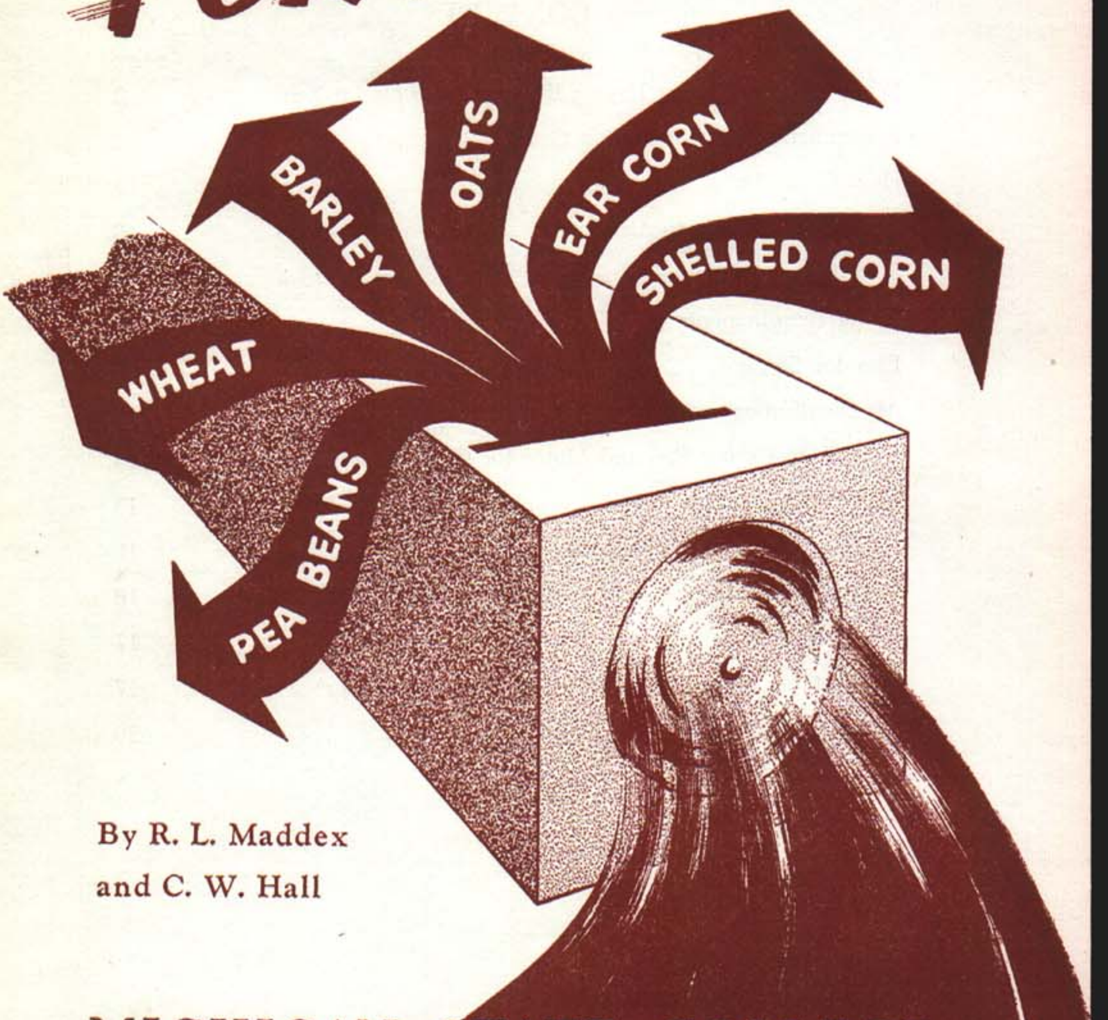
EXTENSION BULLETIN 316

DRYING GRAIN WITH FORCED AIR



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MICHIGAN STATE COLLEGE
Cooperative Extension Service
EAST LANSING

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Drying Grain With Forced Air

By R. L. MADDEX[1] *and C. W. HALL*[2]

Because of high moisture, many farmers in Michigan have suffered substantial cash losses on grain crops during the past several years. High-moisture grain sold at the elevator brings reduced prices. High-moisture grain put in storage is likely to deteriorate in quality.

The combine has reduced the labor requirements for harvesting grain, and has shortened the time of harvesting grain from a matter of weeks to a matter of minutes. The period of time when desirable harvest conditions exist is relatively short. Early harvest yields a high-moisture crop. Late harvest often yields a reduced crop because of shattering in the field, lodged grain, sprouted grain, and more weeds.

The mechanical corn-picker has reduced the labor requirements for harvesting corn, and has also shortened the time of harvesting. The corn picker, too, has added the problem of incomplete removal of husks to the storing of corn. Early harvest yields a high-moisture crop. Late harvest often yields a reduced crop because of bad field conditions, broken stocks, and higher shelling losses in the field.

Conditioning grain by using forced-air circulation can greatly reduce the moisture problems which result from harvesting grain with a combine, and from picking corn mechanically.

WHAT CAN YOU EXPECT DRYING EQUIPMENT TO DO FOR YOU?

A forced-air drying system greatly reduces the weather hazards at the time of grain harvest. It permits:

1. Earlier harvest while crop is standing.
2. Harvesting under better field conditions.
3. Longer working days.
4. Safe binning of grain at a high moisture-content.
5. Reducing losses due to shattering.
6. Reducing deterioration in storage.

A forced-air drying system requires:

1. An investment for equipment.
2. Bins that are in good condition.

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3. Adjustment of harvesting practices to permit the best use of the drying system.

