BETTER HAY BY FORCED-AIR DRYING

By J. H. Ramser, F. W. Andrew, and R. W. Kleis

THIS CIRCULAR EXPLAINS THE ADVANTAGES, INSTALLATION, AND OPERATION OF HAY-DRYING SYSTEMS. IT WILL BE OF MOST USE TO YOU IF YOU CAN ACTUALLY OBSERVE A DRYING SYSTEM IN OPERATION AND HEAR AT FIRST HAND THE EXPERIENCES OF THE OPERATOR. THE LOCATION OF HAY-DRYING INSTALLATIONS IN YOUR VICINITY CAN BE OBTAINED FROM YOUR FARM ADVISER OR ELECTRIC POWER-SUPPLIER’S REPRESENTATIVE, BOTH OF WHOM CAN ALSO GIVE YOU VALUABLE ADVICE ON BUILDING AND OPERATING A HAY DRIER.

The Advantages of Forced-Air Drying

Whatever feeding value hay has when grown, field-drying destroys a large part of it. The main reason for this loss is that hay contains most of its feeding value in its leaves, and hay that is sufficiently field-dried for storage loses much of its leafiness when handled. In the case of alfalfa, for example, which in Illinois is most widely used for hay, the leaves contain no less than 75 percent of its feeding value. For this reason, official United States grading standards for alfalfa consider, besides color and foreign material, the leafiness of the crop. No. 1 alfalfa must have a leafiness of at least 40 percent; No. 2, at least 25 percent; and No. 3, at least 10 percent. Hay having less leafiness than 10 percent is graded sample because it has so little feeding value.

In contrast to field-drying, forced-air drying preserves much of the feeding value of the crop as well as the crop itself because:

1. Hay is only partly dried in the field before it is completely dried on the drying system. This shortens the time that hay may be exposed to rain, which damages the crop, and to sun, which induces enzymatic action that destroys carotene—a source of vitamin A essential to livestock health.

2. Hay can be handled when damp, which reduces leaf loss and saves protein and carotene. Field tests have shown that hay dried by forced air has 10 percent more protein and 50 percent more carotene than the same hay dried in the field.

3. Hay can be prevented from heating and the risk of spontaneous combustion with its attendant losses eliminated.

Where the System Can Be Installed

The system can be installed in a barn mow, a specially built structure, or in an outside stack. The barn is most often used because it saves the cost of building another structure. There are few barns that cannot accommodate a satisfactory drying system.

How the Barn Should Be Prepared

A barn that is not specially built to house a drying system has to be carefully checked and prepared. First, the barn must be strong enough to support the extra weight of the hay, since the hay is stored damp. A mow that has held a full load of dry baled hay is strong enough to stand this added weight. Barns that have not supported such a load should be checked for structural weaknesses.

Second, the mow floor must be airtight. Air that leaks through the floor will not dry hay and will also make the system less efficient. Such a floor should be covered with a new, airtight floor or with a layer of roll roofing.

Third, openings above the hay to the exterior of the barn must be provided to remove moist air. These openings can be made as large as convenient, but their total area should be no less than twice the area of the air inlet to the fan enclosure.

Amount of Air to Circulate

Most hay drying in barns is done by circulating unheated rather than heated air, because it is simpler and more economical. The easiest way to determine the amount of air to circulate is to compute the area of the mow floor. If unheated air is to be used, the minimum amount should be 15 cubic feet per minute per square foot of area to be delivered against a pressure of 1½ inches of water (enough pressure, in other words, to maintain a column of water at a level of 1½ inches). To make this measurement, multiply the length of the mow by its width, then multiply that total by 15. If a greater amount of air than this is circulated, hay will dry faster, but the power requirement and the cost of equipment will be increased.

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When heated air is used, the volume of air circulated can be smaller. This volume varies with the temperature of the air.

**Time of Day When Hay Is Harvested for Drying**

Farmers differ as to what time of day they should cut hay for forced-air drying. Some cut in the morning about 9 o'clock when most of the dew has evaporated, leave the hay in the swath until the surface has dried, then windrow it with a side-delivery rake. How long the hay remains in the swath depends upon the weather. Usually two hours on a warm, sunny day is long enough. Small windrows can be stored sooner than large ones because they dry faster. If larger windrows are desired for chopping, two small ones can be pulled together. If there is good drying weather, hay can be stored the same day it is cut.

