THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXTENSION SERVICE

PB1255

Drying, Handling, Storing and Feeding Hay in Tennessee

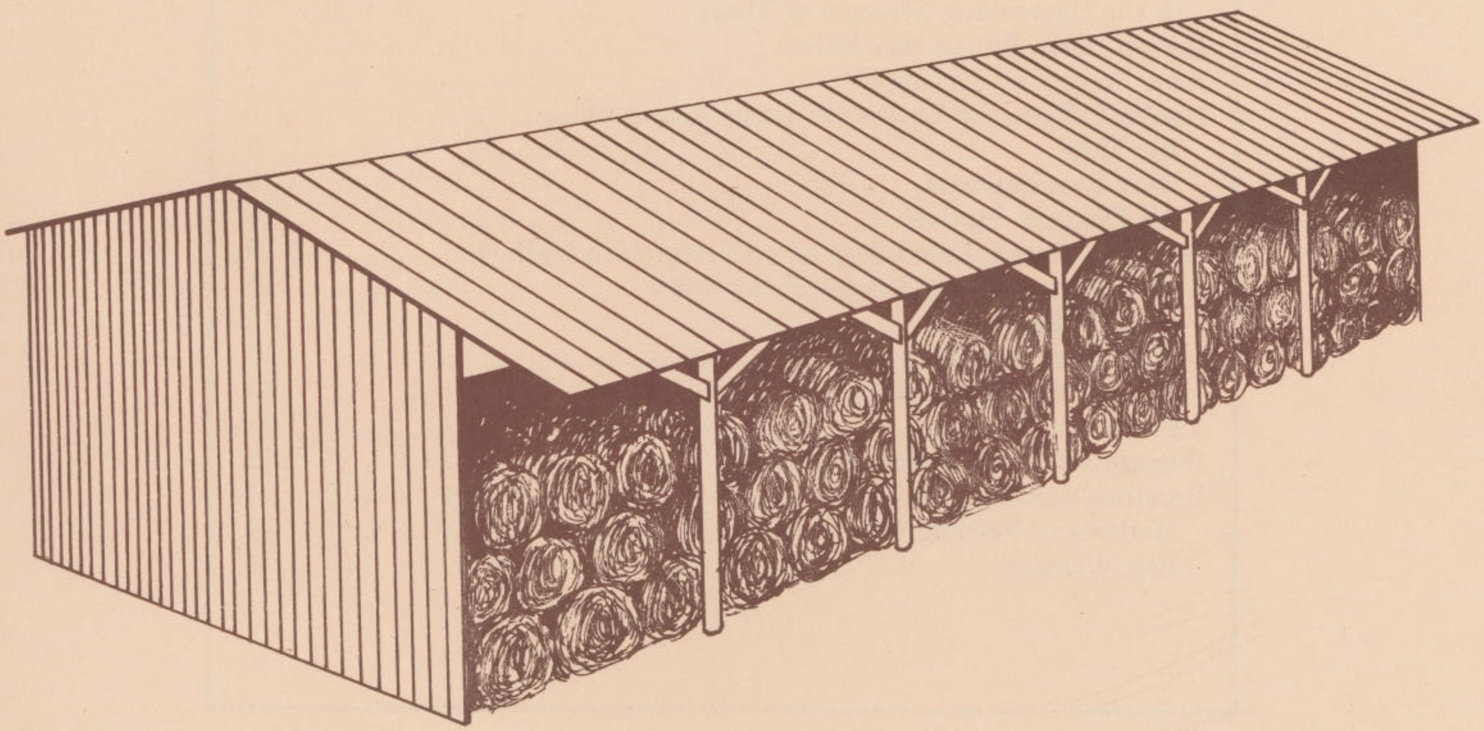


Table of Contents

Drying, Handling, Storing and Feeding Hay in Tennessee

Kenneth E. DeBusk, Professor (Retired)
George F. Grandle, Associate Professor
Agricultural Engineering

Introduction

Tennessee farmers have long recognized the cash crop value of high quality hay when grown as feed for animals. There is a type of hay that will grow well on most soils. Likewise, some hays are more suitable and feasible for certain types of animals.

Hay can be packaged, dried, handled, stored and fed in a variety of ways. This publication will emphasize artificial curing of high quality hay. All systems of haymaking will not be included.

An essential part of producing top quality hay, after optimum cultural practices have been followed, is the curing procedure. After hay is cut, it has two potentially dangerous enemies — rain and sun. Rain can be partially neutralized, and the sun can be almost completely compromised. Artificial curing is the neutralizing agent that will combat both of these antagonists.

