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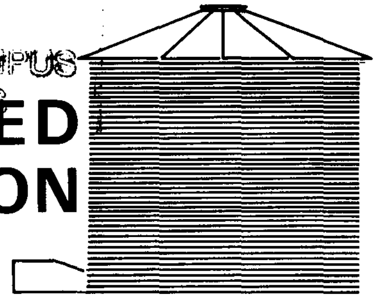

MANAGEMENT OF STORED GRAIN WITH AERATION

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WHY AERATE?

Aeration is the practice of moving air through stored grain to reduce the rate of grain deterioration and prevent storage losses. Spoilage in stored grain is caused by mold growth and insect activity, which is related to the moisture content and temperature of the stored grain. Aeration greatly improves the "storability" of grain by maintaining a cool, uniform temperature throughout the storage to reduce mold development and insect activity and to prevent moisture migration.

Temperature differences in a bin of stored grain cause moisture to migrate from warmer areas to colder areas. Figure 1 shows moisture migration in a bin when grain temperature differences are created due to colder weather. The warm air rising in the center of the bin cools when it reaches the cold grain near the surface. This results in moisture condensation near the surface and leads to rapid spoilage when the weather turns warmer. Crusting on the surface of stored grain is a common symptom of moisture migration. Moisture can also migrate to colder grain near the bin walls during cold winter weather. It is also possible to get moisture migration inward if the outside temperature is warmer than the grain. This is usually not as serious as the moisture migration upward and outward during cold winter weather.

Temperature differences can be caused by changes in outside temperature while the grain is being delivered to the bin. The temperature of corn delivered to storage from a high-temperature dryer will vary due to temperature changes throughout the day or with weather changes. Aeration is necessary to equalize and maintain uniform temperatures throughout the storage.

Effect of Temperature on Storability

The effect of temperature and moisture content on the allowable storage time of shelled corn is given in table 1.

The allowable storage times given in this table are based on deterioration of the grain associated with 0.5 percent dry matter loss. As shown, the deterioration rates depend on grain moisture content and grain temperature. Proper aeration maintains grain temperatures low enough to minimize grain deterioration. An illustration of the importance of proper aeration to the cash corn producer is to compare the "storability" of 15 percent corn at 50° F (16 months) to that of 15 percent corn at 70° F (5.2 months) and to 14 percent moisture corn at 70° F (11 months). These comparisons indicate the importance of maintaining uniformly low temperatures in all stored grain.

Table 1. Maximum storage time in months for shelled corn*

Corn temperature	Corn moisture content 13%	14%	15%	16%	17%	18%
40° F	150	61	29.0	15.0	9.4	6.1
50	84	34	16.0	8.9	5.3	3.4
60	47	19	9.2	5.0	3.0	1.9
70	26	11	5.2	2.8	1.7	1.1
80	15	6	2.9	1.6	0.9	0.9

*Based on 0.5% maximum dry matter loss—calculated on the basis of USDA research at Iowa State University

Table 2 shows the moisture content of various grains that can be stored in Minnesota for different lengths of time with good storage management.

Table 2. Storage moisture contents for aerated grain

	Shelled corn	Soybeans	Wheat and barley	Sunflowers
Short term*	15.5%	13%	14%	11%
One year	14	12	13	10
Long term	13	11	13	9

*Short term means until the following June.

These moisture contents may be too high if the grain is poorly managed in storage. On the other hand, grain can be stored at higher moisture contents with exceptionally good management. If you have been successfully storing corn at 13 percent, *do not* attempt to increase to 15.5 percent in one step. Increase the moisture content to 14 percent and gain experience in storage management; then gradually work up to the desired level.

Aeration changes the temperature of stored grain in response to seasonal temperature changes and maintains uniform temperatures throughout the storage. Aeration *is not* a grain drying system and must not be considered as such. Some changes in grain moisture content occur as a result of aeration. The heat removed during cooling results in some drying. Grain moisture content will be reduced about one-fourth percent for each 10° F reduction in temperature. Little moisture change results from the drying or rewetting capacity of the small amounts of air necessary for changing the temperature of the grain. However, significant changes in moisture content can occur if substantially more air is moved through the grain than is required for a temperature change. This can happen when high airflows are used for extended periods beyond that necessary for changing the grain temperature.

