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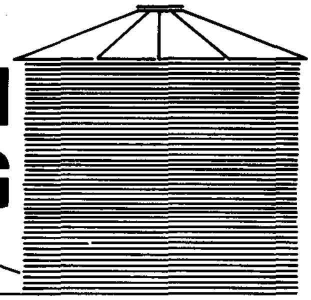

SAVING ENERGY IN CORN DRYING

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Rising energy costs and concern about the availability of propane and natural gas, the fuels commonly used for grain drying, are leading many corn producers to consider ways of reducing the energy required in their high-speed drying operations. A high-speed dryer is any dryer which uses heated air to rapidly reduce the moisture content to the desired level. As shown in figure 1 these include: continuous flow; batch, both automatic and manual; batch-in-bin; stirring bins; and continuous-flow, bottom-unloading bins. With any high-speed dryer, most of the energy to evaporate water comes from the fuel that is burned.

The following alternatives should be considered when looking for ways to reduce energy in drying shelled corn.

- Reduce overdrying.
- Use dryeration.
- Use in-storage cooling.
- Use a combination of high-speed drying followed by natural-air drying.
- Use a natural-air drying system when it is feasible.

The first alternative should be at the top of everyone's list when considering ways to reduce energy for corn drying. One or more of the other alternatives also may be applicable in many drying systems. The purpose of this publication is to help sort out the alternatives that may apply in each situation. Five other publications in this series provide more detailed information on each alternative. They include "Dryeration and In-Storage Cooling for Corn Drying" (M-162); "Combination High-Speed, Natural-Air Corn Drying" (M-163); "Natural-Air Corn Drying" (M-164); "Management of Stored Grain with Aeration" (M-165); and "Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems" (M-166).

There are two other reasons that make it worthwhile to explore all of these alternatives. In addition to saving energy, each of these alternatives has the potential for *increasing drying capacity* and *improving grain quality.* Comparative estimates of energy requirements and dryer capacities are summarized in table 1.

REDUCE OVERDRYING

Everyone needs to take a careful look at this alternative first (figure 2). Overdrying is removing more moisture than necessary for safe storage over the period of time corn is stored. Table 2 shows the moisture contents at which corn can be stored in Minnesota in *well-managed, aerated storages.* When corn is dried to lower moisture contents, extra energy is required at levels shown in table 1. Many farmers are still drying corn to 12 percent because they feel it is necessary for safe storage. This may be based on past experience where higher moisture corn spoiled because it was not stored in a suitably aerated and properly managed facility. A properly equipped and well-managed storage facility allows higher moisture corn to be stored successfully, thus realizing the benefits of the energy savings indicated in table 1. The publications "Management of Stored Grain with Aeration" (M-165) and "Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems" (M-166) provide information on aeration management and design.

Table 3 shows the penalties for drying shelled corn to lower moisture contents. If corn is marketed, an economic loss will be incurred if the corn is sold at moisture contents below 15.5 percent. If the corn is fed, there is no extra shrinkage cost; but overdrying still requires extra fuel, and overdried corn may not be as palatable to livestock as corn at higher moisture contents. Corn which is to be fed during the winter months can often be safely held at moisture contents above 15.5 percent if enough airflow is provided in the storage to keep it cold. The key to saving corn drying fuel is to remove only as much moisture as necessary for safe storage.

As indicated in table 1, the increase in dryer capacity can be significant when overdrying is reduced. Less drying can also reduce stress cracking of the kernels, decreasing their susceptibility to breakage in subsequent handling operations. Also, reducing overdrying will normally provide an increase in test weight. These improvements in corn quality may result in less dockage when the corn is marketed.

Table 1. Comparative estimates of energy requirements and dryer capacities when drying 25.5 percent moisture corn.[1]

Alternative		Gallons of propane/100 bu [2]	Kilowatt hours of electrical energy/100 bu	Change in high-speed dryer capacity relative to drying from 25.5 to 15.5% with in-dryer cooling
Reduce overdrying (High-speed drying with in-dryer cooling)	to 15.5%	20	10	------
	to 14%	23.5	11	12% less
	to 13%	26	12	18% less
	to 12%	28.5	13	24% less
	to 11%	31.5	14	30% less
Dryeration	to 15.5%	14.5	7	60% more
In-storage cooling	to 15.5%	17.5	8	35% more
Combination drying	to 15.5%	8	70	300% more
Natural-air drying[3]	to 15.5%	----	140	------

[1]These are estimates intended to help compare alternatives. There is wide variation in energy use from one system to another. The high-speed drying comparisons are representative of typical automatic batch or continuous-flow dryers removing 10 points of moisture (25.5 to 15.5%).