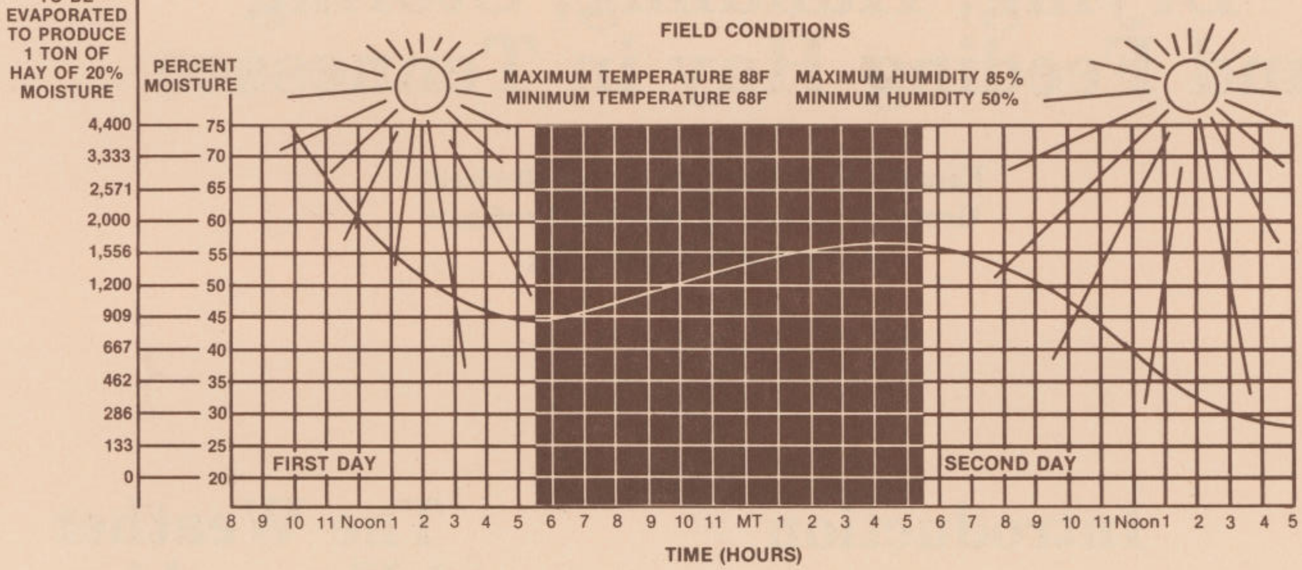
Artificial curing can be defined as the process of substituting mechanical or artificial drying for natural evaporation during a part of the curing and drying process. Artificial drying and curing reduces the probability of rain damage, includes the baling of hay before excessive leaf loss occurs (in some hays), and reduces biological and chemical degradation due to the bleaching effect of the sun. Obviously some hays are more susceptible to loss from certain of these causes than others. Similarly, some hays are not of sufficient value to justify very much expense to retain even their highest quality.

The Weather and Haymaking

Weather and rain are elusive factors when it comes to an economic analysis of their contribution toward hay losses and deterioration. The grower can easily remember situations where a cutting of hay has been lost. It is seldom possible to prove "before the fact" precisely what will happen where weather is involved. Thus, it is difficult to present bona fide evidence as to the effect of this element. What can be said is that most farmers who have used mechanical or artificial curing have benefitted in varying degrees by its use. Where hay is concerned, eliminating all of the risk of weather is not economically feasible. Figure 1 shows a typical situation for the field drying and cutting of alfalfa.

Using historical weather data for the months during which hay is made in Tennessee, it can be shown that there is a 28 to 62 percent probability that 0.10 inches or more rain will occur sometime during any three-day period. If the hay can be in place on a mechanical dryer in two days, these probabilities will be reduced by approximately 25 percent. In low humidity periods, it will be possible to have the hay on a mechanical dryer in 24 hours. Only a 10 to 28 percent chance that 0.1 inches or more rain would fall exists in this case. Figure 2 summarizes this data. All of these probabilities of hay getting wet would be reduced somewhat by reliable weather forecasting. It is a reality

FIGURE 1. COMPARISON OF FIELD DRYING AND BARN DRYING OF HAY
Curve shows rate of drying alfalfa in field with favorable weather conditions.



that short-range weather forecasting is much more reliable than longer-range forecasting.

If hay is to be cut at its optimum stage of development, a compromise between growth stage and weather risk is often necessary. Another complicating factor is scheduling drying facilities so the dryer can be utilized on a nearly full basis, in order to keep ahead of the crop. For these and other reasons, it is often necessary to cut hay when the weather forecast or the bloom stage is not ideal.

Figure 2. Rain probabilities during the haymaking season.

Period	Probability that 0.1 Inches or More Rain Will Fall (Range)
Sometime within a 72-hour period during the haymaking season	28-62 percent
Sometime within a 48-hour period during the haymaking season	20-48 percent
Sometime within a 24-hour period during the haymaking season	10-28 percent

Leaf Loss in Hay Curing

It is obvious that some hay types will lose their leaves more easily after curing than others. Grass hay has less shatter loss than leafy legume hays such as alfalfa and clover. Alfalfa has the highest value and greatest potential benefit from artificial drying. It usually has more leaf loss than any hay, if it is not properly handled. Alfalfa leaves will shatter and drop off easily, unless the leaves are contained within the bale before they are dried.

Studies of leaf loss in alfalfa hay have shown that relatively little leaf loss occurs if the hay is baled while the moisture content is above 35 percent. The recommended time for mowing old stands of alfalfa is the bud stage for the first cutting and one-tenth bloom stage for the second and later cuttings. In order for leaf and nutritive losses to be held to a minimum, both of these conditions (moisture content and bloom stage) must be met. If hay is allowed to over-mature, some of the leaves will fall off the plant or will be partially dry and subject to easy shattering. However, stemmy hay is not always overmature hay. Loss or absence of leaves makes hay look stemmy.

At 10 percent bloom stage, the alfalfa plant has about equal weight of leaves and stems. When it is baled at 35 percent moisture and barn dried, a very small amount of leaves are left in the field. However, if the alfalfa is allowed to field-dry to 20 percent before it is baled, 10 to 15 percent or more of the leaves can be lost to leaf shatter. Approximately 75 percent of the food value of alfalfa, when cut, is in the leaves (see Figure 3). Therefore, when baled at 20 percent moisture, the nutrient loss can be higher than the leaf loss. Good alfalfa hay contains 20 percent or more crude protein. An additional benefit is that this is more than twice the crude protein value of shelled corn. Figures 3, 4 and 5 summarize the value of artificial curing of alfalfa hay.

Figure 3. Facts about alfalfa.

- Leaf-stem ratio at 1/10 bloom stage — 50 percent leaves/50 percent stems.
- Protein content ratio, leaves vs. stems at 1/10 bloom stage — 75 percent of protein in the leaves/25 percent in the stems.
- Crude protein content of good alfalfa hay — 20-23 percent.

