatively high precipitation. The minimum for the Tennessee Valley is at the mouth of the Tennessee River, the average at Mayfield and Paducah, Kentucky, being 45 inches; while the maximum of 82 inches is near the source of the Little Tennessee River, at Highlands, North Carolina. During the hay-curing season — May through September—the average monthly rainfall is 4.07 inches. Although this natural water supply is excellent for growing crops, it is recognized as a problem from the standpoint of soil erosion. Hay crops tend to reduce soil erosion.

The high rainfall is a serious handicap to the harvesting of hay. The amount of hay damaged by rain is hard to estimate. It is sufficient, however, to warrant a study of improved methods of harvesting. Unfavorable weather conditions occasionally result in a total loss of the crop.

Reports from other investigators (22) show that the loss of leaves in field-drying of alfalfa hay varies from 2.3 percent to as much as 34 percent, with an average of 19 percent over 7 seasons of cutting. Losses of dry matter varying from 10 to 30 percent, and of digestible nutrients from 15 to 35 percent, are reported. Protein-equivalent losses of 17, 29, and 54 percent are reported when drying is done respectively in very fine weather, fine weather, and showery weather.

Any method of harvesting hay which will tend to counteract the hazard of rain damage, reduce leaf shattering, and at the same time produce a good quality of hay at a reasonable cost, deserves definite consideration. Drying hay in the barn is such a method.

Rain damage and leaf shattering have been recognized for years as limiting factors in the production of quality hay. It appears that a method of drying hay artificially was developed first in England about 1870. The Annual Report of the United States Department of Agriculture for 1875 carried a brief description of this early hay drier (16). In 1910 the Department began to develop and test a forage-crop drier at Hayti, Missouri (2). In 1911 Arthur J. Mason built an experimental drier at West Point, Mississippi. The Louisville Drying Machinery Company, of Louisville, Kentucky, began experimenting in hay drying about 1915. The Department of Agriculture, state experiment stations, commercial companies, and various individuals have invested much money, time, and effort in developing the hay driers of today. The enormous amount of activity in this field is evidenced by a recently compiled bibliography (17) on natural and artificial drying of hay, and related subjects, which lists 531 separate references, representing 450 authors and investigators.

LARGE HAY DEHYDRATORS

About 15 makes of driers have been developed in this country since 1910, of which at least 6 are available at the present time. Each of these driers, in general, consists of a heated tunnel or other retort, through which the hay is carried on some form of conveyor or by a blast of hot air. They cost from $3,500 to $25,000, while the fuel and power costs for operating average about $3.50 a dry ton. According to an estimate based on a survey (9) made in 1936 by the Committee on Crop Drying of the American Society of Agricultural Engineers, there were possibly 80 driers operating in this country at that time, with a combined annual production of about 100,000 tons. This means that each drier produced an annual average of 1,250 tons of dried forage in 1936.

At the U. S. Dairy and Livestock Experiment Station (6), Lewisburg, Tennessee, about 170 tons of hay was dried artificially with a commercial rotary-drum drier during the 1935 season. The rated capacity of this drier is 1 ton of dry hay per hour, or about 2,000 tons per year. The total cost of drying the hay, including interest and depreciation, was $11.77 per ton of dry hay. Repairs, including labor and parts, accounted for $3.20 of this cost, the major portion of which was spent on the upkeep of field-harvesting machinery. It is clear that this method of drying hay lends itself to large-scale farming (8) and commercial production, where operations are extensive, and it is imperative that a high grade of hay be assured.

It is believed that if a method of drying hay artificially on the small farm, producing from 20 to 60 tons of hay annually, is to be made practical, there must be several hours of field-drying to evaporate most of the water in the hay, leaving the balance to be artificially evaporated by some inexpensive method. A few operators and investigators of commercial driers now are recommending that hay be allowed to dry in the field from 2 to 5 hours to reduce the operating cost of the drier.

SELECTION OF A LOW-COST METHOD

With these facts in mind, it was decided to direct all efforts toward the development of a method, or system, involving low first cost and low operating cost, to complete the drying artificially after taking advantage of several hours of field-drying. The system was designed for relatively small capacity, requiring no more labor than is required by present methods of harvesting, and to make use of machinery and equipment already employed on the average farm.

By a review of the work of previous investigators, it was found that the lowest-cost method of drying hay attempted prior to 1934 was that of forcing atmospheric or slightly heated air through hollow-center stacks or ricks of green hay. This method was attempted first in 1894 by an English farmer named Neilson (11). A suction pipe led from a fan to a hollow-center stack of green hay, permitting atmospheric air to penetrate the stack. From 1 to 3 weeks were required to dry the hay when the fan was operated from 15 to 60 minutes each day.