AIRFLOW AND EQUIPMENT

Since the purpose of aeration is temperature control, the quantity of air required depends on the desired rate of temperature change. An airflow rate of one-tenth cubic foot of air per minute per bushel of grain (0.1 cfm/bu) will change the temperature of a bin in 100 to 200 hours of fan operation. The temperature change occurs as a cooling or warming front moves through the grain and is not complete until the front is completely through the bin.

The fan time required is proportional to the airflow rate. An airflow of 0.05 cfm/bu takes twice as long as 0.1 cfm/bu to change the temperature of a bin. An airflow of 0.5 cfm/bu requires only 0.2 the time for a temperature change as 0.1 cfm/bu.

Although stored grain can and is being aerated with airflow rates as low as 0.03 to 0.02 cfm/bu in commercial storages, a minimum of 0.1 cfm/bu is recommended for on-farm grain storages since this level of airflow can be easily attained. Higher airflows allow the operator to get the job done faster and therefore do not require as much attention. In fact, there is an increase in the use of higher airflow aeration (0.2 to 0.5 cfm/bu) to help manage stored grain, particularly shelled corn, at higher moisture contents (15.5 to 18 percent) for feeding and/or blending. It should be remembered that increasing the moisture content of stored grain is accompanied by an increase in storage risk. However, well-designed aeration systems and good management allow the producer to gain the advantage of storing at higher moisture contents.

The operator must gain experience in the time it takes to change the temperature in the bin by monitoring the temperatures during periods of fan operation. Nonuniformity in airflow and uncertainty of airflow rates makes this necessary. Inadequate fan time is probably the major source of problems when aerating stored grain.

Fan and Equipment Selection for Aeration

Figure 2 shows a variety of aeration systems. The round bins are all shown with the surface of the duct flush with the floor. This facilitates ease of unloading with underfloor and sweep augers. Properly designed above-floor ducts perform as well as flush ducts and are commonly used in storages originally constructed without aeration.

Figure 3 shows some possible duct arrangements for flat storages, where proper duct arrangement is generally more of a problem. Figure 4 gives a guideline for duct spacing which provides good air distribution in flat storages.

Table 3 contains the static pressures that can be used to select fans for aerating wheat and shelled corn with duct systems. For complete details and a fuller understanding of equipment selection, see "Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems," M-166.

Table 3. Static pressures* (inches of water) for fan selection

	Shelled corn		Wheat	
Grain depth	0.2 cfm/bu	0.1 cfm/bu	0.2 cfm/bu	0.1 cfm/bu
Up to 20 ft	1.0 inches	1.0 inches	2.0 inches	1.5 inches
20 to 30	1.5	1.0	4.5	2.5
30 to 40	2.5	1.5	7.5	4.0
40 to 50	4.0	2.0	---	5.5

*Static pressures are listed in increments of one-half inch with a minimum of one inch.

Proper sizing of the duct flow area and the perforated surface area is necessary for adequate performance. Enough perforated surface should be installed to provide one square foot for each 25 cfm. For example, if a fan is selected to move 1,500 cfm, 60 square feet of perforated surface area should be installed (1,500 ÷ 25 = 60). The ducts carrying the air should have enough cross-sectional area to provide one square foot for each 1,500 to 2,000 cfm. For example, the same fan moving 1,500 cfm would require a duct with one square foot cross section (1,500 ÷ 1,500 = 1).

AERATION MANAGEMENT

Proper Temperature Levels for Stored Grain

The purpose of aeration is to maintain a relationship between storage and outside temperatures that will minimize moisture migration and keep grain temperatures low to minimize deterioration rates (consistent with ambient temperatures).

Figure 5 shows the average monthly temperatures at Windom and Hallock, Minn. It might be argued that the ideal grain storage temperature would be the same as the average outside temperature. However, it is not necessary to cool the grain to the minimum average monthly temperature occurring in January, nor is it necessary to warm the grain to the highest average monthly temperature occurring in July.

Figure 6 shows the temperature levels of stored grain that provide a reasonable schedule that can be maintained with good aeration management. There are four calendar periods on figure 6:

- Cool-down period from September to December,
- Winter holding period from December to March,
- Spring warm-up period from March to June, and
- Summer holding period from June to September.