Figure 4. Example of calculating the value of artificially drying alfalfa hay to reduce leaf loss.*

- Weight of the leaves in 6400 pounds of 80 percent moisture content alfalfa (adjusted to 20 percent moisture content) .... 1000 pounds
- Crude protein per ton.
  20 percent x 2,000 pounds .. 400 pounds
- Crude protein per ton in leaves (see Figure 3).
  75 percent x 400 pounds ... 300 pounds
- If 10 percent of the leaves are lost in field during curing, the crude protein loss per ton is
  300 x 10 percent .... 30 pounds**
- Value of leaves lost per ton compared to an equivalent amount of 44 percent soybean meal @ $200 per ton $6.82

** Other values for the conditions used in this example can be used if more applicable.*

*** Inadequate data is available for leaf loss in alfalfa for Tennessee conditions. Losses are generally believed to be much higher than 10 percent when alfalfa is baled at 20 percent moisture content.*

Effects of the Sun on Hay Quality

Part of the benefit of artificial drying of hay is an improvement in the quality and feeding value of the final product. Particularily in alfalfa hay, exposure to the sun during curing reduces the protein and xanthophyll content. Reduction of the sun-exposure time by artificial drying will help to accomplish this objective.

Tests of alfalfa baled at 35 to 40 percent moisture content and artifically cured versus alfalfa baled at 20 percent, after field curing, have been conducted by researchers at the University of Tennessee. The results have shown a 1 to 3 percent better crude protein value for the artifically cured alfalfa.

Figure 5. Example of calculating the value of artificially cured alfalfa to preserve protein value.*

- Loss of protein value per ton of field-cured alfalfa versus artifically dried alfalfa .... 20 pounds
- Pounds of protein lost per ton of alfalfa .... 20 pounds
- Value of protein lost per ton compared to an equal amount of 44 percent soybean meal at $200 per ton $4.54

** Other values for the conditions used in this example can be used if more applicable.*

Haymaking Systems and Artificial Drying

The large package baler has brought a new era in haymaking. The advantage of this method of making hay — mowing to storage — from the tractor seat has great advantages in today's labor conscious agriculture. Although machines for eliminating manual labor from making small rectangular bales are available, the method is expensive. Storage structures are necessary for either system.

If hay is to be fed in the vicinity where produced, the large round or the large square bale probably has no peer. However, a substantial market still exists for small conventional bales of high quality hay. This market usually is far-removed from the farm where the hay is produced such that transport by large trucks is necessary. Small bales are the definite choice for this situation. Proven drying systems are available to accommodate both the small and large bale.

In Tennessee weather conditions, it is difficult to bale any type of hay in large round bales during parts of the haying season. Some hays such as fescue and other grass hays can be successfully baled, except in extended rain periods. Alfalfa is difficult to bale in large round bales at conventional moisture contents (18-20 percent) in any weather without losing an excessive amount of leaves. Quite often, four days of drying are required to assure a safe storage moisture level for alfalfa. Under these conditions the weathering and leaf loss effect is great. Small bales can be dried sooner at a slightly higher moisture level, and the effect of the baling process on leaf loss does not appear to be as severe as in large round bales. To summarize, a farmer who wants to bale large round bales of good quality alfalfa should definitely have an artificial drier. A farmer wanting to dry small bales could also realize the same advantages for artifically dried hay. The benefits of a mower-conditioner are present whether hay is dried artifically or in the field. The use of a mower conditioner makes it possible to cut, bale and begin drying hay the same day in exceptionally good drying conditions. This timeliness would be impossible without a mower conditioner.

A Look at the Total Picture of Artificial Drying in the Haymaking Systems of Today

Artificial hay drying is not for everyone. Factors determining its application include type and quality of hay grown, quantity of hay to be made, utilization of hay after drying and availability of capital for the system and equipment.

The farmer will most likely not want to consider artificial drying unless land resources for making high yields of good alfalfa are available. Alfalfa should be the first prerequisite and the base crop in artificial drying. This is not to say that other lower value hay or hay mixtures cannot be dried on the same system if time is available. The alfalfa that is dried should carry the burden of the economic justification load for the system.

Production of alfalfa as a cash crop is a feasible enterprise and is more profitable than many others. Any producer who is or who plans to get into commercial alfalfa production should consider artificial drying. The market expects high protein content, mold free, good color alfalfa that is cut at proper growth stage and has experienced minimum leaf loss. Artificial drying will assure four of these requirements. Dairy farmers are in the best position to realize the highest return for utilization of high quality alfalfa in their enterprises. The case for this area of artificial drying has previously been presented in Figures 3, 4 and 5.

Capital outlay availability is increasingly important in today's agriculture. An artificial hay drying system is expensive. Information will be presented later in this publication on this cost. Certain field equipment such as a mower-conditioner, a baler, bale loader, wagons, frontend tractor loader and hay storage facility may need to be purchased or built in addition to the dryer. Capital outlay will, in most cases, need to be meshed into the cash-flow situation for the farming operation.

Drying Large Round Hay Bales

High quality leguminous hay can be successfully stored in large round bales if heated air is forced through the bale to dry it before internal heat causes bacterial and fungus buildup. The approach of baling alfalfa at 35 percent moisture and artifically drying it, for reduced leaf and nutrient loss, can produce excellent quality hay. This method eliminates strenuous hand labor and reduces weather risk drastically. The structure and equipment to accomplish these objectives must be built to accommodate the drying of large round bales.