To remove moisture from grain requires:

1. A storage bin equipped with suitable ducts.
2. A fan to force air through the grain.
3. A power unit to drive the fan.

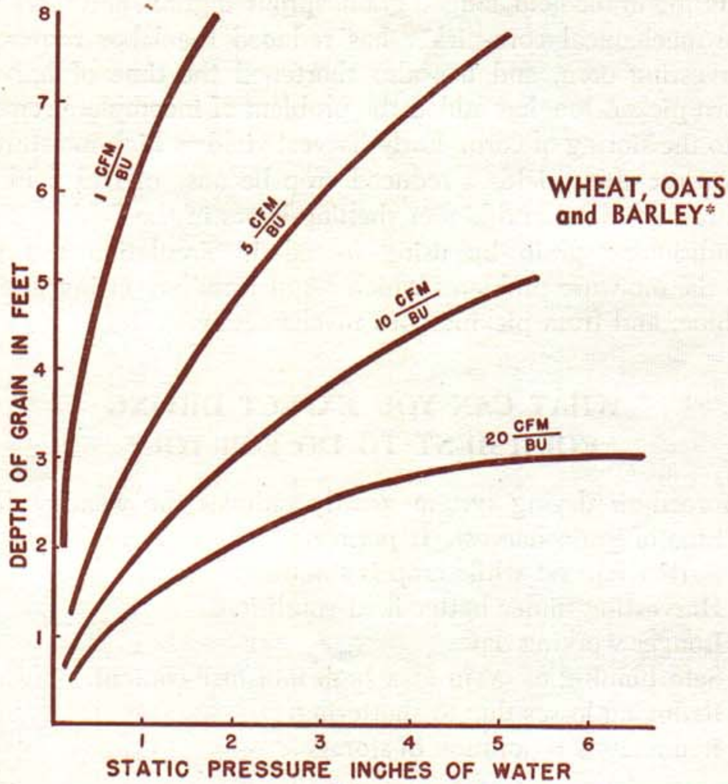
RECOMMENDATIONS FOR DRYING GRAIN

AIR FLOW—

Small grains—3 to 5 CFM/Bu.

Pea beans, shelled corn, and ear corn—5 to 10 CFM/Bu.

(More CFM/Bu. increases rate of drying.)



*Approximately the same static pressure is developed in Wheat, Oats, and Barley.

Fig. 1. Chart showing the relationship of static pressure to depth-of-bin, according to the rate of air-flow through wheat, oats, and barley. (Resistance to the flow of air builds up as the cubic feet of air a minute, per bushel, or the depth of the grain is increased.)

DEPTH OF STORAGE—

Small grains —4 to 6 feet.

Pea beans and shelled corn—4 to 7 feet.

Ear corn—Up to 15 feet.

SIZE OF FAN—

Determined by depth of storage, rate of air-flow, and the crop being dried. (See Figs. 1 and 2; Table 3, and Examples 1 and 2.)

TIME REQUIRED FOR DRYING—

2 percent of moisture can be removed in 24 to 48 hours in favorable drying weather, during the summer months, using an an air-flow of 5 CFM/Bu. Because of less favorable drying weather during the fall months, it may take 2 to 3 times as long to remove 2 percent of moisture with an air-flow of 5 CFM/Bu.

HOW GRAIN DRIES

The drying-rate of grain in storage depends on 1) the temperature and humidity of the air at the time of drying, and 2) the rate of air movement through the grain. Grain dries from the bottom up when the ducts are on the bin floor. When the moisture in the top layer has been reduced to the limit required for safe storage, all grain in the bin is safe for storage.

Table 1 gives the amount of water that must be removed from high-moisture grain to make it safe for storage through the fall and winter months. A lower moisture content is required to store grain safely through the late spring and summer months. Additional drying can be done, if necessary, in the spring if the grain is to be held over.

TABLE 1—Amount of water in high-moisture grain

CROP	Pounds in bushel	Moisture-content for Fall and Winter storage (Percent)	Pounds of water to be removed from 1 bushel of grain harvested at a moisture-content of				
			16%	*18%*	*20%*	*22%*	*24%*
Wheat..........	60	14	1.4	2.8	4.2	5.6	...
Oats............	32	14.5	0.6	1.3	2.1	2.8	...
Barley..........	48	14.5	1.0	2.0	3.1	4.2	...
Navy beans......	60	18	...	...	1.5	3.0	4.4
Ear corn........	70	18	...	...	1.7	3.4	5.1
Shelled corn......	56	13.5	1.6	2.9	4.2	5.5	6.8

Table 2 gives the rate of drying for each 1,000 CFM of air used for several air conditions.

TABLE 2—Moisture removal

Temperature (*Degrees F.*)	Relative humidity of air (*Percent*)	Pounds of water removed in one hour (*Using 1,000 CFM of air*)
80°........................	75	2.2
80°........................	50	12.0
70°........................	60	5.0
60°........................	60	4.0
50° or lower..................	..	*No appreciable drying takes place**
	85–100	*No appreciable drying takes place**

*From a practical standpoint, it is not economical to operate a drier under these conditions for the purpose of moisture removal.

Although no appreciable drying takes place when the temperature is below 50° F. or the relative humidity above 85 percent, operating a fan will cool the grain and prevent deterioration.

Since the temperature and relative humidity may vary considerably during any 24-hour period and on succeeding days, it is difficult to predict how many hours of fan operation will be required to dry a bin of grain. However, an approximation can be made by using Tables 1 and 2. As the moisture-content of the grain increases, the time required for removing the excess moisture increases. As the quantity of air forced through the grain increases, the amount of water removed each hour increases.