The aeration management schedule is discussed for each of these periods. Proper management requires the use of these instruments:

- Thermometers to measure ambient and bin exhaust temperatures (One that shows maximum and minimum temperatures will provide additional desirable information.);
- Thermometer probe for smaller bins, or temperature cables in large bins (20,000 to 25,000 bu and up);
- Moisture tester that has been checked and calibrated with a known moisture tester (elevator tester, Brown Duvel tester, or oven drying); and
- Deep-bin probe for taking moisture samples from the bin.

Fan Operation During Cool-Down Periods

During the cool-down period, the objective is to reduce the temperature of the grain below 35° F but not lower than 20° F. In southern Minnesota a range of 25 to 35° F would be reasonable. In northern Minnesota the range could be 20 to 30° F. The fan should be operating when the average weather is capable of cooling. Since the stored grain has a large heat storage capacity, it serves to average the outside temperatures during fan operation. If the 24-hour average outside temperature is 10° F or more below the exhaust temperature, adequate cooling is being accomplished. A good guideline to follow is to let the fan run continuously night and day when the exhaust temperature from the bin is at or above the maximum daily temperature. The normal day-night temperature variation is about 20° F. When the exhaust temperature from the bin is the same as the maximum daily temperature (usually afternoon) the average 24-hour temperature will be about 10° F lower and adequate cooling is being accomplished.

A question often raised is the effect of air relative humidity on fan operation during aeration. Table 4 shows the equilibrium moisture content of grain at several relative humidities for a 60° F temperature.

Table 4. Equilibrium moisture content of grain at 60° F

	Relative humidity			
	50%	60%	70%	80%
Corn	11.4%	12.9%	14.5%	16.4%
Wheat	12.3	13.7	15.2	16.9
Soybenas	8.6	10.5	12.8	15.7
Sunflowers*	---	8.0	10.0	12.0

*Oilseed sunflowers—estimated based on comparative storability

If the average relative humidity of the ambient air during fan operation is at or below the equilibrium moisture content of the grain, no moisture can be added to the grain. The average 24-hour relative humidity during reasonably fair weather is never high enough to cause a problem. A day or two of fan operation during rainy weather or other high relative humidity periods will do no harm if the fan operates for a day or two of fair weather following these periods. The only thing to avoid is extensive fan operation during rainy, wet weather after the fan has run enough to cool the grain to within 5 to 10° F of the average outside air temperature.

Aeration should be started as soon as grain is delivered to the bin. Grain out of a high-temperature dryer or grain combined during warm, sunny days will always be cooled by immediate fan operation. Cooling progress should be checked and the fan run enough to cool the grain to within 5 to 10° F of the average outside air temperature. Extensive fan operation beyond this (particularly in bad weather) should be avoided. The temperature of the grain can be reduced to the desired level in several steps if necessary.

The bin should be cooled to 20 to 35° F where it will be held during the winter holding period. Be sure all parts of the bin are cooled. The top center of the bin will be the last to cool with upward airflow and the bottom center will be the last to cool with downward airflow.

Fan Operation During the Winter Holding Period

When the fans are off during the winter holding period, they should be covered (with canvas or plywood) to prevent the grain near the ducts from getting too cold during severe winter weather. Large temperature differences result in condensation in the cold grain. Spoiled grain over the aeration ducts or perforated floor is a common problem caused by not covering the fan during extended off periods.

During the winter holding period, the grain should be checked weekly and the fan should be run periodically for a day or two during good weather when the outside temperature is near the temperature of the grain.

Fan Operation During the Spring Warm-Up Period

Many operators do not warm the stored grain in the spring. If the grain is to be moved out by July and has not been cooled below 30° F, it does not need to be warmed. However, if there is a possibility that the grain will be held longer or is colder, it is desirable to warm it to 50 to 60° F. This is best done in several stages by starting early (end of March, first of April) and running the fans in fair weather (night and day) when the average 24-hour temperature is 10° F warmer than the grain. This means the fan is operating continuously when the minimum daily temperature is about the same as the bin exhaust temperature. When the exhaust temperature increases to the new level, wait until the weather warms up another 10° F and bring the temperature up another stage. Be sure to bring the entire bin up during each stage. If the fan is shut off before the entire bin has warmed up, there may be some condensation in the area between the cooler and warmer parts of the bin. This causes spoilage if left more than several days. The condensation is more severe with larger temperature differences.