Other farmers cut hay in the afternoon of one day, and, if drying weather is good, rake it about 10 the next morning and store it that afternoon. This practice may be less satisfactory than the other because hay remains on the ground overnight and is subject to change of weather.

**Moisture Level at Which to Store Hay for Drying**

Standing hay contains up to 80-percent moisture. To reduce that moisture so that the hay can be stored safely, a large amount of water has to be removed. The drying load on the system is greatly reduced by partly drying hay in the field first, then storing it wet enough to be sufficiently tough to avoid leaf shatter.

If hay is stored as long, loose hay, its moisture should be reduced to 45 percent in the field.

Chopped or baled hay should have its moisture reduced to 35 percent because it is denser and, for that reason, more difficult to dry. Chopped hay dries better when it is cut long rather than short. A cut of 4 to 6 inches is best, if it can be handled satisfactorily.

Forced-air drying of baled hay is more difficult than forced-air drying of loose hay. If baling is done, the hay should be pressed lightly and the bales stored on edge.

The approximate volume of alfalfa hay that can be stored for drying as long, loose hay, chopped hay, or baled hay is shown below in **bold face**. The other volumes shown are for comparison. Volume is given in cubic feet per ton.

| Stored dry | 500 |
| Stored at 45-percent moisture and after being dried | 400 |
| Stored at 45-percent moisture and before being dried | 275 |

**Chopped hay**

| Stored dry | 450 |
| Stored at 35-percent moisture and after being dried | 300 |
| Stored at 35-percent moisture and before being dried | 225 |

**Baled hay**

| Baled medium tight and stored dry | 240 |
| Baled lightly, stored at 35-percent moisture, and after being dried | 250 |
| Baled lightly, stored at 35-percent moisture, and before being dried | 200 |

The more moisture hay contains, the more hay it takes to get 1 ton with 15-percent moisture. For instance, it takes more than three times as much hay to get 1 ton with 15-percent moisture when the moisture content is 80 percent as when the moisture content is 35 percent.
Loading the Drying System

Blowers, though commonly used to store hay on drying systems, have two disadvantages: they use a large amount of power and tend to separate the leaves from the stems. Elevators, similar to those used for grain, do not have these disadvantages, but they operate slower and do not distribute hay in the mow as well as blowers. Whether a blower or an elevator is used, some manual spreading of the hay is needed to cover the drying system uniformly. If this is not done, unequal drying will occur and hay may mold in places.

In spreading, avoid walking on the hay in order to prevent unequal packing. One way to avoid this is to walk on a ladder laid upon the hay. This practice will equalize the pressure caused by walking and pack the hay uniformly.

The first filling of hay, whether chopped, long, loose, or baled, should not exceed a certain distance from the air outlets. These distances are:

For chopped hay .................. 6 feet
For long, loose hay ................. 8 feet
For baled hay ...................... 6 bales

Once this filling is dry, more hay may be added. Each additional filling, however, must be no more than 4 feet deep, and, all told, should not exceed a certain depth as measured from the duct outlets. These depths are:

For chopped hay ................ 12 feet
For long, loose hay .............. 16 feet
For baled hay .................... 12 bales

Operating With Unheated Air

As soon as all air outlets are covered with hay, start the fan and run it continuously for at least 72 hours for each filling. After this time, hay just beneath the surface will be almost dry, and the fan will have to run only during the daylight hours until drying is completed.

If it should rain after the 72 hours, run the fan intermittently to keep the hay cool and prevent it from absorbing more moisture. If the rain lasts, run the fan one out of every four hours.

The drying system requires hardly any attention when unheated air is used. For trouble-free operation, however, you will want to be guided by these five rules:

1. Keep belts properly adjusted for tightness.
2. Lubricate fan and motor bearings according to manufacturer's instructions.
3. Keep shields and other safety devices in order.
4. Provide motor overload protection.
5. Keep electric wiring in good condition.

Operating With Heated Air

Heating air to dry hay presents a fire hazard to a hay barn. Other than for this disadvantage, hay dries fast, even during periods of high humidity, when heated air is used. Air heaters can be used with any duct system.

There are two types of air heaters used in crop drying, direct and indirect. Direct heaters allow the burned fuel to mix with the circulating air and pass through the crop. Indirect heaters (exchanger type) prevent gases from mixing with the circulating air by using a combustion chamber in which fuel is burned and from which gases are exhausted to the outside of the drier. Of the two, indirect heaters are safer for hay drying because there is less danger of sparks entering the duct system.