Heat Energy for Hay Drying

Much work has been done by researchers in drying large round bales using solar energy as a heat source. Availability of funds to finance solar development has been largely responsible for the direction of this research. The cost of energy has not accelerated at the rate predicted; as a result, solar energy is not always cost effective as a heat source for drying large round bales. Solar energy itself is free, but the structure to collect it efficiently is not. Solar heat is also not always available when most needed. When tax credits were available for solar facilities, the payback period for solar hay drying facilities was usually less than four years.

Propane gas is the fuel most used in Tennessee and the United States for drying grain and crops. Natural gas is seldom available, but is less expensive than solar or propane at present prices. Coal and wood are the least expensive fuels, but require more human attention, special furnaces and are more difficult to control automatically. All of these heat sources are available and can be successfully used to dry hay. Electricity as a heat source is not feasible except for a very small drying system.

Design Criteria for Dryers for Large Round Bales

Air, heat and a method of directing the heated air through the bale are the essential elements of a large round bale drying system. Various combinations of these elements have been researched and demonstrated by universities and others. Some effective methods and designs have evolved from those efforts.

Air Flow

Large round bales have a variety of diameters, lengths (or heights), densities (tightness) and variation in density across the diameter of the bale. Baler manufacturers have differing designs and concepts for forming the bale, resulting in various combinations of these bale characteristics. The diameter of large round bales varies from 4.5 to 6 feet. Some balers produce a bale that has fairly uniform density across the bale diameter. Other balers turn out a bale that has a high density shell and a lower density core.

Research and experience has revealed that a bale with a low density (soft) core is easiest to dry artifically. Since air is forced into the center of the bale by pressure, the center will be the first to dry and the drying process will progress to the outer rings of the bale. The low density core offers a built-in passage way that has less resistance to air flow. However, some method of sealing off most of the air flow through the core is usually necessary to prevent the air from passing straight through the soft bale center without drying any of the shell. Figure 6 shows air flow patterns for different types of bales.

Present research by agricultural engineers at the University of Tennessee indicates that the quantity of air per bale should be at least 800

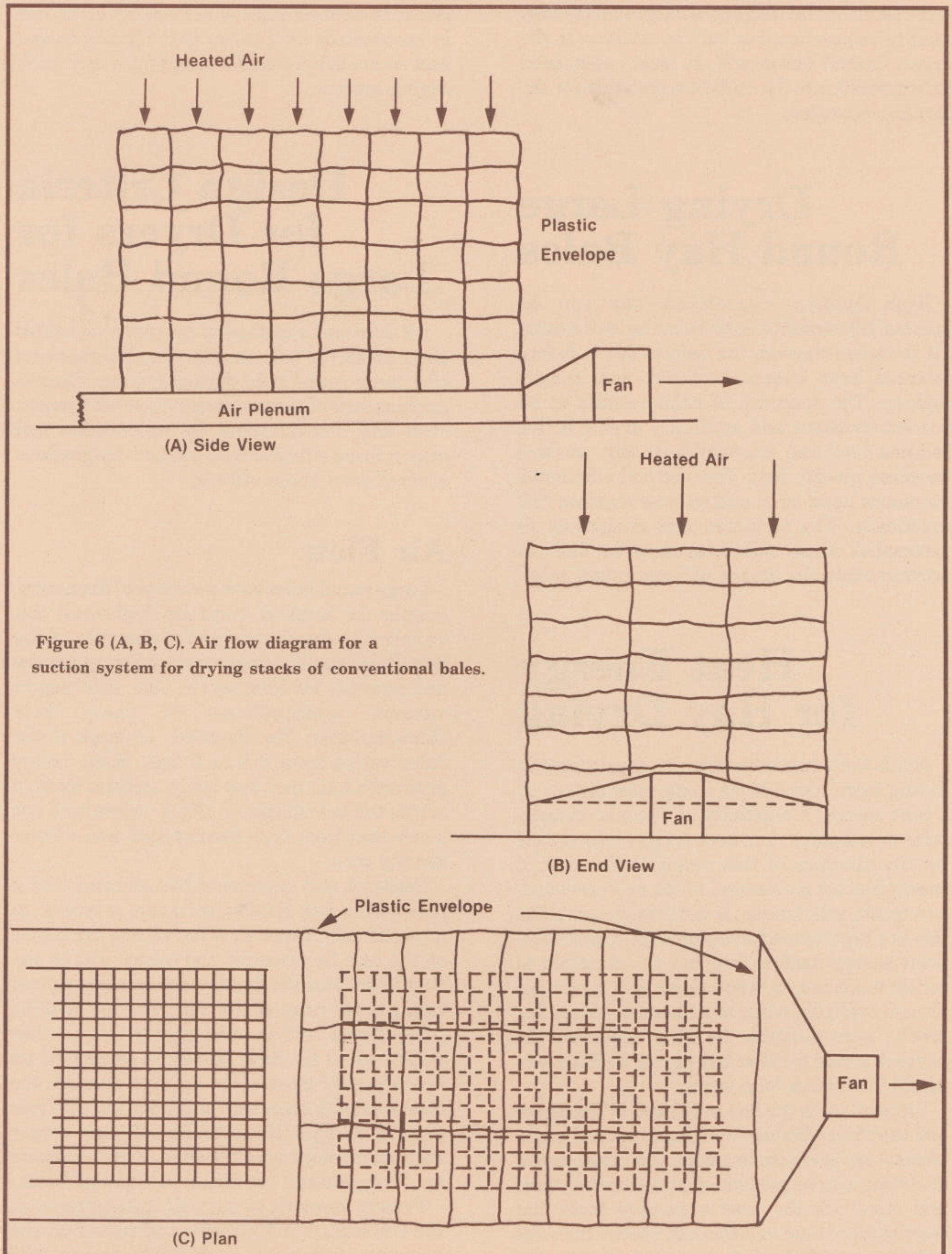


Figure 6 (A, B, C). Air flow diagram for a suction system for drying stacks of conventional bales.

cubic feet per minute (cfm) per bale when the static pressure is 3.5 inches of water. Vane-axial or centrifugal crop drying fans must be used for this application. Some types of bales will not require that the fan operate against 3.5 inches of water, but sizing the fan at this pressure will give the added advantage of more air flow if the static pressure is less.