Fan Operation During the Summer Holding Period

Be sure all the grain is warmed to 50 to 60° F by the middle of June. Again, be sure to cover the fan when it is off during the holding period. If the grain is between 50 and 60° F and the duct or plenum chamber is open, there may be condensation in this cooler grain during warm, high humidity periods during summer. This results in spoilage next to the ducts.

Check the grain periodically, and run the fan during cool, fair weather when the outside temperature is close to the grain temperature.

The top layer of grain warms up due to high temperatures between the grain and bin roof. It is better to move the air upward to carry this warm air out of the bin rather than draw it downward through the rest of the grain.

Direction of Air Movement

Aeration can be accomplished by moving the air up or down through the grain. The air delivery system will move the same amount of air either way. However, there are advantages and disadvantages to each. If the operator understands them either direction can be used to do a good job.

The main advantage of moving the air down and exhausting it at the bottom is to minimize roof condensation when aerating warm grain during cold weather.

The main disadvantage of downward air is the uncertainty of knowing when aeration is complete. The grain at the bottom is the most difficult to check. A thermometer in the exhaust air, preferrably on the suction side of the fan, helps check the progress of aeration; however, it will read the average exhaust temperature and may not reflect the higher temperature of the air leaving the bottom center. The operator must check to see if aeration is complete by probing with a thermometer or checking the temperature of some grain unloaded through the center hopper.

The main disadvantage of upward airflow is that moisture may condense when warm air hits a cold bin roof. This would happen when warm grain is aerated during cold weather. The problem can be minimized by starting aeration early and reducing the grain temperature over a longer period of time. The best way to operate fans—regardless of airflow direction—is to change the grain temperatures gradually, in several steps.

Screening, Spreading, Unloading

Accumulation of fine particles, weed seeds, and other foreign material interferes with airflow. Such accumulations are prime locations for increased mold and insect activity, which result in localized heating and grain deterioration. Normally, these accumulations are in or near the center of the bin due to separation as the grain flows toward the walls.

Several good management practices can reduce the storage risks incurred through accumulation of foreign material. Screening the grain reduces the amount of foreign material and greatly improves the storability. Screening is a must for long-term storage unless the grain is delivered in good, clean condition.

Spreaders are used to more uniformly distribute the foreign material throughout the storage. This helps provide more uniform airflow during aeration. However, there is research evidence to show that distribution of fines throughout the bin increases the resistance to airflow, which reduces airflow.

Another good management practice in bins equipped with center unloading hoppers is to unload some grain from the center to remove some accumulated material. Fill the bin so it is peaked and unload some of the grain (300 to 1,000 bu, depending on bin size). This removes some of the accumulation and increases airflow in the center if enough grain is unloaded to allow the center core to fill with clean grain. A better way to accomplish this, if possible, is to unload some grain periodically as the bin is filled.

It is impossible to provide a single answer to questions related to screening, spreading, and unloading the center. All of these practices improve the ability to manage stored grain. However, the degree of improvement depends on the amount of foreign material, bin size, grain temperature and moisture content, spreader performance, and unloading procedures. Each operator, based on experience and examination of the stored grain, can make reasonable decisions as to the risks involved in each case. Based on these considerations, the operator can decide which bins are the greatest risks and can arrange the unloading schedules to best meet the situation.

Some general guidelines are:

- Higher moisture grain should be unloaded first.
- Grain that has been dried in high-temperature bin dryers and stored in the same bin should be moved first.
- Grain delivered to bins for long-term storage (more than 10 months to one year) should be screened.
- If spreaders are not used in storage bins, the bins should be peaked and the centers unloaded immediately following filling.
- Even though spreaders are used, if the grain being delivered to storage contains large amounts of fines, weeds seeds, or other foreign material and the grain is not screened, the bin should be filled to the peak and the centers unloaded.
- If the grain is fed, the operator should unload some grain from all bins before completely unloading one.
- After all bins are filled, the operator should properly check the condition of each and arrange the unloading schedule to best manage the situation.