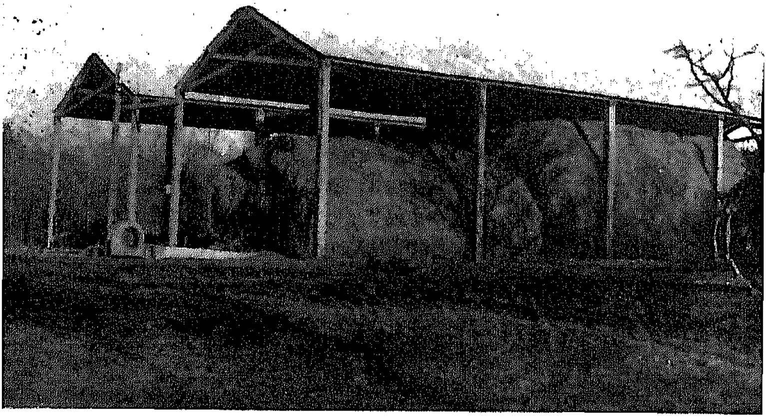

Fig. 1—Early English method of drying hay in stacks under shelter, 1924. Courtesy Dr. John H. Goff, Commerce Department, Tennessee Valley Authority.

In 1905, Professor Oscar Erf (4), of Ohio State University, built a barn in which green hay was put into the mow and drying attempted by the blowing of air with a pressure blower through a pipe system laid on the floor. The hay did not retain its green color. Chlorine gas and, later, formaldehyde were introduced into the hay to preserve it, but neither proved satisfactory.

In 1923, the Institute of Agricultural Engineering of the University of Oxford (12) started a series of experiments in which atmospheric and slightly heated air was forced into an open space under stacks and ricks of green hay, in a manner similar to that illustrated in figure 1. Peas, beans, and cereals were dried successfully with atmospheric air. It was concluded, however, that this method could not be depended upon under adverse weather conditions.

In 1926, William Aitkenhead (1), of Purdue University, developed a system similar to that employed at Oxford, except that combustion gases from a furnace were mixed with the air forced through the stack. This method successfully dried alfalfa and soybeans.

Of paramount significance is the fact that all four of the investigators named above either dried or attempted to dry green hay, whereas the work reported in this bulletin deals altogether with partially dried hay.

EXPERIMENTS TO DEVELOP A PRACTICAL LOW-COST METHOD

DRYING IN STACK

Actual work (18) by the University of Tennessee and the Tennessee Valley Authority began late in the season of 1934 with an attempt to complete the drying of partially field-dried hay by blowing air through hollow-center stacks and long, low ricks of hay in the field (figure 2). While a good quality of hay resulted from several trials, the process was too slow and did not eliminate the weather hazards of regular field-drying. Considerable extra labor was required to cover the hay with tarpaulins each night and during rainfall. These tarpaulins had to be supported on a framework over the hay to prevent spoilage, and precautions were necessary to keep surface water from running under the hay.

Fig. 2—Experimental method of drying hay in 30-foot ricks, 4 feet high and 5 feet wide. Air, tempered with heat, given off by a 3-h.p. engine, was liberated from 6-inch pipes under the hay.

DRYING ON WAGON

A second plan was attempted in 1935 which involved the use of several wagons (figure 3) equipped with special racks, or frames. Hay partially field-dried was loaded on the wagons in late afternoon and driven under shelter, where air was forced through the hay by a blower. It was found impossible to complete the drying of the hay on wagons before time to take up a second lot of hay from the field

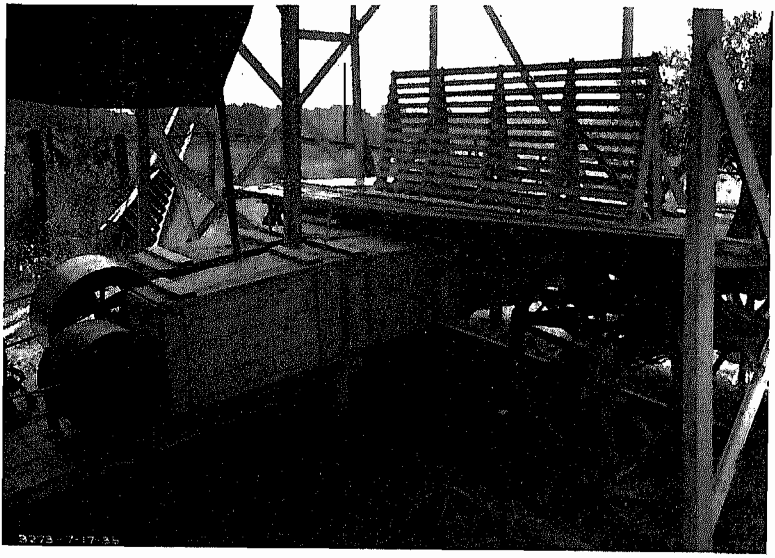

Fig. 3—Hay, dried in the field to 45 percent moisture content, was hauled in on special wagon frames, where drying was completed by forced air.

on the following afternoon. The use of a moderate amount of electric heat (15 K.W.) to warm the night air proved to be too costly. The electric heater raised the temperature of night air about 10° F., which was no better for drying than normal outside air on a sunny day.

Late in the season of 1935, records were available which showed that on normal sunny days, if such hays as alfalfa, lespedeza, and orchard grass were cut about 9 o'clock in the morning, side-raked about 11:30, and loaded about 2 in the afternoon, a moisture content of approximately 75 percent at the time of cutting could be reduced to about 45 percent at the time of loading. Hay such as soybean or Johnson-grass had to be left in the field a second day, or longer, to reduce its moisture content to 45 percent.

DRYING IN BARN

The third plan of drying was tried in the late summer of 1935, and has been developed and followed to the present time. Hay partially field-dried is stored in a barn, and air forced through it by a blower until curing is completed. This has been designated as the "barn hay-drying system" (19).