Heat Requirements

The drying aii temperature for large round bales can be as high as 140 degrees. The total BTU heat requirement for a large round bale system can be determined from the equation: Total BTU per hour = 1.4 x desired temperature rise x CFM of fan.

Example: If the maximum outside air temperature is selected as 90 F, the maximum temperature rise will be 50 F (140 F — 90 F = 50 F). If the cfm air flow per bale is 800, the BTU per hour required per bale would be 56,000 (1.4 x 50 x 800 = 56,000). When the outside air temperature is only 60 F, the drying air temperature for a 50 degree temperature rise would be 110 F.

The number of drying fans can be varied to accommodate a variety of situations. When possible, it is desirable to provide opportunity to use more than one fan on any duct (or ducts) when the system is at less than full capacity. For a centrifugal fan, the motor should be shrouded so the motor heat can be saved by directing it into the drying air stream. The temperature and relative humidity of the drying air should be automatically controlled with appropriate devices. A 24-hour timer to allow several on-off operations is desirable.

Air Delivery System

Most researchers have used a pressure system to force air through large hay bales. Bales are set on end over a floor opening through which air enters the bale. For some types of bales, a sealing ring is necessary to prevent excessive air loss at the bottom of the bale. For the soft center bale, a sealing ring does not appear to be necessary.

Floor ducts to deliver the heated air from the fans can be metal corrugated or plastic corrugated culvert pipe of the proper diameter for the air flow. At least one square foot of cross-sectional duct area for each 1,000 CFM of air flow is desirable. From one to four bale openings for each lateral floor duct can be used. If more than four bale openings per lateral are used, the first section of the floor duct should be 2.5 feet diameter or larger. Duct arrangements should be planned to minimize the number of sharp turns or changes in the direction of air flow. Figures 6 and 7 show the schematic air flow direction for a pressure system (Figure 6) and a suction system (Figure 7).

Balage or Round Bale Silage as a Preservation Method

Silage as a livestock feed has been in use for more than a century in this country. One of its most attractive features is that it can be moved immediately from cutting to storage with very little loss in quality or nutrients. Grass silage has also been widely used for several decades. Making hay crops into silage without the necessity of curing takes the risk out of haymaking. When it can be sealed in an oxygen-free environment, silage of acceptable quality can be made. A practice referred to as "balage" or round bale silage has combined these features into a fairly successful method of preserving hay.

The advent of plastic film is one of the factors responsible for the development of balage. Individual plastic bags make it possible to package, ensile and store a small amount of hay in each single package. Using the large round baler for a quick, labor-free field operation and coupling it with a plastic film storage container has given the farmer the manageable practice of balage.