RESISTANCE OF GRAIN TO AIR FLOW

The "static pressure," that is the resistance to the flow of air, increases as the depth of grain increases and the rate of air-flow increases. Figures 1 and 2 show the static pressure developed in small grain. The static pressure in bins of ear corn is much less than in the small grains, and seldom exceeds a static pressure ½-inch to ¾-inch. An air-flow of 30 CFM/Bu. develops a static pressure of ⅝-inch in 12 feet of ear corn.

Weeds, hulls, chaff or dirt in grain greatly increase the resistance to air flow. If cleaning equipment is available on the farm, foreign material should be removed from the grain before it is put into the drying bin.

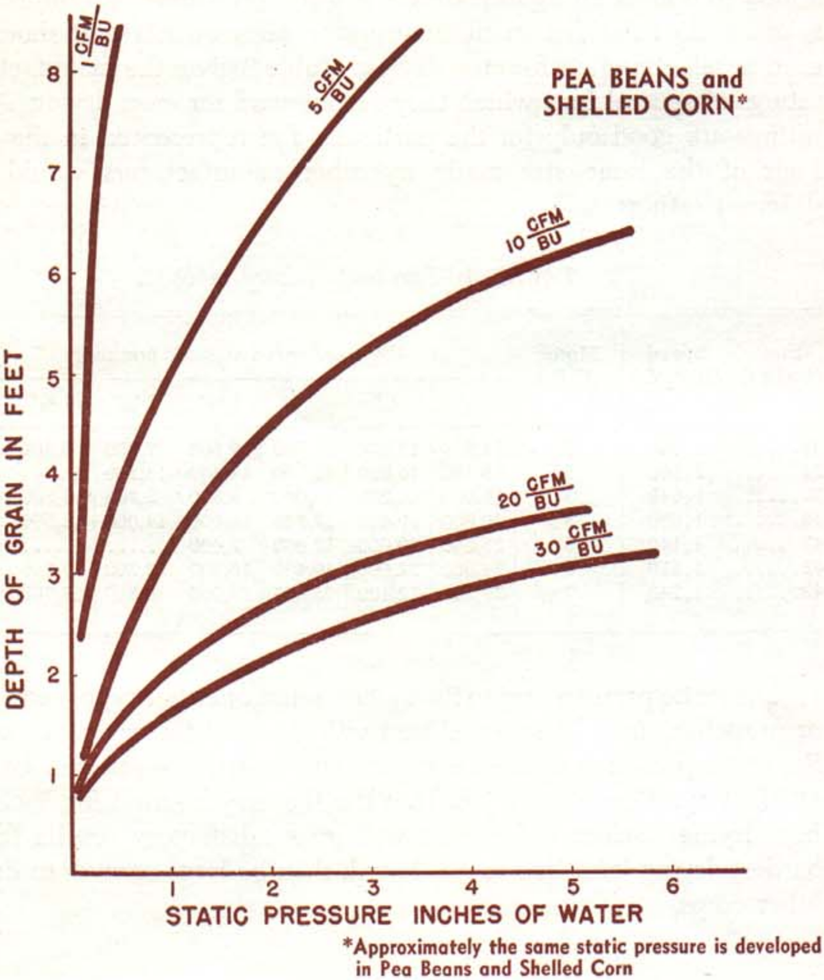


Fig. 2. Relationship of the static pressure to the depth-of-bin for different air-flows through pea beans or shelled corn. (Compare with Fig. 1.)

SELECTION OF EQUIPMENT

The rate of air movement through the grain, the depth of grain, and the size of the storage—these are the three factors which determine the size of the fan and power unit needed for removing the moisture from the grain.

Either a centrifugal- or a propeller-type fan may be used to force air through grain. However, all fans do not have the same ability to deliver air. Fans are rated by the manufacturer according to their ability to deliver air against different static pressure. This information is available from fan manufacturers or sales outlets and should be used in selecting fans for crop drying. Table 3 gives the manufacturers' ratings of several fans which they recommend for crop drying. These ratings are good only for the particular fan represented in the table. Fans of the same size made by other manufacturers would have different ratings.

TABLE 3—Fan performance table

Size (Inches)	Speed (R.P.M.)	Motor (H.P.)	CFM delivered at static pressures of						
			½"	¾"	1"	1 ¼"	1 ½"	1 ¾"	2"
32......	2,040	3	14,500	13,000	11,500	9,800	7,800	5,300	2,500
32......	2,360	5	18,100	16,900	15,700	14,400	13,100	11,700	10,300
36......	1,640	3	16,000	14,200	12,000	8,800	5,200	1,800	.....
36......	1,980	5	20,800	19,400	17,700	16,000	14,000	11,500	8,400
42......	1,140	5	25,000	20,000	12,800	2,000	......	......	.....
42......	1,510	5	24,000	22,000	19,400	16,400	12,200	7,600	3,600
42......	1,740	7 ½	29,500	27,400	25,200	23,000	20,500	17,500	14,000

For static pressures up to 2½ inches, a fan of either type (centrifugal or propeller) may be selected that will give satisfactory performance. For static pressures above 2½ inches, the centrifugal fan will be more satisfactory. Consider all jobs that the fan may be used for, including hay drying. Select a fan that will give satisfactory results for the hardest drying job it has to do. It will then be large enough to dry the other crops.