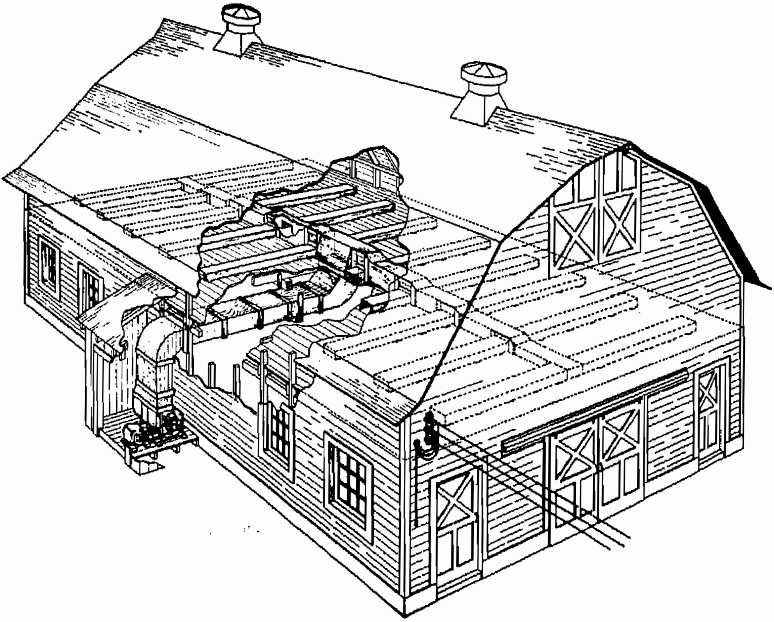

Fig. 4—Cut-away drawing of typical barn hay-drying system. After several hours' drying in the field, hay is stored in the barn, where drying is completed by air forced through it by a blower.

BARN-DRYING SYSTEM

A barn in which the system is installed at the University of Tennessee is shown on the front cover. Briefly, the barn-drying system consists of air ducts, constructed of lumber, on the floor of the hay mow. Partially dried hay from the field is stored as usual in the mow, over the air ducts. An electrically driven blower, which may be located in a small room on the side of the barn or on the ground floor within the barn, is connected with the air ducts underlying the hay (figure 4).

The interior of the blower room is shown in figure 5. The glassware, hotplate, and balances in the left foreground were used to determine the moisture content of hays by a modification of the Dean and Stark method. The blower in this case was driven by a 5-h.p. motor, and when in operation forced 12,000 cubic feet of air per minute through the hay. Systems for smaller barns can be operated by smaller motors. A delivery duct carries the air from the blower to the ducts under the hay (figure 6). Where space is available, it can be brought through the side of the barn above the floor of the hay mow, eliminating at least one elbow and the necessity for cutting a hole in the mow floor. If desired, an air-control gate can be located in this duct so that hay can be dried in either half of the mow independently of the other half, though this usually is not necessary.

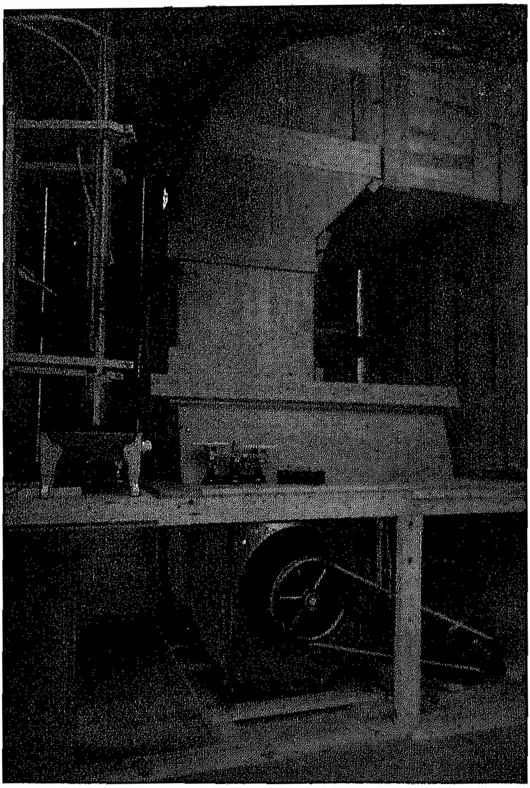

Fig. 5—The cost of motor and blower is about three-fourths the total cost of the barn-drier. The motor can be used for other work, such as hoisting hay, sawing wood, and grinding feed.