EQUIPMENT FOR MONITORING, MANAGEMENT

To properly manage stored grain the operator must be able to obtain samples from the stored grain, determine moisture content, monitor grain temperatures, and keep a simple record of both grain and ambient temperatures.

A deep bin probe should be used to obtain samples at different locations to determine the moisture content, the level of fine material, and general grain conditions. A reasonably accurate moisture tester is needed. The operator must know the accuracy of the moisture tester under all conditions. Inexpensive electrical testers can give inaccurate readings under many conditions. Readings on freshly dried grain, warm or hot grain, and excessively cold grain can be inaccurate. The operator can "calibrate" the tester under these conditions by checking readings with the local elevator or other more accurate testers.

Thermocouple cables installed in larger bins (20,000 to 25,000 bu and up) are valuable in monitoring temperatures in storage to determine the progress of aeration. In bins without cables, thermometer probes should be used to check the temperature at different locations within the bin. This helps in monitoring the progress of the aeration and in locating troublespots.

A thermometer to measure the exhaust air temperature and one to read ambient air temperature is necessary for proper fan management. Maximum-minimum thermometers are especially helpful because they provide the operator an indication of changes in temperature with time.

This equipment not only helps the operator manage the stored grain but provides information on how the aeration system works and how stored grain responds to treatment.

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. Moisture migration in grain stored without aeration

