AE-791 (Revised)

Crop Storage Management

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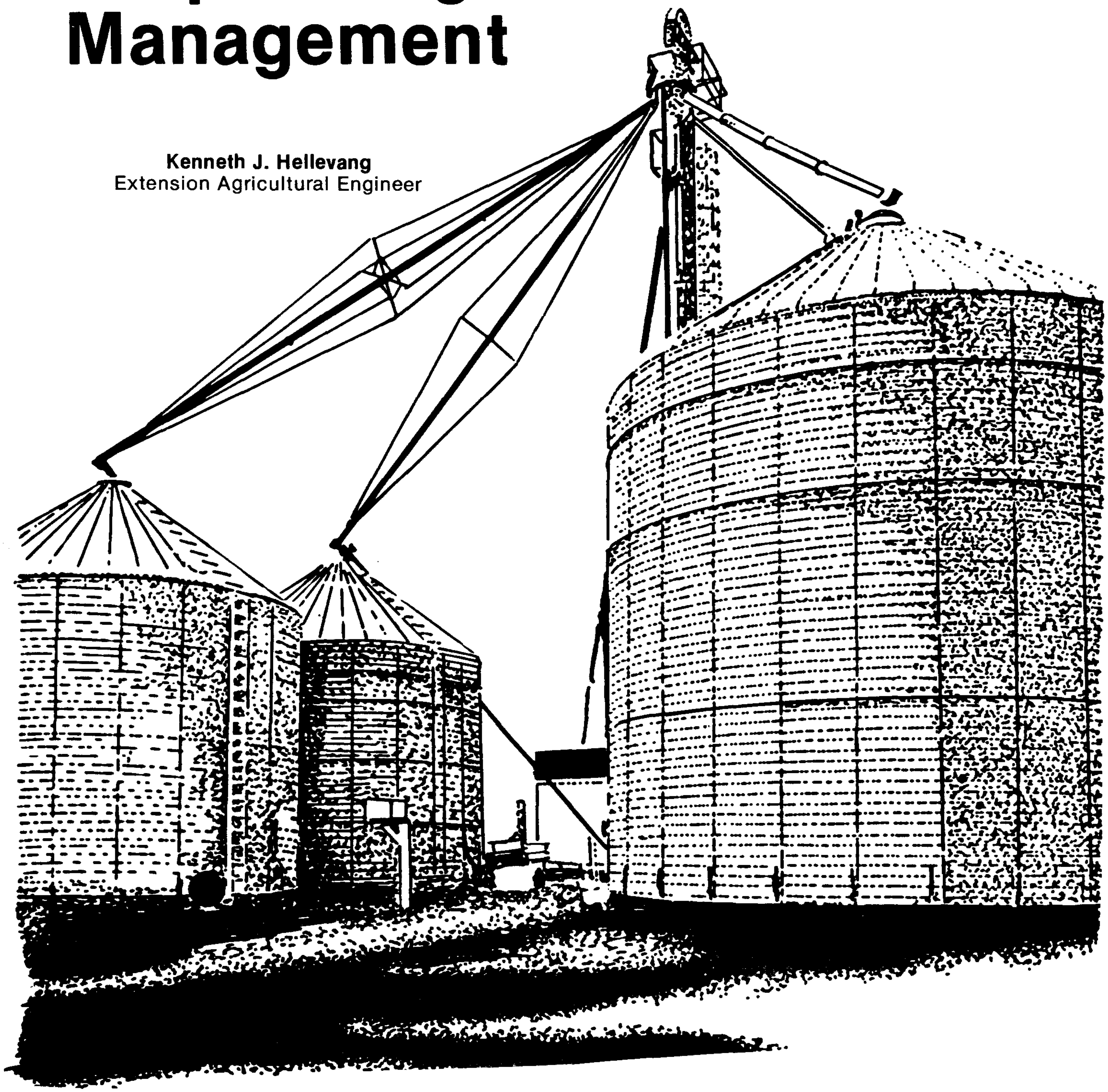

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Crops have a limited storage life due to insects and mold. There are basic management pratices, however, that can prolong this storage life. Appropriate actions taken as the crop goes into storage and during the storage period will minimize the chance of problems.