THE AIR DUCTS

Figure 7 shows the duct system under construction on the haymow floor. The floor must be as nearly air-tight as possible. A tongue-and-groove floor is preferable, though matched boards may be satisfactory if covered with building paper. The completed duct system may be seen in figure 8. In this case air is delivered through the mow floor to the central portion of the main duct. Here the air flow is divided, half being directed toward one end of the main duct and half toward the other end. The main duct is 16 inches wide, and varies in height and length according to floor dimensions. The lateral ducts extend to within 5 feet of the side walls. They are spaced from 4 to 5 feet apart, depending on the length of the floor. Each of these

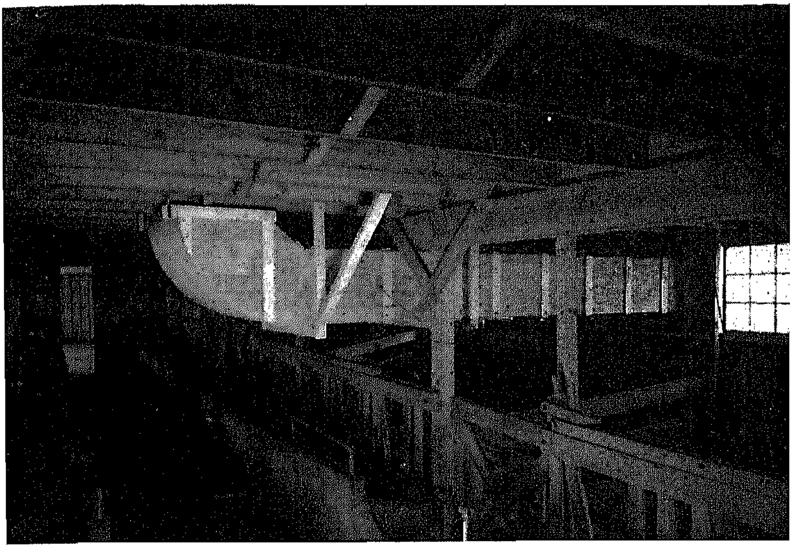

Fig. 6—Delivery duct for conveying air from blower to series of small ducts on floor of hay mow.

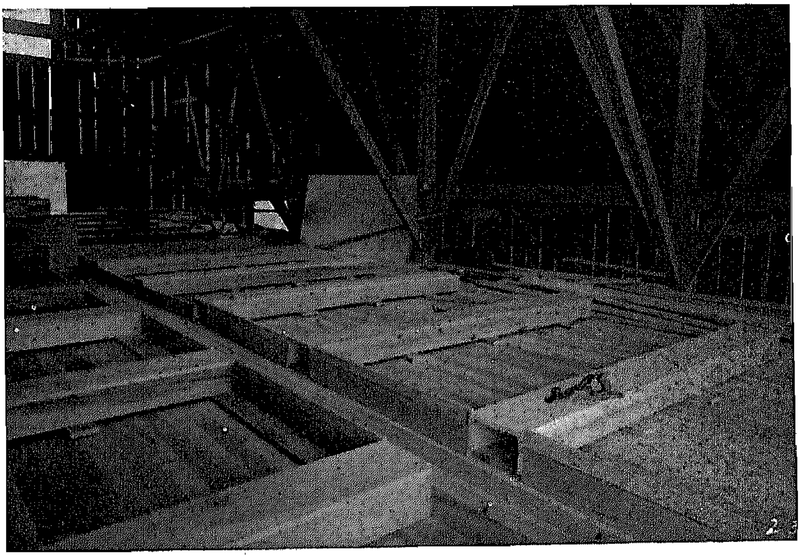

Fig. 7—Header and 12 pairs of lateral ducts under construction on mow floor, 26 x 60 feet, at Alex Locker's farm near Florence, Alabama.

lateral ducts has its bottom side open, resembling a homemade horse trough turned upside down, and rests on 1 by 3-inch strips fastened to the floor. This allows a 1-inch opening along each side and the end of each lateral duct, through which the air is forced into the hay.

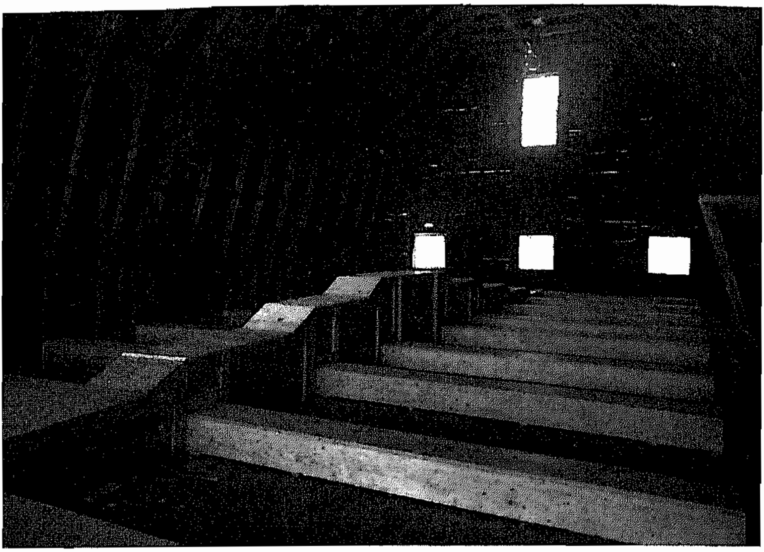

Fig. 8—Completed header and 10 pairs of lateral ducts on mow floor, 30 x 50 feet, at West Tennessee Experiment Station, Jackson.

AIR REQUIREMENTS

After the design of the duct system was settled upon, more attention was given to determining the air flow required to dry the hay to best advantage. In a test made in 1937 the relative humidity of air emerging from the hay during the first 3 or 4 days ranged from 90 percent to near saturation. Under these conditions the upper layers of hay remained very damp, and could be dried only by a reversal of the direction of air flow through the hay. The reversed flow, however, caused the bottom layers of hay to become too damp. Mouldy, dusty hay was found in this area.