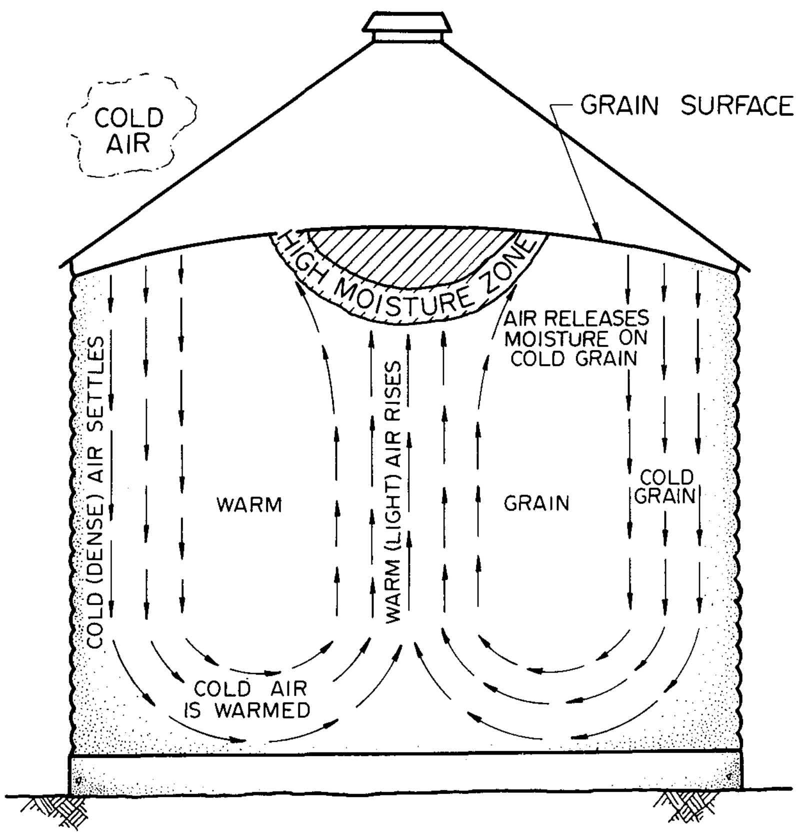


Figure 2. Typical grain storage aeration systems

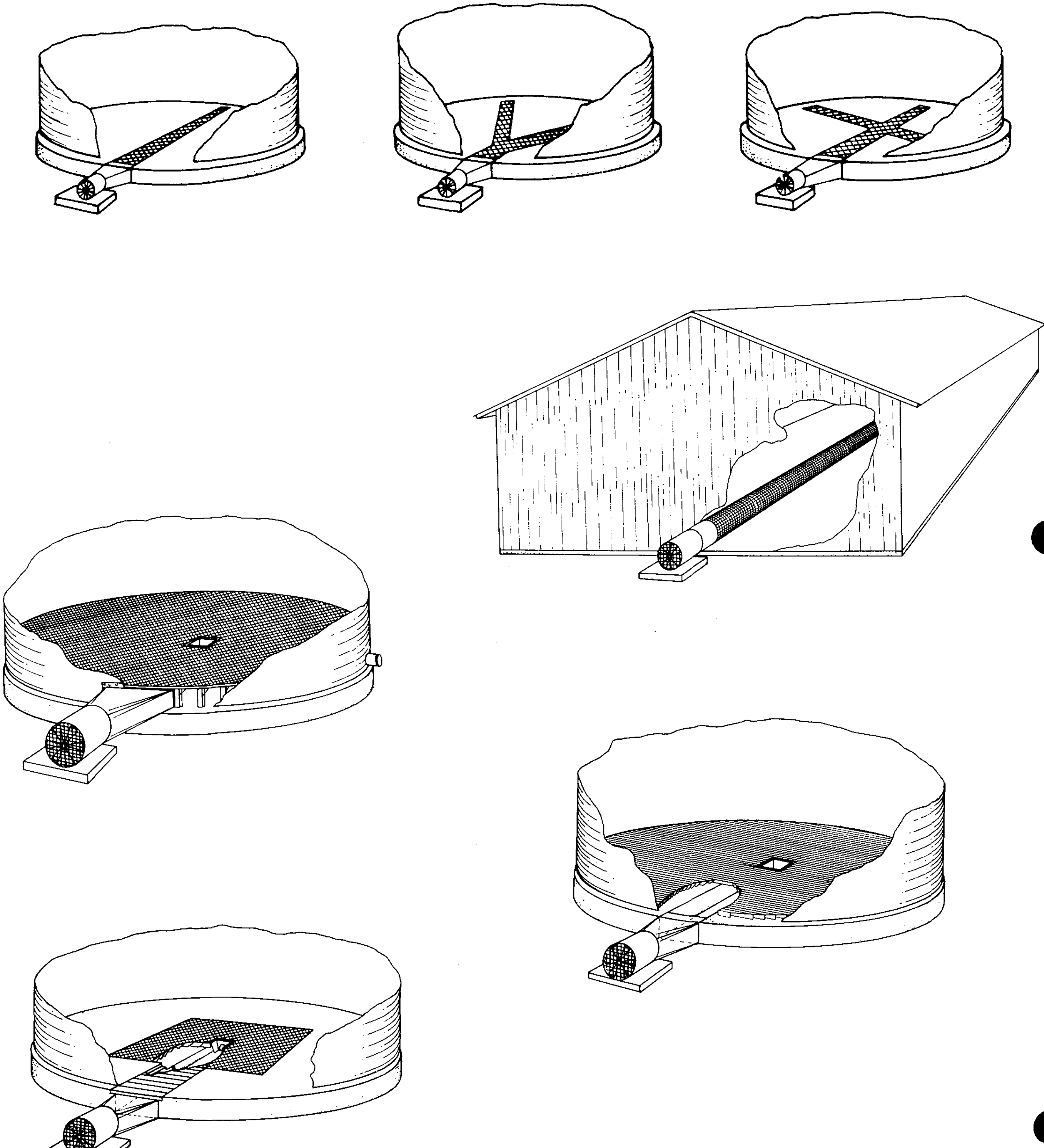