Whether you use a direct or indirect heater, it must have at least two controls for fire prevention—a flame-failure control and a temperature shut-off. The flame-failure control prevents unburned fuel from accumulating in the heater when the fuel fails to ignite. The temperature shut-off turns off the fuel when the temperature within the heater rises above a set temperature. You may also find a thermostat desirable to maintain a set temperature.

Your fire insurance policy may not cover fires resulting from using heated air for drying hay. If not, you will want to obtain additional insurance that does.

How to Tell When Drying Is Finished

To determine whether drying is finished, test the hay that lies about a foot from the surface four or five days after operating the drying system. If the hay there is brittle, indicating that it contains about 15-percent moisture, turn off the fan for 10 hours. Then, to make sure that no damp spot remains, start the fan again after this period and run it for 20 minutes. While the fan is running, feel if the air coming from the hay is warm. If the air is warm, you still have a damp spot and you will have to run the fan for another 24 hours and repeat the test.

As a safety measure, make this test two or three
times after warm air stops coming from the hay.

Drying time varies a great deal with the moisture content of the hay, the depth at which it is stored, and with weather conditions. It may take as little as 4 or 5 days to dry hay and as much as 21 days.

**Electric Motors Versus Internal Combustion Engines**

An electric motor is considered better for a hay-drying system than an internal combustion engine because it is more convenient to operate and is less liable to cause fire. Rural electric lines, however, usually supply single-phase current and do not often permit motors larger than 7 1/2 horsepower. This restriction limits the amount of hay that can be dried in a given period on a single installation. And sometimes there may be no electric current available. In such cases, a stationary internal combustion engine or a tractor offers a solution.

**Costs of Installation and Operation**

The cost of an installation — and this includes motor, fan, and duct system — is about 75 cents per square foot of mow area. If you plan to use heated air, add the price of the heater.

The cost of power for drying one ton of hay with unheated air ranges from about $1.00 to $1.50. If you use heated air, the cost will be about the same, for while less power is required, the expense for fuel must be added.

**Choose a Drying System to Fit Your Storage Structure**

The function of any duct system is to distribute air to hay as evenly as possible. The type of system used varies with the shape and size of the storage structure. The main types of systems (shown in detail on the following pages) may be classified in this way:

For mows less than 30 feet wide and not over 12 feet deep: *Single central duct systems.* Easiest to install and cheapest to build. Prefabricated models are available.

For mows more than 30 feet wide and not over 12 feet deep: *Lateral duct systems.* Prefabricated models are available. *Slatted-floor systems.*

For mows less than 30 feet wide and over 12 feet deep: *High central main duct with air-control doors or low central main duct with flues.*

For mows more than 30 feet wide and over 12 feet deep: *High central main duct with two sets of laterals or low central main duct with laterals and flues.*

**REMEMBER:** Before you install a hay-drying system in your barn, check for structural weaknesses and correct them. Only in this way will you be sure that you can store hay free of trouble and operate your drying system most efficiently.
SINGLE CENTRAL DUCT SYSTEMS for mows less than 30 ft. wide and not over 12 ft. deep

If your mow is narrow, the most practical installation is a single central duct system. Either type shown on this page—the rectangular or the A-frame—is cheaper and easier to install than any other type of duct system. For most effective operation:

1. Cover the duct with hay, if only lightly, before starting to dry.
2. Maintain a uniform depth of hay on the duct at all stages of filling.
3. Don’t let hay extend more than 12 feet from the sides of the duct.
4. Load hay above the duct 1 foot deeper than the width of the hay on either side.

With either of the duct systems shown on this page, be sure to provide 1 square foot of cross-sectional area for each 1,000 cubic feet of air per minute carried. This amounts to about 1 square foot for each 3 tons of wet hay when the duct is fully loaded.

The cross-sectional area for a rectangular duct is its width (in feet) \( \times \) its height (in feet). The cross-sectional area for an A-frame duct is one-half its width (in feet) \( \times \) its height (in feet).

The sides and end of the duct must be at the same distance from the mow walls so that air meets the same resistance in all directions of travel and is distributed uniformly.

Distance a (shown in the drawing) should not exceed 12 feet.

The fan end of the duct should be made airtight for a certain distance to prevent an excessive amount of air from escaping toward the fan. This distance should be 2 feet less than the space measured from the opposite end of the duct to the mow wall.