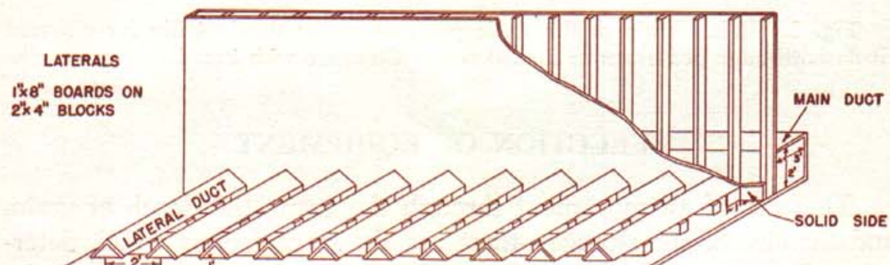


Fig. 3. Adapting a rectangular storage bin for forced-air grain drying. The main air duct, installed outside of the bin, feeds a series of lateral ducts placed on the bin floor. The main duct is usually a permanent installation; the lateral ducts can be removed. The system dries the grain from the bottom up.

POWER REQUIREMENTS

The horsepower required to operate a fan increases rapidly as the quantity of air delivered by the fan increases, and as the static pressure against which the fan delivers air increases. Either an electric motor or a gasoline engine can be used to drive the fan. The electric motor has proven most satisfactory as a power unit, since it can operate continually for long periods without attention. A 5-horsepower or 7½-horsepower motor connected to an appropriate fan will deliver air up to about 2½-inches of static pressure. Where the static pressure is above 2½-inches, power requirements will probably be 10 horsepower or more.

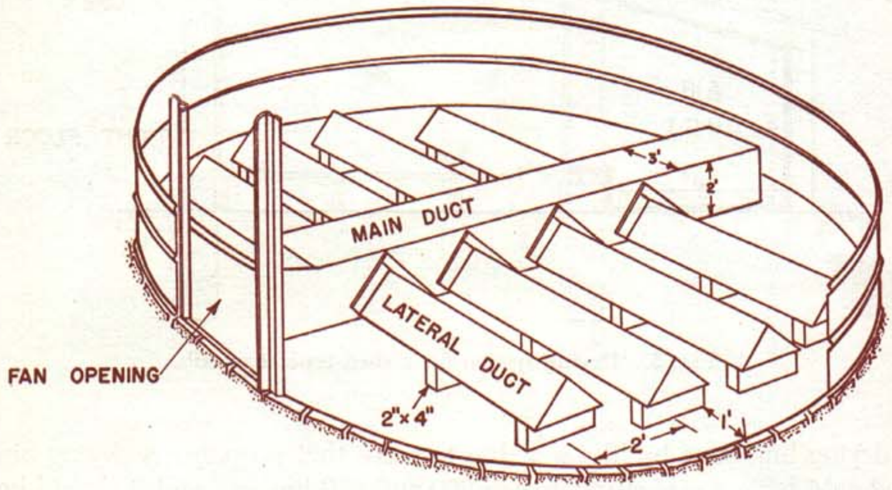


Fig. 4. Adapting a round crib for forced-air grain drying. The main air duct is inside the bin, resting directly on the floor. The entire duct system can be made removable.

BINS FOR STORAGE

Many of the storage bins used for grain and corn can be adapted for grain drying, as is shown by Figs. 3, 4, 5 and 6. Other bins can not be adapted for grain drying because of location, or because the grain is stored to a depth too great for drying with forced air.

Where it is not practical to install a drying system in existing bins, it may be practical to remodel a portion of the storage area into a

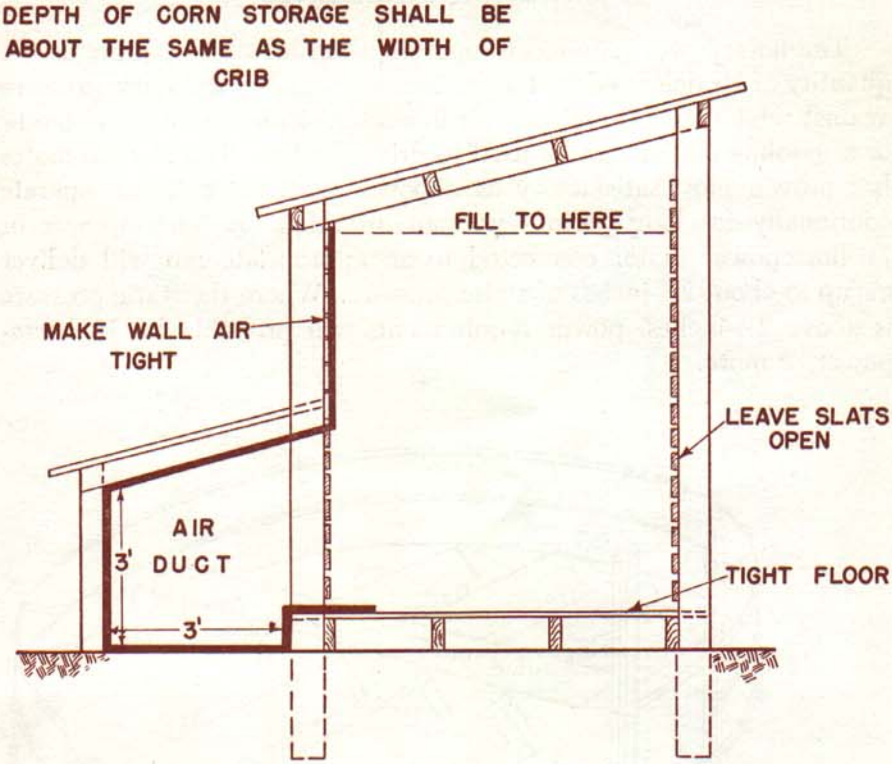


Fig. 5. Drying system for a shed-type corn crib.

drying bin, or to build a new bin to serve that purpose. A drying bin should have a capacity between 300 and 600 bushels, and it should be so constructed that grain can be moved in and out mechanically.