Figure 3. Aeration duct arrangements for flat storages

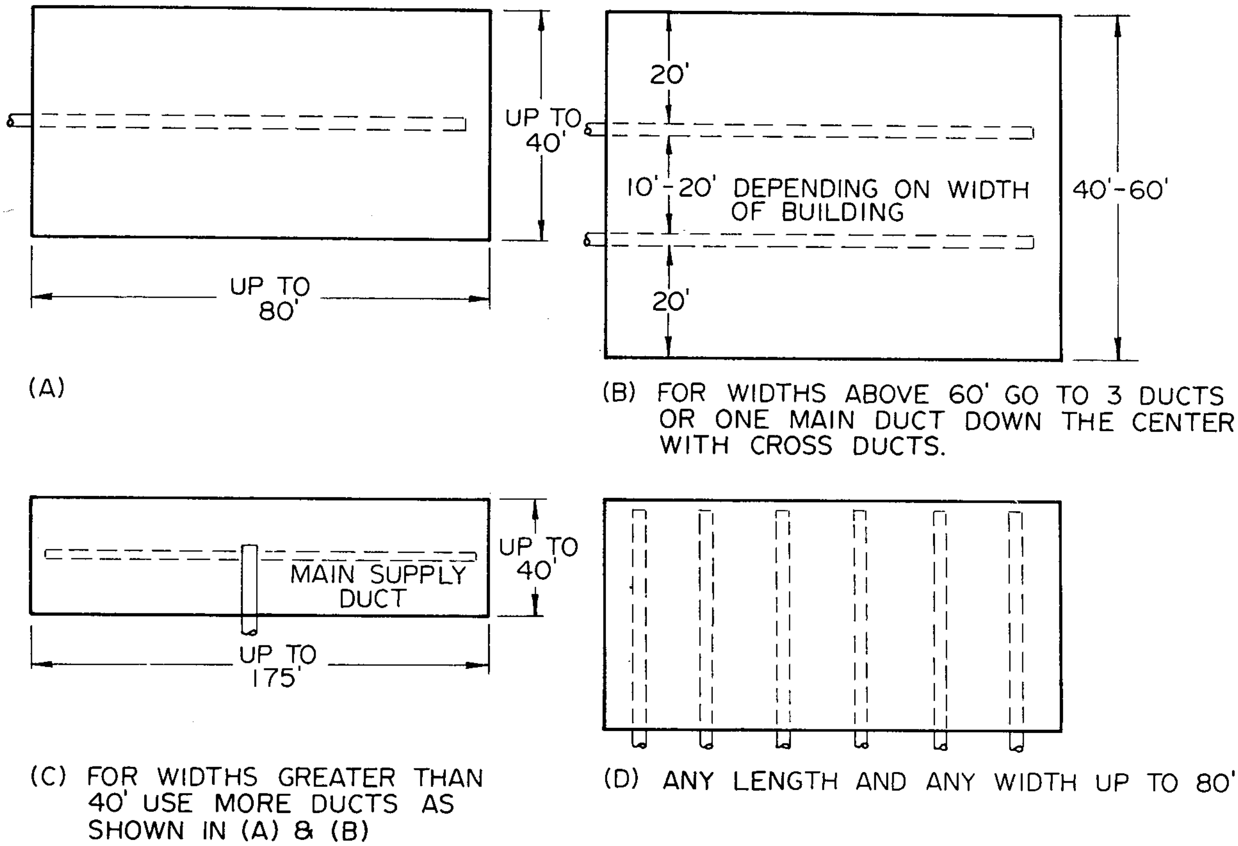
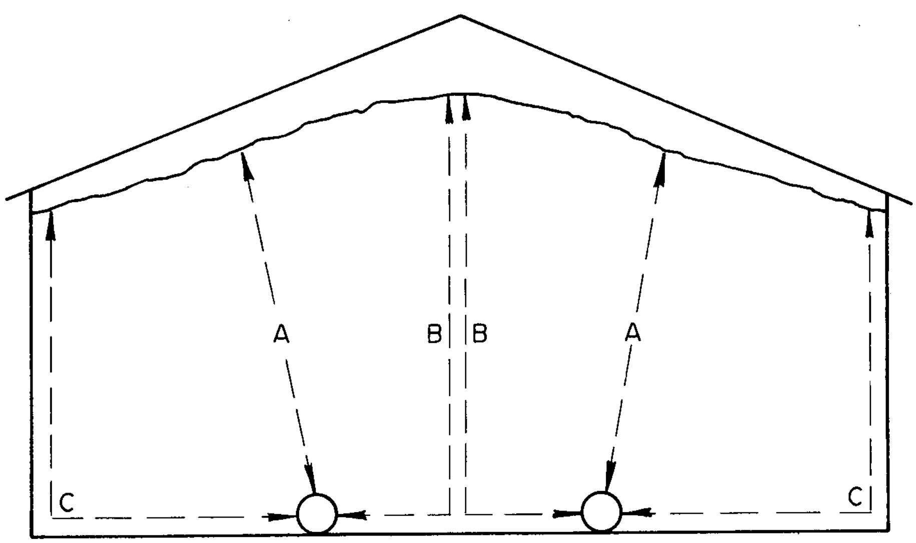