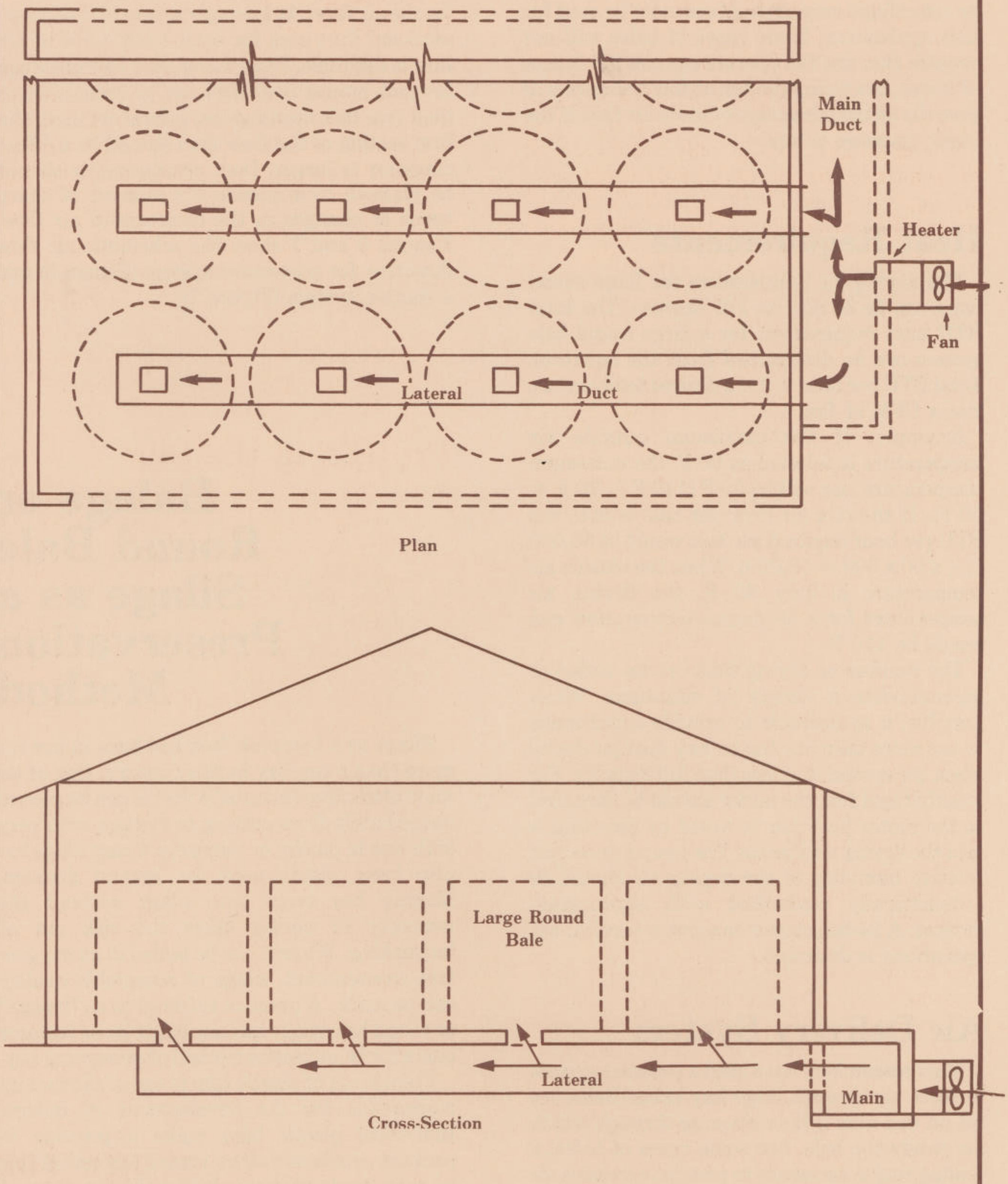


Figure 7. Pressure system for drying large round bales.

Key Factors in Using Balage Successfully

The ensiling process is only possible in an oxygen-free environment. If oxygen is present, rotting — not ensiling, takes place. So the key is to provide an air-tight container that will keep out oxygen.

Plastic Bags

A good quality bag is the place to start in balage. A 6-mil film thickness should be minimum. Some bags are multi-ply, which can benefit in preventing loss of the air seal due to tearing or punched holes.

Field Management

- Start with good hay. If poor-quality material is put into the bag, good feed is not possible.
- The crop should be wilted to about 50 percent moisture. At this moisture content, the fermentation process willbe more satisfactory than for wetter or drier material. A moisture test will be necessary for consistent accuracy in determining the correct moisture level.
- The baler should be set to make the most dense bale possible. A firm bale contains less air and allows ensiling to take place more rapidly.
- Full size bales might be much too heavy for some handling equipment. If hay is baled in large bales at 50 percent, the bale diameter must be reduced to keep the bale weight reasonable. For example, a 40-inch diameter bale at 50 percent moisture content might weigh more than a 60-inch diameter bale at 20 percent moisture content.

Putting the Hay in the Bag

- The hay should be placed in the bag immediately after it is baled. If the interior of the bale begins to heat, deterioration can take place rapidly. Some oxygen penetration into the bale takes place if it is not sealed out quickly.
- As much air as possible should be squeezed from the bag before tying. The bag must be tied tightly after being gathered and folded over. If two-ply bags are used, it is sometimes possible to tie each ply separately. A commercial plastic heat sealer is preferable to tying.

Protecting the Bag

- If even a small hole is made in the bag, the entire bag of balage can be ruined. Rodents, playing children, hailstones or even crickets might cause holes in the bags and lead to spoilage. Continual attention must be given to insure that the bags retain their seal. When holes or tears are detected, plastic tape can be used to stop air leaks. Never "peep" into a bag for inspection unless it is to be fed immediately.
- It is best to store the balage inside since protection of the bale from puncturing will probably be easier. There is no conclusive evidence of sunlight causing deterioration of quality of the balage. Protection of polyethylene from direct sunlight will prolong its life and possibly allow bags to be used more than one year.
- Polyethylene tends to become brittle and breaks easily in cold weather. For this reason, short term storage seems best for balage.

Storage for Large Round Bales

Most hay is now baled either in small rectangular bales or in large round bales.

Producers take it for granted that small rectangular bales will be stored inside. Yet, inside storage of large round bales is constantly debated. Part of the debate has to do with the way bales are handled. Small bales can be hand loaded into almost any existing barn loft or odd sized shed. These structures, however, are seldom suitable for storing large round bales. This means that a new building must be built if large round bales are to be stored. Producers are sometimes simply reluctant to consider building a new structure.

Perhaps the biggest factor in the debate over constructing large round bale hay storage is revealed in Table 1. At least twice as much storage space is required for hay in high density large round bales as compared to the same amount of hay in small rectangular bales. Low density, large round bales require about 3½ times as much storage space per ton as small rectangular bales. In other words, a storage structure for large round bales will cost 2 to 3½ times as much as a storage structure for the same amount of hay in small rectangular bales.

Table 1. Approximate storage space required for three different types of hay bales.

	Bale Density (lbs. per cu. ft.)	Storage Space (cu. ft. per ton)
Small Rectangular Bales	9	222
High Density Large Round Bales	9	444
Low Density Large Round Bales	5	800

There are several factors which may help offset the additional cost of a structure for storing hay in large round bales. Spoilage loss in bales stored outside is the most commonly cited. However, each producer should decide about building a hay barn based on a comparison of the total costs of the complete hay production systems available. Such factors as the fixed cost of production, labor availability and cost, and feeding losses must be considered along with spoilage loss and building cost.

Proper site selection and building orientation are important considerations for those producers planning a hay storage barn. The site must be well drained. Locate the barn on a hilltop or grade the site so that water will drain away from the barn in all directions. Construct and maintain diversions if needed.

The prevailing wind directions in Tennessee (subject to local variations) are either northerly or southerly. As a good general rule, the north, south and west sides of a hay barn should be enclosed — leaving the east end or side entirely open. End-loading barns should therefore be oriented with the ridge running east-west, while sideloading barns should be oriented north-south.

Figure 8 illustrates the two basic barn designs which can be used for storing large round bales. Side-loading barns allow equal access to more hay. This feature provides flexibility in the feeding program because hay can be stored in each bay according to type and quality. End-loading barns, on the other hand, require less area outside the barn for turning. Also, there are no posts to obstruct equipment movement.