It was decided then that insufficient air was flowing, and that for best results the relative humidity of the air emerging from the hay should never exceed 70 to 80 percent. When the air flow was increased to this point a good quality of hay resulted throughout the mow, and there was no necessity for reversing the flow. From these and later observations the proper air flow has been determined. The most efficient air flow was found to be 8⅓ cubic feet of air per minute for each square foot of mow-floor area. For example, the proper air flow for a 30 by 50-foot mow is 30 x 50 x 8⅓, or 12,500 cubic feet of air per minute.

When the duct system is proportioned for this air flow, the static pressure is from 6/10 to 8/10 of an inch water column, depending upon the depth of hay.

OPERATION OF THE BARN-DRYING SYSTEM

Loose hay of more than 20 percent moisture content cannot be stored without undergoing considerable heating and deterioration in quality. To produce a ton of hay of 20 percent moisture from hay that contained 75 percent moisture when cut, it is necessary to evaporate 4,400 pounds of water (figure 9). Records show definitely that on a sunny day the amount of water evaporated from hay in the field the first hour after cutting is about 5 times the amount evaporated the fourth hour after cutting. The principle of the barn-drying system takes advantage of the very rapid drying of hay in the field the first few hours after cutting. Field-drying hay for from 4 to 6 hours reduces the moisture content to about 45 percent before the hay is stored on the duct system in the barn. From this point, only about 900 pounds of water must be evaporated to produce a ton of hay of 20 percent moisture.

Repeated tests proved that the barn-drying system can complete the drying of hay of 45 percent moisture. It took from 4 days to 2 weeks, depending upon weather conditions and the amount of hay stored. The damper the outside air, the more time was required. After the first cutting of hay was dried, the second cutting was stored upon the first; then the third cutting upon the second. The maximum height to which hay was stored on the barn drier was about 10 feet after settling. With one set of air ducts no more than 6 feet should be stored at one cutting.

Air for drying is forced through the hay only during the day. Thermocouples thrust into the hay mass while the blower is operating show the temperature within the hay to be several degrees below that of the outside air. The cooling is credited to the evaporation of moisture from the hay. The blower is not operated at night except for about half an hour each of the first 3 or 4 nights after the hay is stored. During this period there is a tendency for the hay to heat if the blower is kept idle all night, but air forced through the hay for 30 or 40 minutes about 2 o'clock in the morning removes the heat, and the hay remains cool until drying is started the next day.

There seems to be a tendency also for mold to develop in the green hay if the temperature remains long at 105° F. to 110° F.

SPONTANEOUS COMBUSTION

There is no danger of fire from spontaneous combustion of the hay as long as the system is operated properly. About 250 tons of hay, with moisture content sometimes as high as 65 percent, has been dried during 5 years of experimenting, and the maximum temperature observed in the hay was 138° F., in 1937. Since the development last season of an automatic control, maximum temperatures rarely have exceeded 110° F.

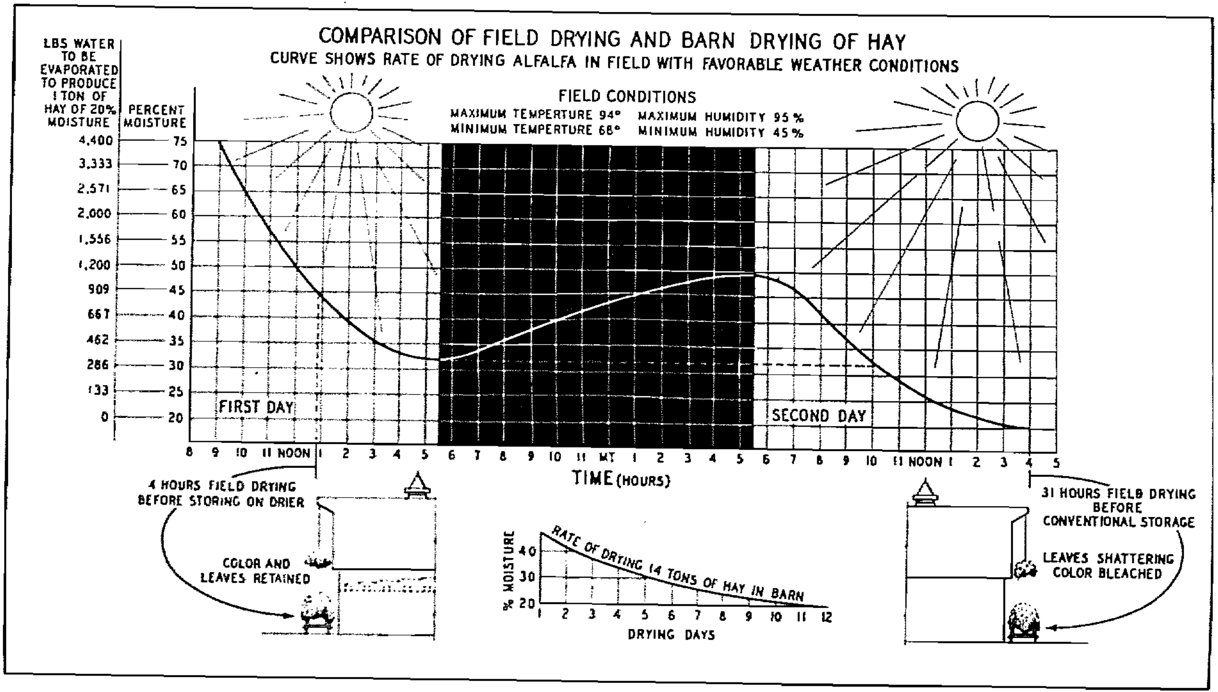

Fig. 9—Chart showing effectiveness of the system and its principle of operation. Most grasses and legumes when cut contain about 75 percent moisture, which must be reduced to 20 percent.