The end of the duct away from the fan should be slatted or covered with wire mesh in the same way as the sides.
LATERAL DUCT SYSTEMS for mows more than 30 feet wide and not over 12 feet deep

If your mow is wide, you will need a more elaborate system to distribute air. The systems shown on this and the following pages are some of the types that can be used. For most efficient operation of such systems, observe these rules:

1. The main duct should be airtight except for the openings into the laterals.
2. The main duct should have 1 square foot of cross-sectional area for each 1,000 cubic feet of air per minute carried. This amounts to about 1 square foot for each 3 tons of hay when the main duct is fully loaded.
3. The combined cross-sectional area of all the laterals should total at least the area of the main duct.
4. The duct covering should be on the inside of the framing members to provide a smoother channel for air flow.

Laterals are enclosed on the top and sides, as shown above. They are supported 4 inches off the floor by legs so that air is released from the open bottom and allowed to pass into the hay. If laterals must be more than 15 inches wide, a ½-inch crack should be provided along the center top of each lateral to dry the hay directly over it.

Because laterals need not be completely airtight, rough or unmatched lumber can be used in building them. A short 1" x 4" sill across each pair of legs distributes the weight and provides a way to fasten the laterals to the floor.

The main duct extends from the fan to within 5 feet of the opposite end of the mow. The laterals on each end of the system should also be 5 feet from the ends of the mow. The length of the laterals depends on the width of the mow, but in any case they should extend to 7 feet from the sides of the mow.

Left: The reason that the laterals on this central main duct were made uneven was to prevent air from escaping through chutes and along barn-framing members.
OTHER SYSTEMS for mows more than 30 feet wide and not over 12 feet deep

Slatted-floor systems do the same work as lateral duct systems, but they are simpler to construct and make hay removal easier.

Here are some points to consider about slatted-floor systems:
1. The design and construction of the main duct are the same as for the lateral duct system shown on page 7.
2. The combined cross-sectional area under the slatted floor at the main duct should total at least as much as the cross-sectional area of the main duct.
3. The slatted floor can be built in sections, which can be moved out of the way as they are uncovered during hay removal.
4. Joists should be at least 2" x 6" and spaced 2 feet apart. For mows 36 feet or more wide, 2" x 8" joists should be used to provide enough room for air flow.
5. The floor section near the wall can use joists 2 inches narrower than the section near the main duct, because some of the air goes into the hay through the first section. The joists may also be tapered, if you want to take the trouble.

The slatted floor should be 5 feet from the ends of the mow and 7 feet from the sides. The ends of the joists need not be covered or slatted.

The main duct can be built along the side of the mow too, as shown here. This arrangement is more convenient when the mow is empty, but it is more expensive.

A side main duct requires greater air tightness than a central main duct, since air that leaks out does not pass through the hay and is wasted.

This arrangement uses fewer but longer laterals than the central main duct with laterals (see page 7). These laterals are built in two or three sections for easier handling. The section nearest the main duct is made largest and the other sections are made smaller so that they will fit into each other.

Each of the laterals must have twice the cross-sectional area as those used with the central main duct because only half as many are used.
PREFABRICATED DUCTS

Prefabricated ducts of various sizes that can be used either as single central ducts or as laterals are obtainable from commercial companies. Complete systems consisting of main duct and laterals are also obtainable. These may not, however, fit your barn as well as a system specially designed for it.

If you choose one of these systems, make sure that the ducts are large enough so that air flow does not exceed 1,000 cubic feet per minute per square foot of duct cross section.

This prefabricated unit, built in 3-foot sections, can be used either as a main duct or as a lateral.
*Courtesy Baughman-Oster, Inc.*

SELF-FEEDING HAY DRIERS AND STORAGE UNITS

A round metal bin with perforated outside walls makes an economical structure for drying hay, especially when you have no barn space available. For air supply, a vertical central duct is used. The air that is forced into this duct passes through the hay and is exhausted through the perforated walls. To ensure uniform air flow, the hay surface should be just about level at all stages of filling.

The air duct is built with a square cross section, with air outlets to the hay on all sides. These outlets, extending across the sides of the duct, are 10 inches wide and spaced 2 feet apart. Wire mesh on the outside of the duct prevents hay from passing into the duct through the outlets.

Tight-fitting doors that can be opened and closed as the bin is filled provide control of air passing from the duct. In this way, air is circulated only through wet hay and not through hay that has been dried.

This bin can be constructed with openings at the base for self-feeding, as shown in the drawing.