[2]Comparisons are made on the basis of 100 bu of corn at 15.5 percent moisture content. For example, overdrying to 11 percent will yield only 94.9 bu at 11 percent instead of the 100 bu. If comparisons are made on actual 56-lb. bushels at the reduced moisture contents, the fuel and electrical requirements would be higher.

[3]Natural-air drying may not be a feasible alternative as a complete drying system. See the publication "Natural-Air Corn Drying" (M-164) for more information.

Table 2. Moisture contents at which shelled corn can be stored in Minnesota in properly-aerated, well-managed storages [1]

Storage period	Corn moisture content
12 months	14%
Harvest through June	15.5%
Harvest through March	16-17%

[1]Assumes corn that normally meets No. 2 corn standards.

Table 3. Overdrying penalties when marketing shelled corn below 15½%[1]

Moisture content	Extra energy requirements per 100 bushels[2]		Loss in bushels sold due to additional shrinkage per 100 bushels[2]
	Propane Gallons	Electricity Kilowatt hours	
14	3.5	1	1.7
13	6.0	2	2.9
12	8.5	3	4.0
11	11.5	4	5.1

[1]Based on high-speed drying with in-dryer cooling.

[2]100 bushels of #2 corn, 56 pounds at 15½% M.C.

Additional Equipment

It is necessary for storage bins to be equipped with adequate aeration facilities. Since this is highly recommended for *all* storages, no extra equipment is required when you reduce overdrying.

DRYERATION

With dryeration, corn is not cooled in the dryer but delivered hot to a separate cooling bin (figure 3). The hot corn is allowed to "steep" or "temper" at least 4 to 6 hours, then cooled slowly. After cooling has been completed, the corn is transferred to storage.

Dryeration provides the following benefits:

- Tempering followed by slow cooling increases the efficiency of moisture removal during the cooling process.
- It reduces the stress in the kernels developed during the final stages of high-speed drying and rapid cooling. This leads to improved corn quality.
- Significant increases in dryer capacity are achieved because of the increased efficiency of moisture removal, elimination of cooling in the dryer, and the possible increase in drying air temperature in the high-speed dryer.

During the tempering or steeping process, condensation can build up around the walls of the cooling bin. As a result, corn that has been tempered in a cooling bin should always be transferred out after cooling and never left for storage in the cooling bin. At the end of the drying season the dryeration bin can be used for storage, possibly with in-storage cooling. This is discussed in the next section.

Additional Equipment

At least one and preferably two cooling bins are required along with additional materials handling equipment to accommodate the extra corn transfer. Generally, dryeration is more adaptable to larger operations—50,000 bu per year and larger. However, it is a flexible system and may, in many instances, fit the needs of smaller operations.

IN-STORAGE COOLING

Instead of cooling the corn in the high-speed dryer, it is discharged hot to storage and cooled there (figure 4). Experience has shown that as long as the cooling fan delivers adequate air and is turned on immediately, corn can be cooled and stored in the same bin. Because cooling is delayed somewhat, the heat contained in the corn is used more efficiently for the removal of water. Probably the biggest advantage of in-storage cooling is the significant increase in capacity that occurs when the cooling cycle in a batch dryer is eliminated, or when the cooling section in a continuous-flow dryer is converted to full heat.

In-storage cooling provides some of the advantages of dryeration without the extra transfer operation. However, when corn is to be stored in the bin in which it is cooled, a tempering period is *not recommended.* The resulting condensation can cause problems around the bin walls.

Additional Equipment

In general, an increase in aeration airflow is required, depending on the capacity of the high-speed dryer.

COMBINATION HIGH-SPEED, NATURAL-AIR DRYING

Combination drying is high-speed drying followed by in-storage cooling and natural-air drying (figure 5). The purpose of the high-speed dryer is to reduce the moisture content of the corn to a level where drying can be safely completed in storage with natural (unheated) air. Natural-air drying is accomplished by moving unheated air through the stored corn. This may take from 4 to 8 weeks or even longer to complete. In many situations, drying may be stopped in the late fall and completed the following spring. Propane or natural gas requirements are substantially reduced compared to normal high-speed drying with in-dryer cooling since only the water above 20 to 22 percent moisture content is removed in the high-speed dryer. The savings depend on the moisture content at which corn is discharged from the high-speed dryer. As shown in table 1, electrical energy requirements are increased because of the fan operation in the natural-air drying stage. However, the net result is a reduction in total energy requirements.