The hay storage barn should be placed to allow adequate turning space (see Figure 8). Consider that additional bays or barns may be added to meet future storage needs. Feeding space should generally not be included as part of the large round bale storage structure. Too much valuable storage space is lost to provide turning room for the handling equipment.

The size of the structure will be determined mainly by the number and size of bales to be stored. Remember that bales tend to fluff. For example, a so-called 5-foot diameter bale will likely measure closer to 5½ feet. Adequate overhead clearance is a must. At least 16 feet of height is needed for pyramid stacking 5-foot diameter bales three high. Allow 19 to 20 feet for 6-foot diameter bales.

A clear-span structure — that is one with no interior posts — will provide maximum convenience and flexibility in bale moving. Doors tend to restrict the movement of bale handling equipment. The orientation suggested in Figure 8 eliminates the need for doors. Even the enclosed sides of a hay barn should not be closed too tightly. Hay barns need to "breathe," so leave at least 8 to 10 inches open under the eaves.

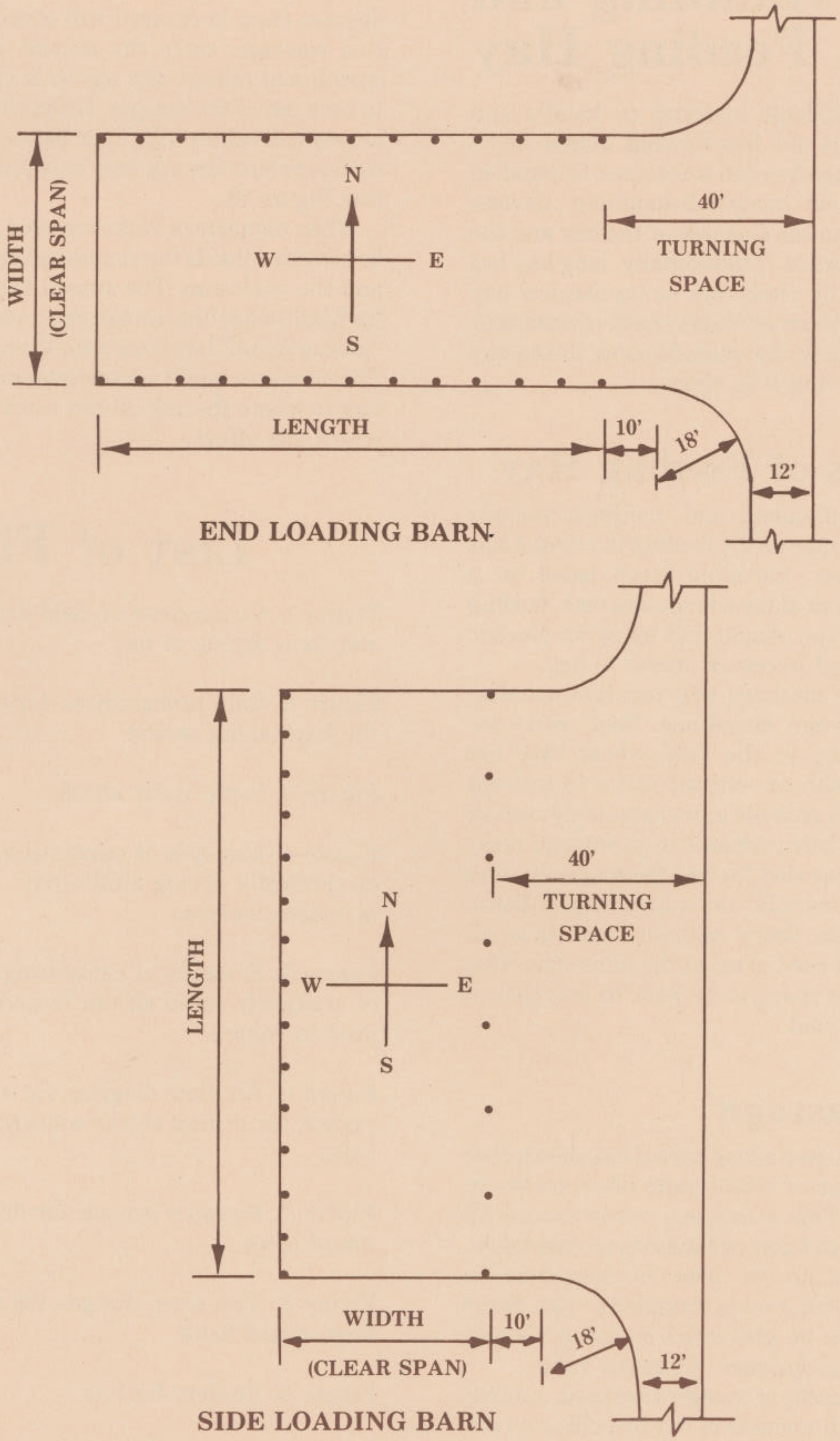


Figure 8. Two basic designs for storing large round bales.

Handling and Feeding Hay

Hay is a difficult material to handle and distribute. It is not free-flowing unless finely ground. Chopped hay can sometimes be handled by conventional materials-handling devices depending upon the fineness of the hay and the particular situation. Traditionally, long hay has been handled by pitch fork or mechanical hay fork. More modern methods trend toward self-feeding or letting the animals come to the hay instead of moving it to them.

Methods of Feeding Hay

Feeding equipment and methods include feeding in circular racks, feeding in rectangular portable panels, unrolling large bales on a concrete apron or along a fence line rack, feeding from a rack type wagon and using an electric fence to control livestock access to hay.