A pole-type building covered on the sides with a snow fence makes a good self-feeding storage and hay-drying unit. Air requirements and duct size are the same as for conventional systems. The air duct is an A-frame tapered slightly so that it can be pulled out by a tractor when drying is complete and feeding starts. This unit can be enlarged.
SPECIAL SYSTEMS for mows less than 30 feet wide and over 12 feet deep

If you want to dry hay in a mow that is over 12 feet deep, you can use the high central main duct with air-control doors or the low central main duct with flues, both of which are shown below.

The high central main duct with air-control doors is built to within 12 feet of the height at which you plan to store hay. This type uses 2” x 6” framing members spaced 2 feet apart and is braced to the floor on both sides. A door in the duct above the fan allows the operator to enter to adjust air openings. These air openings are provided on both sides. A convenient size for them is 10 inches wide by 48 inches long. Vertically, they are spaced 2 feet apart and extend from the fan enclosure to the opposite end of the duct.

Each air opening is provided with a slide or hinged door so that it can be closed or opened from the inside as the mow is filled. This arrangement allows air to be shut off from dried hay and opened to wet hay as the mow is filled and drying progresses. The openings are covered on the outside with slats or wire mesh to prevent hay from entering the duct when the doors are opened.

A low central main duct with flues is another way of drying hay in deep mows that are less than 30 feet wide. Flues have airtight sides and top but an open bottom. The common size of these flues is 12 inches square inside and 6 feet long. The height of each flue should be equal to distance a shown in the drawing. The total cross-sectional area of the flues must equal the cross-sectional area of the main duct. The spacing of the flues depends on the number required.

Before filling the mow, place the flues tightly on the top of the main duct. Air then enters the hay through the openings at the bottom of the main duct. After the hay has been dried to a height level with the tops of the flues, the lower openings of the main duct are closed and flues are raised, keeping the tops of them even with the hay level. This leaves a channel in the hay for air to pass to higher levels.
SPECIAL SYSTEMS for mows more than 30 feet wide and over 12 feet deep

When a deep mow is too wide for a high central main duct, two sets of laterals can be used. Here the main duct is built high enough to supply air to lateral openings above the 12-foot level. All lateral openings have either slide or hinged doors for shutting the openings when not in use. After hay has been dried to a depth of 12 feet, the second set of laterals is laid on the surface of the hay and connected to the main duct openings by canvas connections. These joints, by being made flexible, are not damaged by settling of the hay. Air openings to the lower laterals are closed when the upper laterals are opened for drying hay at the higher level.

An alternative method to the high central main duct with two sets of laterals is the low central main duct with laterals and flues. These flues are similar to those on a low central main duct (see opposite page) and are handled in the same way. A flue is placed on each end of the laterals and additional flues are used so that the spacing is not more than 5 feet. The total cross-sectional area of the flues must be at least equal to the area of the lateral on which they are placed.

STACK DRYING

Long, loose hay can be dried in stacks. Hay, whether placed on the duct with a stacker or by hand, should cover the structure evenly. A tarpaulin can be used to protect hay from weather and to equalize air flow throughout the stack.

Baled hay can also be dried in stacks if the moisture content is limited to 35 percent and the bales are lightly pressed. For best results, limit the wet bale weight to 100 pounds and place bales on edge and pack them tightly together, staggering joints wherever possible to reduce air flow between them. With these provisions, you should be able to dry six bales on each side of the air duct and an equal number above the air duct satisfactorily.
FANS USED IN DRYING SYSTEMS

Two types of fans are used in hay driers, propeller and centrifugal. Of the two, the propeller type is simpler and less expensive.

Within limits, the more blades a propeller-type fan has, the better it performs. Two special types—the tubular and the vane axial—are occasionally used in hay drying, but they cost more than the ordinary propeller type for the same capacity.

Centrifugal fans are of two general types, one having forward curved blades, the other backward curved blades. (Forward and backward curve is defined as toward or away from the direction of wheel rotation.)

Centrifugal fans having forward curved blades are not as satisfactory for hay-drying systems as those having backward curved blades, because they do not have uniform power requirements at different depths of hay. Centrifugal fans having backward curved blades are a constant-load fan and will not overload a motor as the pressure against which it operates varies.

Approximate Capacity and Power Requirements of Typical Hay-Drying Fans

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A 7-bladed, propeller-type fan commonly used in hay-drying installations. Courtesy Aerovent Fan and Equipment Co.