AUTOMATIC CONTROL

An inexpensive time clock was found effective in operating the blower for the short period at night, but it required frequent winding and setting.

The most promising method of automatic control embodied the use of a humidistat and a thermostat connected in the control circuit of the motor starter. The humidistat was located outside the barn, and would start or stop the motor according to the relative humidity of the air. The bulb of the thermostat was inserted into the hay to guard against heating.

After the sun set, the relative humidity increased, and the humidistat stopped the blower at about 7:00 p. m. If the hay began heating, the thermostat started the blower. The heat was blown out of the hay in about 30 minutes, and the thermostat then stopped the blower. With the rising of the sun, the relative humidity of the outside air decreased, and the humidistat started the blower at about 9:00 a. m. In case of a thunder shower during the day, the blower was stopped by the humidistat until air conditions were right for further drying. This method requires a limited amount of attention for setting the humidistat and inserting the thermostat in each cutting of hay. The automatic control will require further study before it can be definitely recommended.

HEAT FROM THE SUN

Outside air conditions occasionally are such that a moderate amount of heat to reduce the relative humidity would improve materi-

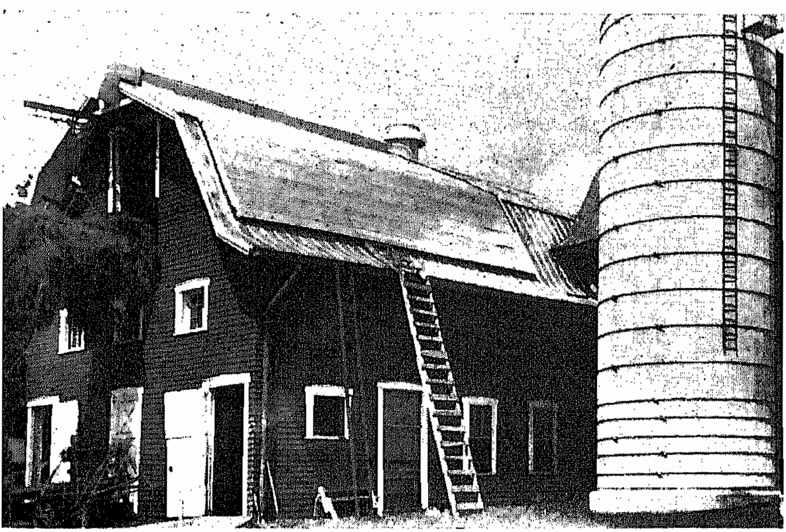

Fig. 10—Experimental solar heat absorber on roof of barn at West Tennessee Experiment Station, Jackson. The absorber (600 sq. ft.) is fastened to 2 x 4-inch supports held in place by 9 bolts.

ally the quality of the barn-dried hay. As indicated above, the cost of electric heat was found to be prohibitive. The danger of fire, and the investment and operating cost, would seem to preclude the use of a furnace or steam boiler for a low-cost hay drier.

Last season a means of obtaining a moderate amount of heat from the sun was developed and observed in operation. The so-called "solar heat absorber" consisted of a 20 by 30-foot false metal roof constructed over a barn roof (figure 10). The temperature of outside air drawn under this absorber, at the rate of 3000 cubic feet per minute, before being forced through the hay, was raised as much as 22° F., while the relative humidity was lowered 33 percent. This method has promise, but must prove its value in further trials before it can be recommended.

DETERMINING WHEN HAY IS DRY

When air is forced up through the hay, the top of the mow naturally is last to be lowered to a suitable moisture content (20 percent) for storage. Anyone familiar with hay usually can determine when it is dry enough for safe storage. Inspection of the top of the mow, by feeling and twisting, will enable one to determine when all the hay is dry. After a cutting has been dried, it should be inspected several times during the first week or ten days. There should be absolutely no heating when the hay is dry. An inspection of the first one or two feet on top of the mow will show quickly whether there is any heating.

For accurate determinations, a moisture tester (figure 11) can be assembled at a cost of about $25. The hay sample, of determined weight, is boiled in a flask with toluene. Water and toluene vapors rise from the flask, are caught in the condenser, and run back into the graduated trap. Water, being heavier than toluene, settles to the bottom of the trap. Thus, in from 30 minutes to an hour all of the water from the hay is caught in the trap. For example, if a 50-gram hay sample yields 20 milliliters of water, its moisture content will be 20/50, or 40 percent.