All of these methods will function satisfactorily in different situations. Beef cattle are usually fed hay in the field where they are pastured — with or without racks to prevent wastage. Dairy animals more commonly receive hay inside the barnyard area in permanent racks or mangers provided for hay feeding only. Hay feeding is, generally, on a free choice basis, particularly for dairy animals, and thus all animals do not need to eat at the same time. This allows feeding space to be kept to less than 6 inches per animal.

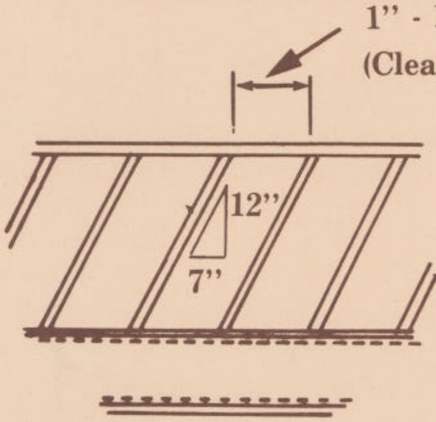
Hay Wastage

Observation over a long period has shown that a large amount of waste quite often occurs in feeding hay. This waste can easily exceed 40 percent if the strictest precautions are not taken. Farmers tend to be poor housekeepers in salvaging hay before it is trampled or lost. Some waste can also be prevented by using manger construction techniques of proven value.

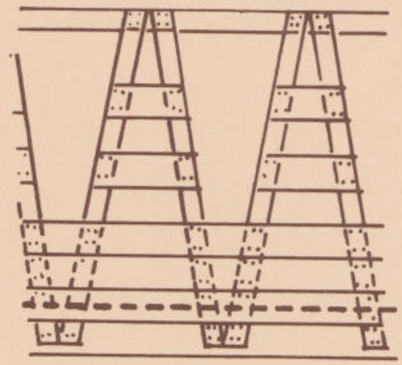
Even when racks or mangers are used, animals can waste large amounts of hay by pulling it back through the rack onto the surface on which they stand. A slant bar divider slanted at about 60 degrees from horizontal will eliminate most of this wastage. since the animal will open its mouth and release any hay as it turns its head to back out of the manger. Horizontal clear space between dividers will range between 10 and 16 inches to suit the age and breed of the animals (see Figure 9).

When mangers or racks are used, space should be provided inside the enclosure between the hay and the enclosure. The animal then must have its head inside the enclosure to eat and cannot "pick and pull" hay back onto the standing area. This measure might necessitate more moving of hay to where the animal can reach it but is well worth the effort.

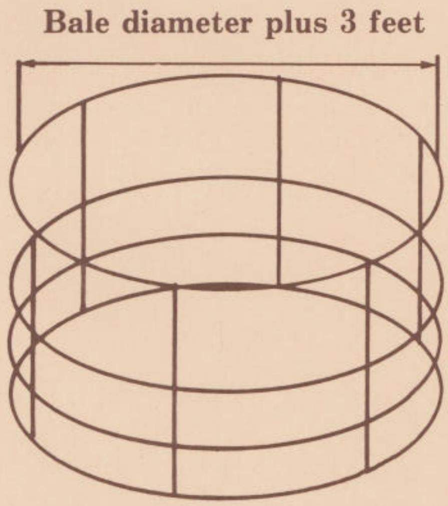
List of Figures



(A) Slant-bar feeder

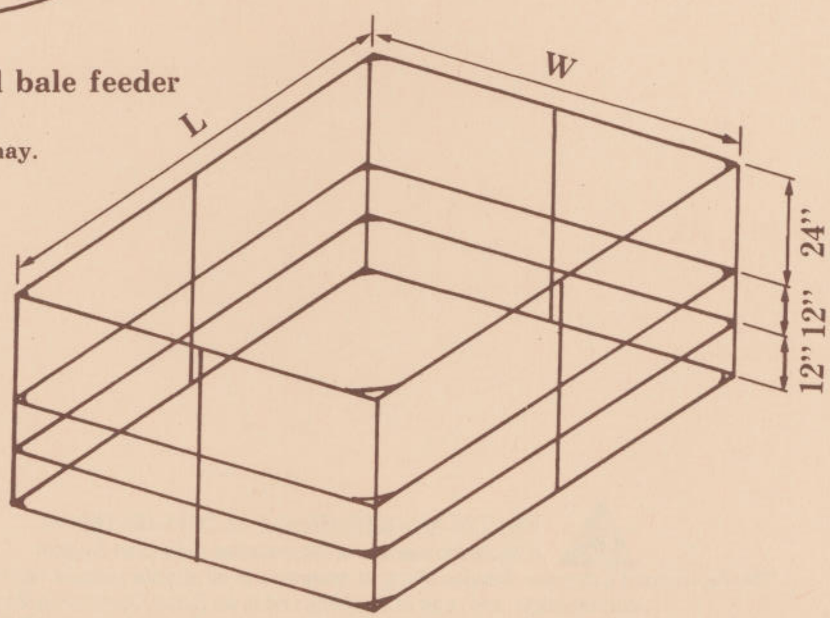


(B) Vee-bar feeder



(C) Portable round bale feeder

Figure 9. Feeders for hay.



W & L = Bale dimensions plus 3 feet
(D) Portable feeder for round or conventional bales

PB1255-5M-10/93(Rep) E12-2015-00-169-94
A State Partner in the Cooperative Extension System
The Agricultural Extension Service offers its programs to all eligible persons regardless of race, color, national origin, sex, age or disability and is an Equal Opportunity Employer.
COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
The University of Tennessee Institute of Agriculture, U.S. Department of Agriculture, and county governments cooperating in furtherance of Acts of May 8 and June 30, 1914. Agricultural Extension Service Billy G. Hicks, Dean