Wheat harvested when the moisture-content is above 14 percent can be placed in the drying bin. When the wheat is dried, it is moved to permanent storage bins; more damp wheat is then placed in the drying bin. Wheat harvested from the field at 14 percent moisture or lower can be put directly into the permanent storage bins.

The same method of handling is used for other grains. When the grain is above the moisture-content for safe storage, it is put into the drying bin, and grain harvested at a moisture-content safe for storage goes directly into the permanent storage bin.

New grain storages should be built to allow the most effective use of grain-drying equipment, and to permit mechanical handling of grain both into and out of the drying and the storage bins. Much of

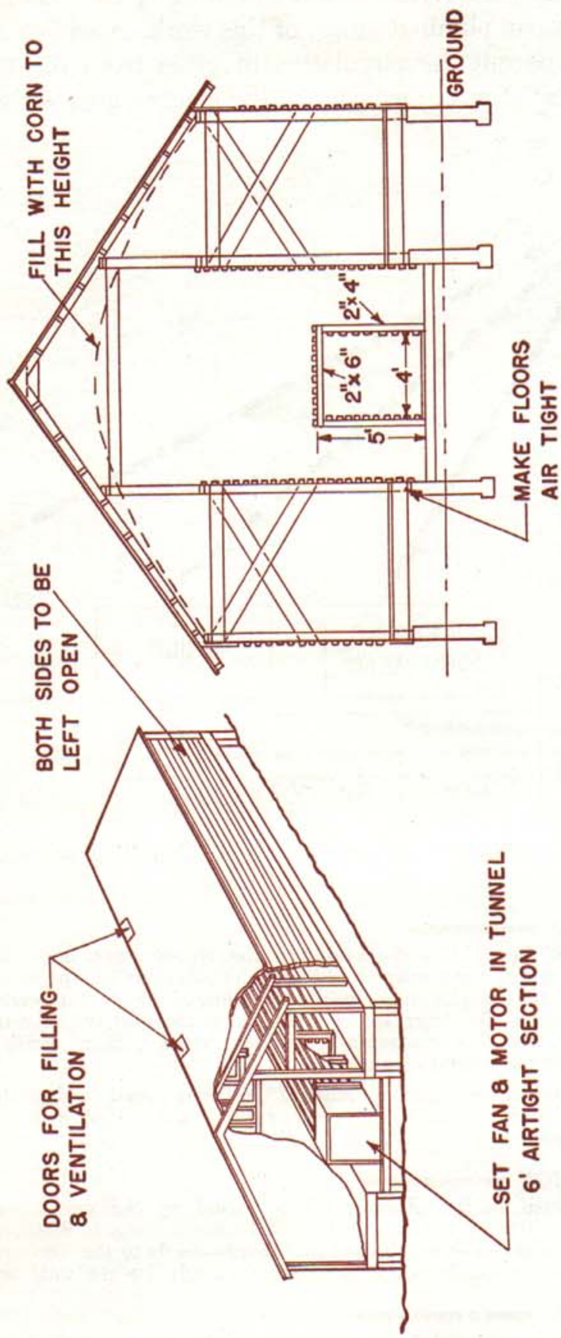


Fig. 6. Adapting a conventional corn crib for forced-air drying.

the work in grain production comes in handling the grain in storage. Proper planning can eliminate most of this work. A well-planned grain storage should permit the circulation of grain from the truck into a bin for permanent storage and back to the loading area without manual handling.

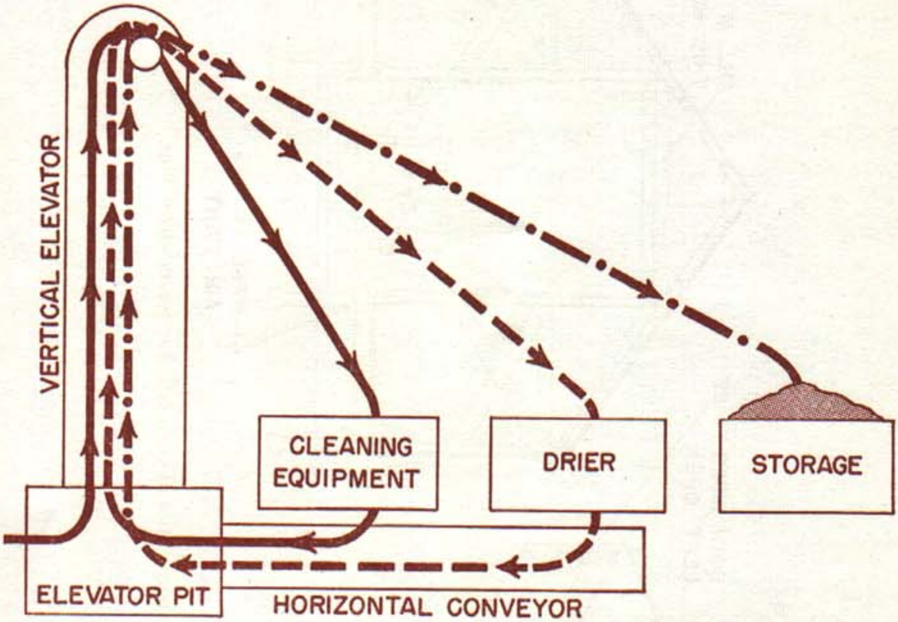


Fig. 7. Schematic drawing of a grain handling system.