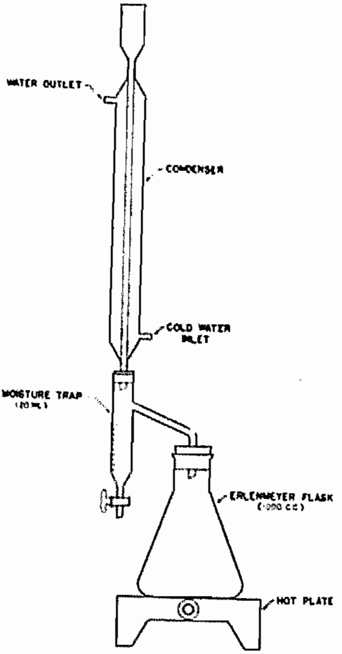

Fig. 11—Apparatus for determining moisture content of hay.

INVESTMENT AND CAPACITY

A system for drying 20 tons of hay annually can be installed in a barn at an investment of $292 for blower, motor, lumber, hardware, wiring materials, and labor. A 30-ton system can be installed for $395. If each lot of hay is moved after it is dried, the 20- and 30-ton systems are capable of drying respectively 60 and 90 tons per year.

OPERATING COSTS

The cost of power used in drying 200 tons of hay, on 20- and 30-ton systems, during the last 3 years, has averaged 86 cents per dry ton, with electricity available at 2 cents per kilowatt hour. The labor requirements for harvesting hay and storing on the barn-drying system are equivalent to those for present methods of drying hay in the field and storing in the barn. Storing hay evenly on the barn-drier requires more labor than regular barn storage, but when unfavorable weather is encountered, more labor is needed in the field to complete field-drying. Labor costs for harvesting and storing the hay, therefore, are not counted in figuring return on investment in this barn-drying system.

IMPROVED QUALITY OF HAY

Analyses made by the Hay, Feed, and Seed Division, Bureau of Agricultural Economics, U. S. Department of Agriculture, show barn-

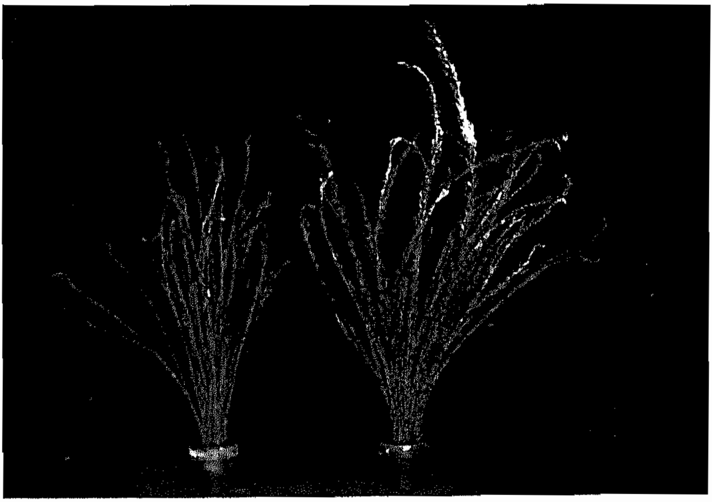

Fig. 12—Leafiness comparison of barn-dried (right) and field-dried sericea hay. U.S.D.A. analyses showed this barn-dried hay to have 5.9 percent more leaves.

TABLE 1—*Results of feeding barn-dried and field-dried hay to dairy heifers.*

FIVE HEIFERS IN EACH GROUP

1937-38, 165 days; 1938-39, 150 days

Item	Barn-dried	Field-dried	Difference
	Pounds	Pounds	Pounds
Total hay consumed per heifer			
1937-38	2185.4	1938.0	247.4
1938-39	1964.4	1876.8	87.6
Total concentrates consumed per heifer			
1937-38	390.0	390.0	0
1938-39	300.0	300.0	0
Total corn silage consumed per heifer			
1937-38	1650.0	1650.0	0
1938-39	1500.0	1500.0	0
Gain in weight per heifer			
1937-38	248.0	230.6	17.4
1938-39	224.4	189.2	35.2
	Inches	Inches	Inches
Gain in height per heifer			
1937-38	3.10	3.55	.45
1938-39	2.75	2.80	.05
Gain in heart-girth per heifer			
1937-38	6.80	6.80	0
1938-39	6.90	6.05	.85

TABLE 2—*Composition of barn-dried and field-dried alfalfa hay.*

MOISTURE-FREE BASIS

Constituents determined	Barn-dried	Field-dried	Difference
	P.P.M.	P.P.M.	P.P.M.
Carotene			
April 1938[1]	7.0	16.0	9.0
March 1939[2]	87.0	18.5	68.6
April 1939[2]	36.4	27.1	9.3
May 1939[2]	29.9	11.3	18.6
	Percent	Percent	Percent
Ash			
1938[3]	7.65	7.08	.57
1939[4]	8.00	8.34	.34
Crude protein			
1938[3]	13.83	12.85	.98
1939[4]	16.78	12.97	3.81
Crude fat			
1938[3]	1.89	1.86	.03
1939[4]	1.69	1.36	.33
Crude fiber			
1938[3]	32.42	32.41	.01
1939[4]	29.59	34.47	4.88
Nitrogen-free extract			
1938[3]	44.21	45.80	1.59
1939[4]	43.94	42.86	1.08