Additional Equipment

The bins used for in-storage, natural-air drying must be equipped with drying floors and fans capable of delivering an airflow of at least one cubic foot per minute per bushel (cfm/bu) of corn in storage. This is ten times the amount of air required for normal storage aeration.

Who should consider combination drying? Potentially, it can be included in a wide range of situations. Because of the in-storage drying facility, it is probably more feasible for operations less than 50,000 to 60,000 bu of corn per year. The substantial increase in capacity of the high-speed dryer occurring when corn is discharged at higher moisture contents makes this an attractive alternative for those who need to expand their drying capacity. The characteristics of the combination system make it particularly suitable to producers who feed their corn.

NATURAL-AIR DRYING

Natural-air drying is an in-storage system which relies mainly on unheated air for all of the drying (figure 6). This may take 4 to 8 weeks or longer, depending on the natural air conditions and the initial moisture content of the corn. The key to natural-air drying is to provide enough air to complete drying within the allowable storage time as determined by the deterioration of the corn. The quantity of air required depends on the moisture content of the corn being delivered to the bin. If the bins are filled rapidly, it is difficult to deliver enough air to satisfactorily dry corn higher than 22 to 23 percent moisture in a natural-air system. Wetter corn can be dried in storage if filling is delayed. However, for corn above 25 percent moisture content, the necessary delay and/or larger fan requirements often become impractical. Usually, it is more practical to use high-speed drying to reduce wetter corn to 21 to 22 percent, a moisture content more easily dried with natural air (combination drying).

In some cases, enough supplemental heat is added to the natural air to increase its temperature an additional 2° to 4° F. When this is done, it is commonly referred to as "low-temperature" drying. The additional 2° to 4° F supplements the drying ability of the natural air. The desirability of adding supplemental heat to a natural-air, in-storage drying system is discussed in more detail in "Natural-Air Corn Drying" (M-164).

MORE THAN ONE SOLUTION?

Producers may decide to incorporate several of these alternative methods in their systems. For example, reducing overdrying can be done in conjunction with in-storage cooling. Or a bin equipped with a drying floor and fan can be added to complement existing storage. This bin can be used for dryeration while filling the existing storage. After the existing storage has been filled, the dryeration bin can be used for natural-air drying as part of a combination system, or as a complete natural-air system if harvest moisture contents have dropped below 21 to 22 percent. It is likely that a mixture of these alternatives will best suit most situations.

Economics

Economic comparisons of the alternatives can be complex; since each situation is different, it is very difficult to make general statements about costs and returns for alternative methods.

Energy costs will be reduced by using any of these alternatives. However, energy is only one part of the total cost of the drying and storage system. For instance, investment or fixed costs are always significant. We recommend that your economic analysis include:

- Costs
  a. Investment costs associated with additions to, and changes in, materials handling equipment and storage bins (For storage bins, cost factors may include drying floors, fans, shallower bins for natural-air drying, and less storage space due to level-fill requirements and space lost for drying air plenums.)

b. Larger electrical service required in some cases to meet increased power demands

- Returns
  a. Energy cost savings
  b. Increased dryer capacity, which may allow more timely harvesting or eliminate the need to increase high-speed drying capacity
  c. Improved grain quality, which may result in less dockage
  d. Reduced reliance on propane fuel

Some of these factors will affect the economic analysis and some will not. Each situation needs to be analyzed separately.

This is one publication in a series that evaluates alternatives for saving energy, improving grain quality, and increasing capacity in corn drying. The series provides information on how to incorporate these alternatives in drying systems. The publications include:

M-161 Saving Energy in Corn Drying
M-162 Dryeration and In-Storage Cooling for Corn Drying
M-163 Combination High-Speed, Natural-Air Corn Drying
M-164 Natural-Air Corn Drying
M-165 Management of Stored Grain with Aeration
M-166 Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems

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Figure 1. Schematic diagrams for five types of high-speed dryers