FIRST OPERATION ▬▬▬▬

(1) Grain from the field is dumped into the *elevator pit*, and (2) moved by *vertical elevator* to top of the storage building. (3) Elevator dumps to chute; gravity feed moves grain into the *cleaning equipment*, situated above the main floor level. (4) Grain is cleaned. (5) After being cleaned, grain gravity-feeds to a portable *horizontal conveyor*, and (6) horizontal conveyor carries cleaned grain back to the elevator pit, ready for the second operation.

(NOTE—In practical operation, a "holding bin" is required to slow the movement, usually preceding the cleaning, so that clean grain is not mixed with the field grain still in the elevator pit.)

SECOND OPERATION ▬ ▬ ▬ ▬

(1) Cleaned grain in the elevator pit is raised by the vertical elevator, and (2) dumped to the *drier* by gravity feed. (3) Cleaned grain is dried by forced air. (4) After drying, the grain—now cleaned and dried—feeds to the horizontal conveyor, and (5) is again carried back to the elevator pit, ready for the final operation.

THIRD OPERATION ▬ • ▬ • ▬

(1) Grain, now cleaned and dried, is again carried up to top of the storage building by the vertical elevator. (2) Elevator dumps to the chute feeding the *storage bin*. (3) Grain remains in the storage bin for removal, as desired, for feeding or sale.

Three main operations in circulating grain through a grain storage are illustrated in Fig. 7. A large grain storage of several thousand bushels should include all three in the grain storage and handling system. With some grain storages only the "First and Second Operations" would be used. With small storages of 600 to 1000 bushels only the "Third Operation" may be needed, and the drying equipment installed in the storage bin. The same vertical elevator and portable elevator or conveyor can be used in all three operations. Home-made or commercial elevators can be tailored to fit a particular storage arrangement; either will move grain rapidly and inexpensively.

Some existing double corn cribs can be adapted to forced-air drying, at a minimum outlay, by adding gutters for the corn removal (construction detail is shown in Fig. 8). But storages built for forced-air drying of ear corn should be wider, allowing for an air duct and the gutters in the original plans (Fig. 9). Either a drag chain or portable elevator can be used to remove the ear corn. An elevator is used to put the corn into the crib through openings in the roof.

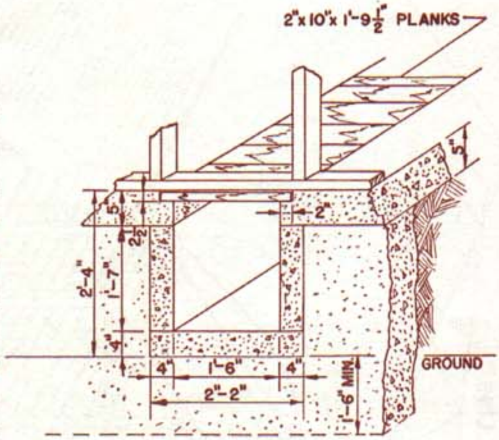
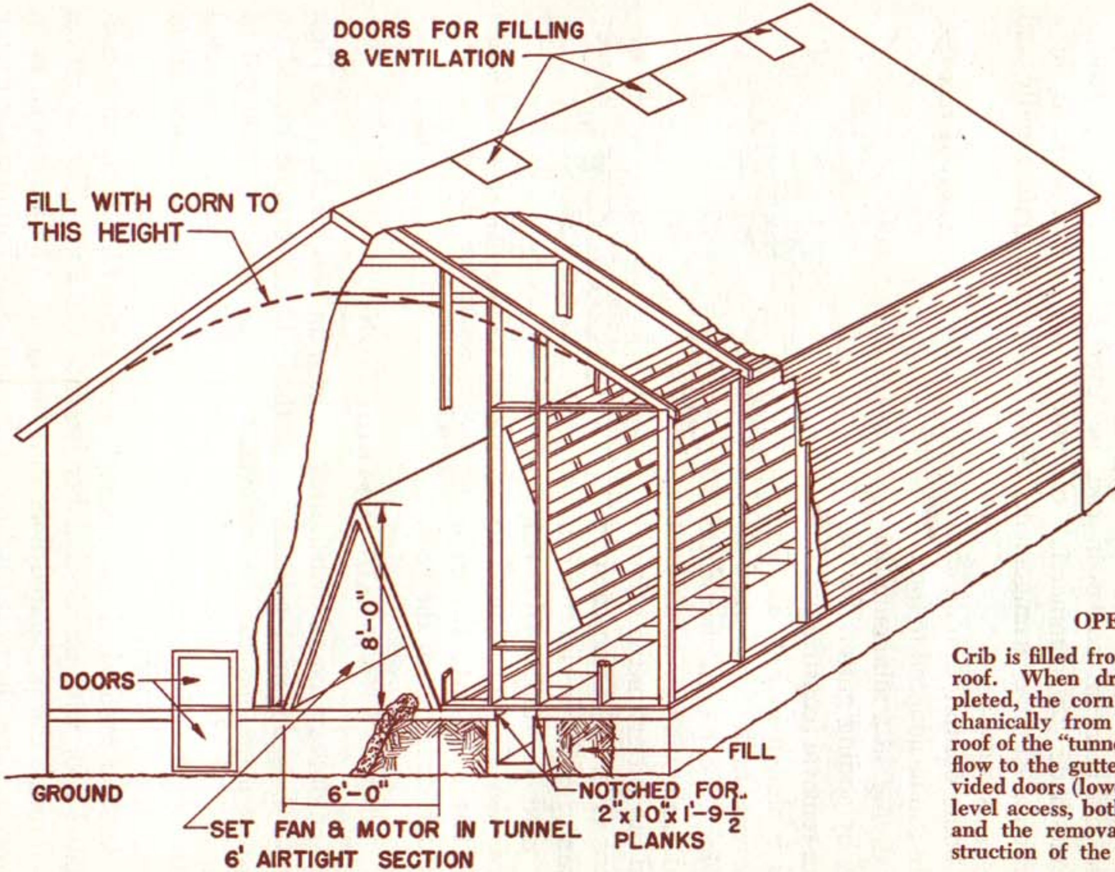