[1]Analyses by O. L. Inman, Antioch College. Hay dried in 1937.
[2]Analyses by W. E. Krauss, Ohio Agr. Exp. Sta. Hay dried in 1938.
[3]Analyses by G. A. Shuey, Tennessee Agr. Exp. Sta. Hay dried in 1937.
[4]Analyses by G. A. Shuey. Hay dried in 1938.

dried hay to average 2.3 percent more leaves, 19 percent more green color, and a quality of one grade and class better than field-dried hay cut from the same field at the same time. Barn-dried sericea hay contained 5.9 percent more leaves than field-dried hay (figure 12). Results of feeding trials with dairy heifers during the winter of 1937-38 showed very little difference between the two hays in animal growth. The heifers made normal growth on the basis of weight, girth, and height at withers (21), and bred without unusual difficulty. The following winter, 1938-39, the same heifers calved, produced well, and continued to grow satisfactorily. Two-year-old steers also made normal gains in weight in a winter feeding trial at the West Tennessee Experiment Station (10). The barn-dried hay, when fed to rats, apparently contained more vitamin A than field-dried hay (14).

During the winter of 1938-39 another feeding trial was made with dairy heifers (20). Because of a better quality of barn-dried hay, resulting from increased air flow, the results favored the barn-dried hay in nearly every particular in which it was compared with field-dried hay. Results of the feeding trials are recorded in table 1. Analyses for digestible nutrients and carotene are given in table 2.

RETURN ON INVESTMENT

A 20-ton system, costing $292, carries an annual depreciation charge of 63 cents per ton when the average life of the system is figured as follows: belts, pulleys, lumber, hardware, and carpentry labor at 10 years; wiring materials and electrician labor at 20 years; electric motor at 25 years; and blower at 30 years. Since the motor can be used for from 3 to 6 other jobs on the farm, only one-fourth of its depreciation is charged to hay-drying.

Quality studies show barn-dried hay to be consistently better by one grade than similar field-dried hay. Survey of the Atlanta, Birmingham, Nashville, and Memphis hay markets shows the average price differential between U. S. No. 1 and U. S. No. 2 alfalfa, lespedeza, and Johnson grass to be $2.45 per ton from July 1, 1936, to June 30, 1938. When the cost of operation, 86 cents, and depreciation, 63 cents, are subtracted from this price differential, $2.45, the profit from the use of the barn-drying system is found to be 98 cents per ton, or a return on the original investment of 6.8 percent.

If each lot of hay is moved after it is dried, the 20-ton system is capable of drying 60 tons of hay annually. Thus, the operating cost remains at 86 cents per ton, the depreciation charge is reduced to 21 cents per ton, and the profit is increased to $1.23 per ton, or a return on the original investment of 25.3 percent. This includes 60 man-hours of labor, at 15 cents per hour, for moving the hay after it is dried.

The foregoing figures do not express the complete value of the barn-drying system, for the reason that there are no data available to account for the large amount of hay that is completely lost or badly damaged in the field each year by rainfall and unfavorable weather.

ADAPTABILITY TO FARMS

This system of forcing air through partially dried hay, supplemented with a homemade sheet-metal furnace, has been under observation by Maynard S. Grunder at the Western Washington Experiment Station (7) since 1937. He concludes: "In view of our experiences in drying the past two years, it is my opinion that the 'forced draft system,' modified as necessary to meet existing conditions, offers definite possibilities for western Washington farms, either to complete the drying of partially cured hay by means of heated air, or without heated air, merely as a means of preventing excessive heating of field-cured hay."

The barn-drying system is known to have been used during the present season in the states of Tennessee, Washington, Alabama, Ohio, and Illinois.

SUMMARY

1. Hay-drying begun in the field may be completed in the barn by unheated air forced through the hay by a blower.

2. The barn-drier is of value mainly in eliminating the damage caused by rain when hay is field-cured. Hence, it would be of most value in seasons with heavy rainfall at harvest time.

3. All of the usual hay-harvesting machinery and equipment, such as mower, rake, loader, wagon, team or tractor, and unloading fork or sling, are used in the barn-drying system.

4. Three-fourths of the water that must be removed from growing plants to make hay is evaporated in the field in 15 percent of the time required to dry the hay completely in the field on bright, sunny days.

5. There is little danger from spontaneous combustion when the equipment is operated properly. The maximum temperature observed in the hay was 138° F., in 1937.

6. Hay dried in the barn is one grade and class better, according to analyses, than the same hay dried in the field. The barn-dried hay averaged 2.3 percent more leaves and 19 percent more green color.

7. Indications from the feeding of rats and from chemical analyses are that the barn-dried hay contains more vitamin A than field-dried hay.

8. Feeding trials with dairy heifers indicate that barn-dried hay is slightly superior in palatability to field-dried hay even when the latter has not been damaged by rain. The heifers made normal growth, as determined by weight, height at withers, and increase in heart girth. The two kinds of hay made little difference in growth in the two groups. Hay damaged by rain may be expected to produce considerably less favorable results than hay cured in the barn.

9. The investment cost of the barn-drying system, from $300 to $500, is only about 10 percent of that of the lowest-cost artificial-heat hay-drier.

10. The power operating cost of the barn-drier, 86 cents per dry ton, is about 25 percent of the power and fuel operating cost of a large artificial-heat drier.

11. There is little difference in the labor requirements for barn-drying and field-drying of hay.

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