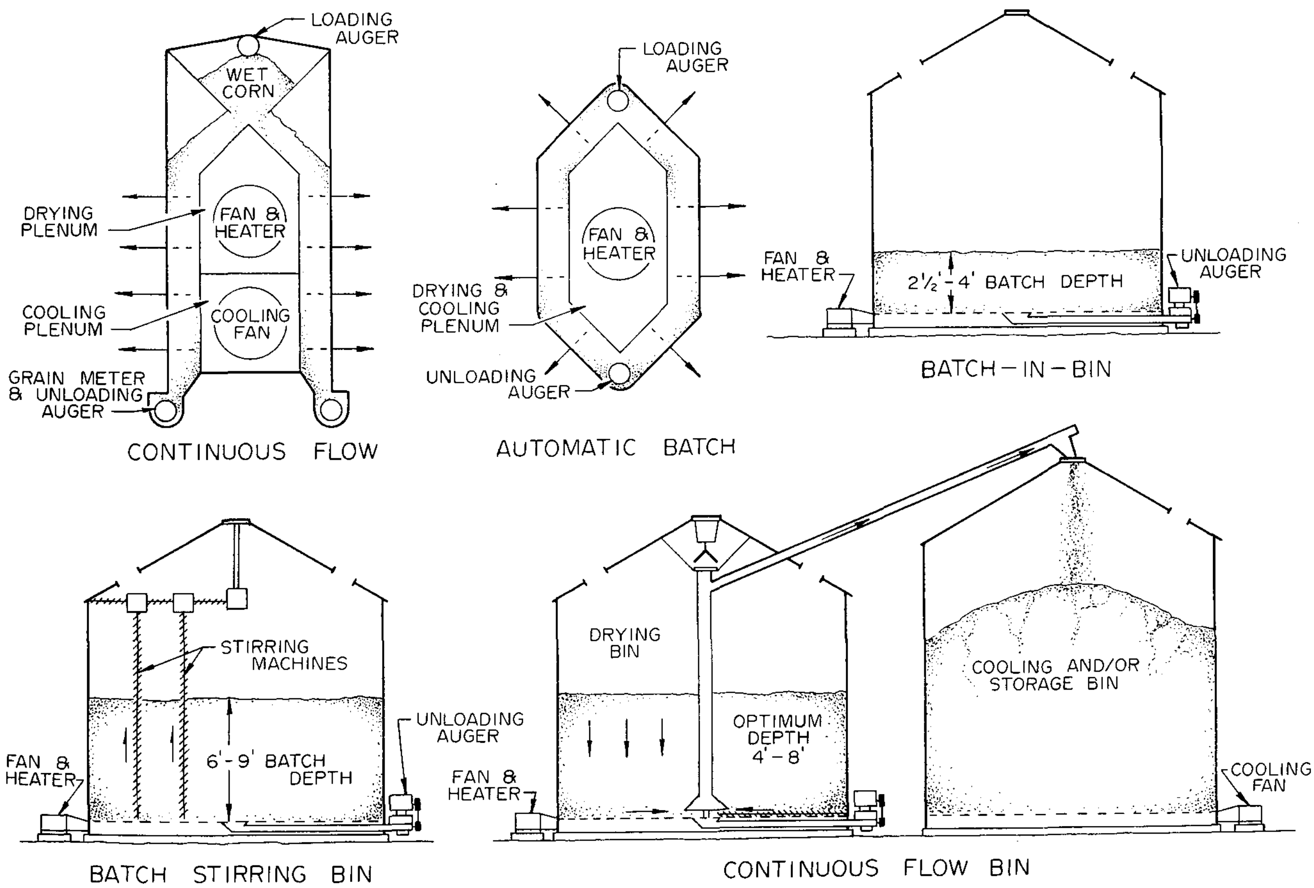


Figure 2. Energy used in overdrying

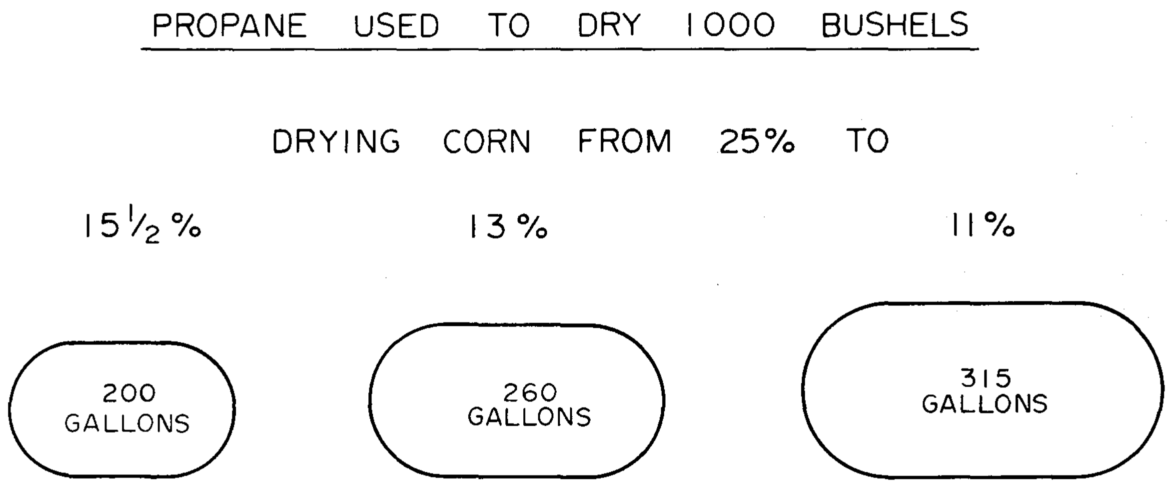


Figure 3. Schematic of dryeration system

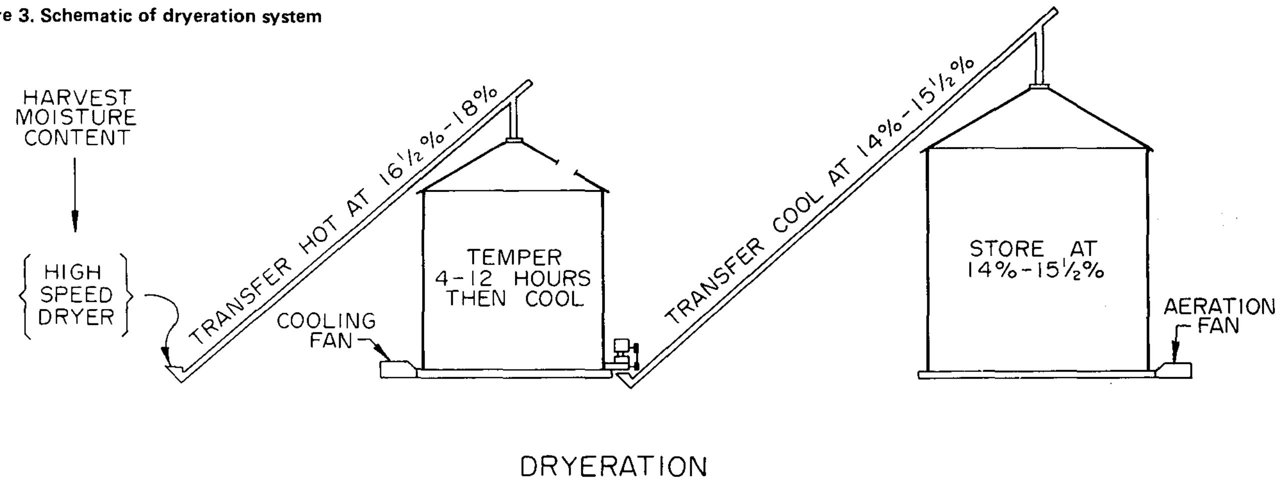


Figure 4. Schematic of in-storage cooling system

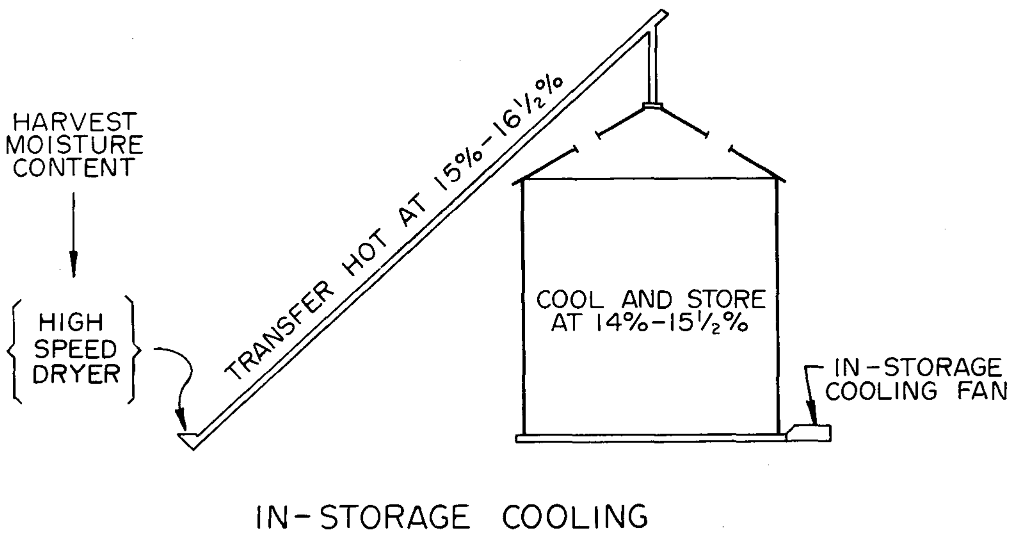