Fig. 8. Construction of gutters with removable covers for the drying crib shown in Fig. 9.

AIR DISTRIBUTION

The duct system of distributing air in grain bins, as shown in Figs. 3 and 4, is the most satisfactory method. Ducts can be placed on existing floors and can be removed when the grain is taken out of the bin. The main duct should be airtight and should be constructed with tongue-and-groove siding. The lateral duct can be made out of rough-sawed lumber.

Another method of distributing air in a grain bin is to use a perforated floor with an air-chamber beneath the floor. The air moves up through the perforated floor into the grain. The perforated floor, however, generally presents more problems in installation of the drying system and in removal of the grain from the bin.



OPERATION

Crib is filled from above, through the roof. When drying has been completed, the corn can be removed mechanically from below — the peaked roof of the "tunnel" providing a gravity flow to the gutters on either side. Divided doors (lower left) permit ground-level access, both to the storage areas and the removal gutters. (For construction of the gutters, see Fig. 8.)

Fig. 9. Crib designed specifically for forced-air drying of ear corn.

USING HAY-DRYING FAN AND MOTOR FOR GRAIN-DRYING SYSTEMS

Much more water has to be evaporated from a mow of hay than from a bin of grain, when using forced-air for drying. Consequently, fans used for hay drying deliver large volumes of air. The static pressure developed in a hay mow is approximately one inch. Fans for hay drying are selected on the basis of delivering a large quantity of air against one inch of static pressure.

When the same fans are used to dry *grain*, a different set of conditions exists. A smaller amount of air is needed for drying purposes, but the static pressure against which the fan delivers air is higher. As the static pressure increases, the volume of air delivered by the fan decreases, as shown in Table 3.

Limiting the depth of grain in storage bins to 6 feet permits the use of hay-drying equipment for grain drying. The volume of air delivered by a hay-drying fan is adequate to dry grain.

FOR DRYING EAR CORN

The use of forced natural air for moisture removal from ear corn is more of a *conditioning process* than a drying process. Air temperatures have to be above 50° F. before appreciable moisture removal is accomplished; however, blowing air through the ear corn prevents heating and mold growth.

During late October and November each year, there are a few days in Michigan during which temperatures rise to the high 60's. Enough moisture can be removed during these periods by operating the fan to allow safe storage through the winter. Additional moisture can be removed from the corn in the spring. The fan should be operated for drying during periods when the temperature is above 50° F., and when it is not raining or extremely humid.

Fan operation should continue from the time of cribbing in the fall until a safe moisture-content for storage is reached, or until the corn is used out in the spring. If temperatures are below 50° F. at the time of cribbing, the fan should be operated several hours during the day to prevent heating of the corn. The fan should be operated a few hours each week during fall to prevent heating, even though outside temperatures remain below 50.

FOR DRYING PEA BEANS

Pea beans can be dried successfully by using 5 CFM to 30 CFM of air per bushel. Pea beans should be harvested in late September or early October to get the most benefit from the warm fall days. Although pea beans may be stored 6 to 7 feet deep for forced-air drying, faster drying will result if the beans are stored approximately 4 feet deep. Because the static pressure is less where the pea beans are stored 4 feet deep, the fan will deliver more cubic feet of air per minute and faster drying of the beans results. During the fall it is advisable to take as much advantage of the good drying days as possible.

The fan should be operated during the day when the air temperature is 50° F. or above—unless it is raining or the relative humidity is extremely high—until the moisture in the pea beans has been reduced to 18 percent. When temperatures are below 50° F., or the relative humidity is extremely high or it is raining, the fan should be operated 4 to 6 hours a day to keep the beans from heating.

Only a few farm operators have used forced air for pea-bean drying up to the present time. Farm operators have found that they could remove 3 to 5 percent of moisture from pea beans harvested in early October. Pea beans have shown no damage because of cracking or discoloration from drying with forced natural air.

The use of heated air for drying pea beans on the farm *is not recommended.* A high percentage of cracking will result if the pea beans are dried rapidly using heated air.

HEATED-AIR UNITS FOR CROP DRYING

The use of heated air for crop drying speeds up the drying process; makes it possible to dry grain, regardless of the weather conditions; and gives the operator control of the rate of drying. For the seed-grain grower where rate of drying is important, or for the large grower where large quantities of grain need to be dried, the investment for heated air-drying equipment is justified. However, on the majority of Michigan farms the use of forced natural air will be more satisfactory and more economical.

Drying with heated air works best where the grain is dried in batches of 100 to 300 bushels. A drying bin located away from the main buildings is desirable for use with a heated air-drier. This bin should be constructed so that grain can be put into and removed from it mechanically. When the grain is dried to the desired moisture-content, it is transferred from the drying bin to a permanent storage bin.