Storage Preparation

Stored grain insects are either already in the storage before filling or may enter later. The following steps will aid in the prevention of stored grain insect problems:

1. Clean storages thoroughly prior to filling.
2. Repair cracks and crevices where moisture and insects may enter.
3. After cleaning and repairing, use a residual spray to treat the inside surfaces of the bin at least two weeks prior to filling. (Follow label instructions to avoid problems of contaminating grain with illegal pesticide residues.)
4. Avoid filling storages with new crop where old crop is already present.
5. Clean and check the aeration system. Foreign material may collect in ducts creating an excellent insect breeding environment and obstructing airflow.

For more information on insect control, contact your local county extension office or the extension entomology section at North Dakota State University.

Crop Condition For Storage

Crops store best if they are cool, dry and clean. Mold growth is dependent on both temperatures and crop moisture content. Figure 1 shows the growth curves for two types of mold which emphasize the need to cool crops shortly after harvest.

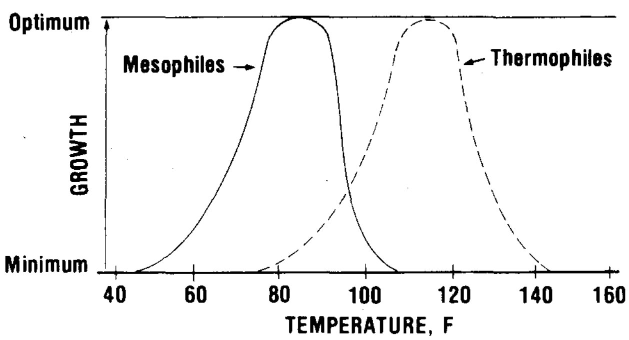


Figure 1. Growth of two microbial types associated with crop storage as affected by temperature.

The maximum recommended moisture contents for storage with aeration of some North Dakota crops are listed in Table 1.

Table 1. Maximum Recommended Moisture Contents of Selected Clean, Sound Grains for Storage with Aeration in North Dakota.

	Short-term	Long-term
	(less than 6 months)	(more than 6 months)
Barley	14 %	12%
Corn	15.5	13
Edible Beans	15	13
Flax seed	9	7
Millet	10	9
Oats	14	12
Rye	13	12
Sorghum	13.5	13
Soybeans	13	11
Non-Oil Sunflower	11	10
Oil Sunflower	10	8
Wheat	14	13

Crops that contain considerable foreign material or broken kernels will be more susceptible to mold and insects. The crop should be cleaned to reduced this hazard or be dried down 1 to 2 percent lower than clean crops.

Filling The Storage

Best storage results are obtained when the crop is leveled in the bin. Lowering the center core of the stored crop improves airflow through the problem-prone central area and makes checking the crop easier. Leveling can be accomplished with a grain spreader or by withdrawing grain from the center after filling. Withdrawing grain from the center removes some fines and foreign material because most fines tend to accumulate in the center of the bin. This is important since fines are more susceptible to spoilage and restrict aeration airflow. A distributor used during filling may spread the fines throughout the storage.

Grain that will be held in storage for a year or more should be treated with a grain protectant such as malathion. After the bin is full, level the surface and apply a surface treatment of malathion spray. Since the Indian meal moth has developed resistance to malathion, dischlorvous (vapora) resin strips can be suspended over the grain to destroy the moths before they lay eggs. One dichlorvous strip per 1,000 cubic feet of space over the binned grain is recommended. The strips should be in place before moths begin to emerge in early spring. Dipel bacterial insecticide is also registered as a top-dress protectant against Indian meal moth larvae. Be sure the protectant used is approved for the crop being stored.

Moisture Migration

Crops are normally placed in storage at temperatures much warmer than winter temperatures. Since crops are good insulators, the crop in the center of a storage of more than about 3,000 bushels will be nearly the same temperature as at harvest even after outside temperatures have dropped well below freezing. This temperature differential causes moisture migration (Figure 2). Air near the bin wall cools and sinks to the bottom of the bin, pushing air up in the center. Since the crop is warm, this air is warmed. When the warmed air is cooled by the crop near the surface, moisture in the air condenses because cool air cannot hold as much moisture as warm air. As this circulation continues, moisture begins to accumulate near the top center of the storage. Crusting is an indication of moisture accumulation and mold growth. Mold and insect activity can begin in the warm moist areas. An aeration system cools the grain uniformly, limiting moisture migration (Figure 3).