Figure 5. Schematic of combination high-speed, natural-air drying system

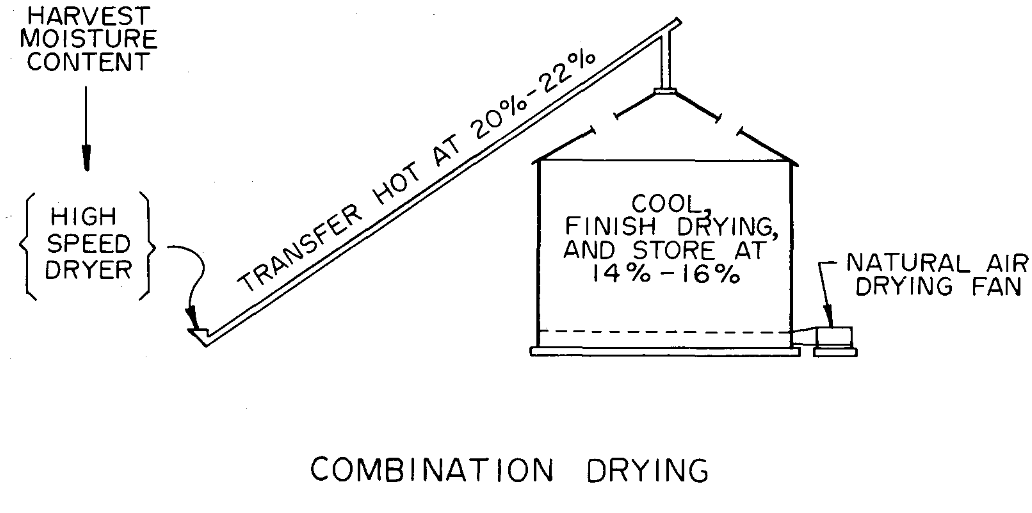
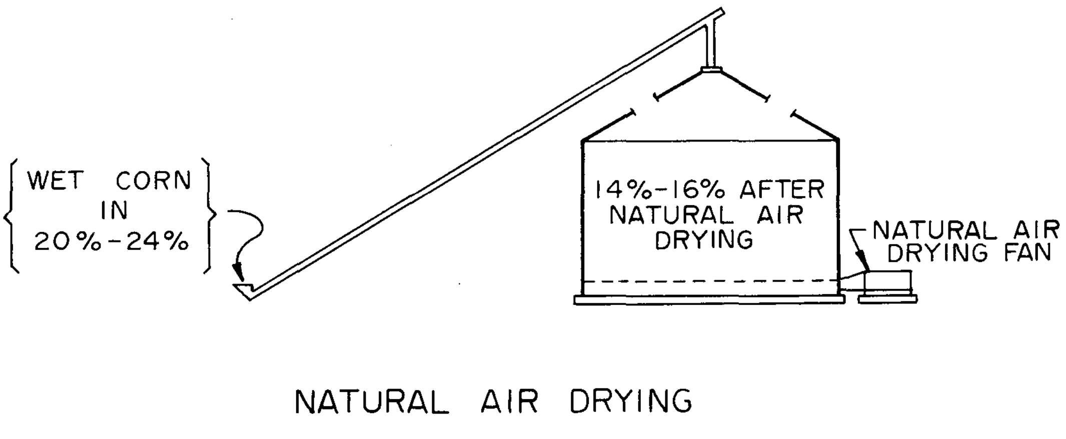


Figure 6. Schematic of natural-air drying system



WARNING: Flowing Grain Is Dangerous

Never enter a grain bin or other grain storage area while the grain is flowing. Flowing grain will exert forces against the body great enough to pull the average size person under the grain in only a few seconds leading to death by suffocation.

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