Figure 4. Guideline for duct spacing in flat storages



(A) IS THE SHORTEST AIR PATH

(B) AND (C) ARE LONGER AIR PATHS THAN (A)

(B) OR (C) SHOULD BE NO LONGER THAN $1\frac{1}{2}$ TIMES (A)

Figure 5. Average monthly temperatures at Windom and Hallock, Minn.

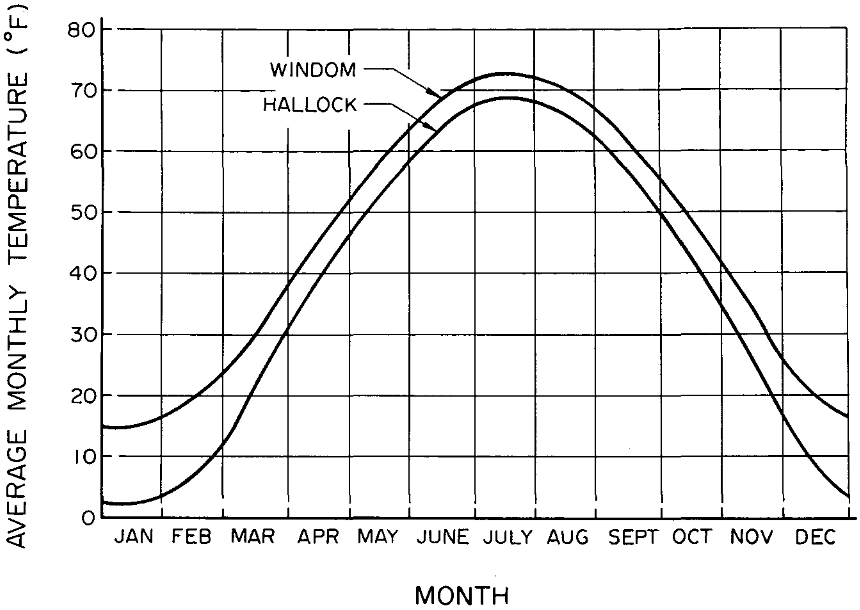
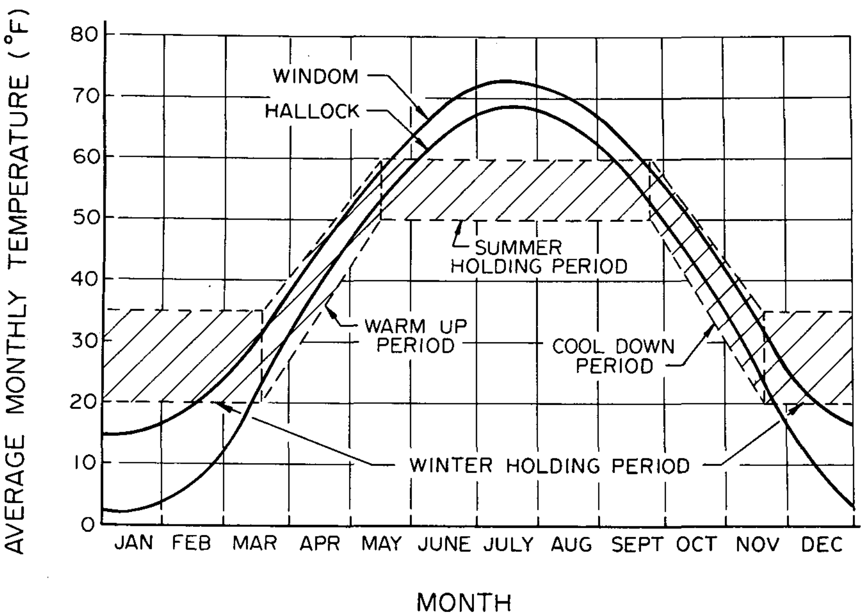


Figure 6. Grain storage aeration periods



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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