Proper control of heated-air equipment for drying crops must be exercised. Germination of seed grain and milling characteristics of cereal grain are affected by high drying temperature. In general, milling characteristics are affected above 130° F., and germination is affected above 110° F. Excessive cracking of pea beans can result from the use of heated air for drying.

VENTILATING GRAIN STORAGES

Grain stored at a moisture-content of 15 to 16 percent can be conditioned by using a low rate of air-flow of 1 CFM per bushel. The air forced through the grain cools the grain, thus preventing mold growth. Moisture removal results from both natural drying and drying from the low rate of air-flow. The fan is operated through the day unless it is raining or the humidity is extremely high. During periods of high humidity or rainy weather, the fan is operated 3 to 4 hours a day to keep the grain from heating.

Intermittent fan operation is required for a period of several weeks. The moisture content of grain conditioned by this method should not exceed 16 percent.

EXAMPLES

Two examples have been worked out below to show how the size of a fan-and-power unit is determined:

Example 1

Wheat is to be dried in a *rectangular bin*
Bin size—*10 ft. x 14 ft.*
Depth of grain stored—*5 ft.*

10 ft. x 14 ft. = 140 sq. ft. 140 x 5 ft. = *700 cu. ft.* (volume of bin)

$$\frac{700 \text{ cu. ft.}}{1.25 \text{ cu. ft./bu.}} = 560 \text{ bu.}$$ (amount of grain stored in bin)

560 bu. x 5 CFM/Bu. = *2800 cu. ft. of air per min.*

(Rate at which air should be forced through the grain.)

Looking at Fig. 1 we see that for a grain-depth of 5 feet and an air-flow of 5 CFM/Bu., a static pressure of approximately 2-inches is developed. A fan is needed that will deliver 2800 cubic feet of air per minute against a static pressure of 2-inches.

Referring to the "Fan Performance Table" (Table 3)—the 32-inch fan listed will deliver 2500 CFM against 2-inches of static pressure.

If the fan were going to be used *for grain drying only*, the 32-inch fan listed in the table (which delivers 2500 CFM at 2-inches of static pressure) would be satisfactory. If the fan were also to be used for hay drying, a larger fan—such as the 42-inch fan driven at 1,510 RPM by a 5-horsepower motor—would be better. That fan would deliver more air against one-inch static pressure for drying hay, and 3600 CFM against 2-inches of static pressure for drying grain.

Example 2

Pea beans are to be dried in a *round crib* (see page 20)
Crib diameter—*12 ft.* Depth of beans stored—*6 ft.*
([12 x 12] x 3.14 ÷ 4 = volume)
144 x 3.14 = *452*

$$\frac{452}{4} = 113 \text{ sq. ft.} \quad 113 \times 6 = 678 \text{ cu. ft. (volume of crib)}$$

$$\frac{678}{1.25} = 542.4 \text{ bu. (amount of pea beans stored in bin)}$$

542.4 x 5 CFM/Bu. = *2712.0 cu. ft. of air per minute*
(Rate at which air should be forced through the grain.)

Looking at Fig. 2, we see that pea beans stored 6 feet deep and using an air-flow of 5 CFM/Bu. results in a static pressure of 1¾-inches.

Referring again to the "Fan Performance Table" (Table 3)—the 32-inch fan listed delivers 5300 CFM at 1¾-inches of static pressure. That rate is satisfactory for drying this bin of pea beans.

However, if the fan were to be used for drying hay or other grains, one should then be selected which would deliver the largest amount of air required by any of the crops dried.

FOR ADDITIONAL INFORMATION

These reference bulletins are also available from the County Cooperative Extension Service Office, or from the Department of Agricultural Engineering, Michigan State College:

Barn Hay Driers in Michigan, M.S.C. Circular Bulletin 219.

Storage of Small Grains and Shelled Corn on the Farm, U.S.D.A. Farmers Bulletin 2009.

"Inclined-Column Grain Drier," U.S.D.A. Leaflet No. 314.

Michigan Vertical Cup-Type Elevator for Small Grains and Shelled Corn, M.S.C. Circular Bulletin 193.

"Michigan Conveyor Elevator," M.S.C. Article 26-6, 1943. (Reprint from *The Quarterly Bulletin* of the Michigan Agricultural Experiment Station.)

DEFINITION OF TERMS

(As used in the text)

Static pressure—Resistance to flow of air being forced through grain. The static pressure is measured in *inches of water*. It is affected by the depth of grain in the bin and volume of air-flow, and is used in fan selection.

CFM—Refers to quantity of air-flow in cubic feet per minute. In this publication the air-flow per minute through a bushel of grain is expressed as $\frac{CFM}{Bu.}$.

Relative humidity—A measure of the amount of moisture in the air at a given temperature.

To figure volume of bin—Multiply the length in feet, by the width in feet, by the depth in feet to obtain the volume in cubic feet.

To figure volume of round crib—Multiply diameter squared by *3.14*, and divide the result by *4*. Then multiply by the height. (All dimensions should be in feet.)

To convert cubic feet to bushels—Divide the number of cubic feet by *1.25* to get the number of bushels of grain, or baskets of ear corn. (Two baskets of ear corn equal one bushel of shelled corn.)

Natural air—Available air influenced only by local weather conditions, and used without benefit of fan or addition of heat.

Forced natural air or *forced air*—Natural air forced through grain by a fan.

Heated air or *heated forced air*—Air to which heat is added by a heater, prior to being forced through the grain by a fan.

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