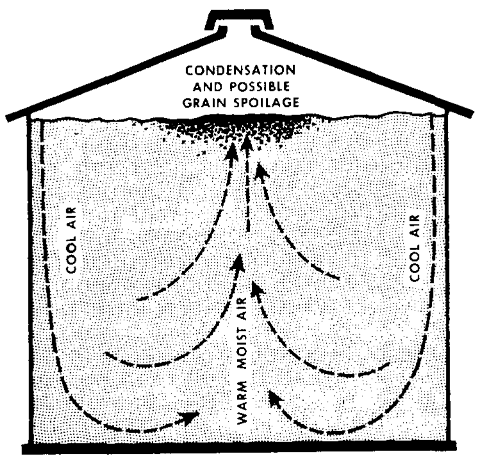


Figure 2. The normal pattern for moisture migration during the fall and winter. High moisture contents and crusting usually occurs at the top center of the bin (the dark area).

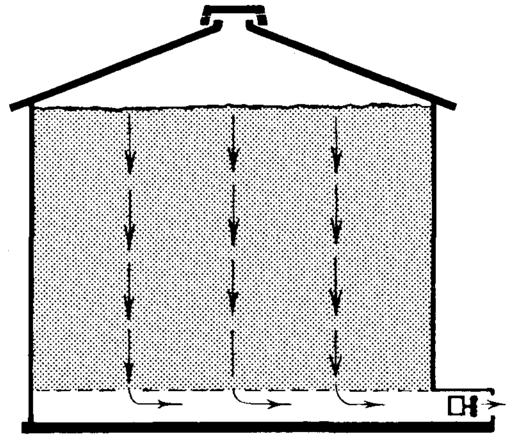


Figure 3. Aeration in grain equalizes the temperature and prevents serious moisture migration from occurring.

Aeration

Crops should be held near average outdoor temperatures during the fall. Modern grain management uses airflow to control grain temperature. Increasing the airflow rate reduces the time needed for cooling or warming but also increases the power requirement (Figure 4).

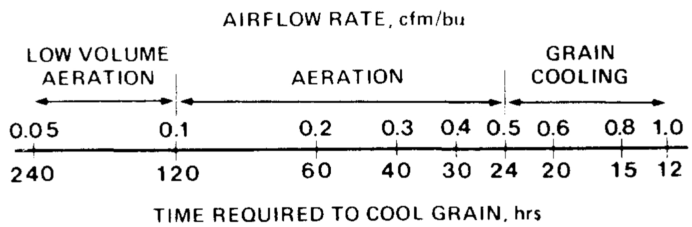


Figure 4. Airflow rates and corresponding times required to cool grain for about a 20° F temperature differential between grain and air. Example: At an airflow rate of .1 cfm/bu, it requires about 120 hours to cool grain from 60 to 40 F.

During summer, reverse migration may cause the grain moisture content of the grain, between the warm grain on the surface and the cooler grain toward the center of the bin, to increase some. The amount of the moisture content increase depends on the amount that the grain is warmed. The increase when grain is warmed from about 50 degrees Fahrenheit to 80 F will be about 0.50 to 1.00 percentage point. If the grain is to be held through summer, it may be advisable to warm it to between 40 F and 50 F in the spring.

Begin aeration to reduce the crop temperature when the average outdoor temperature is about 10 to 15 F lower than the crop temperature. The average outdoor temperature is the average of the daily high and low; $\frac{(high + low)}{2}$

Cool the crop to 25 to 35 F, which may require several cooling cycles. If the crop is put into storage at 75 F, the first cooling cycle will cool it to 60 F, the second to 45 F, and the third to 30 F. There is no advantage to cooling the crop below 25 F. Actually, there are some hazards. Temperatures below 32 F may cause wet grain to freeze and may reduce germination of wet grain.

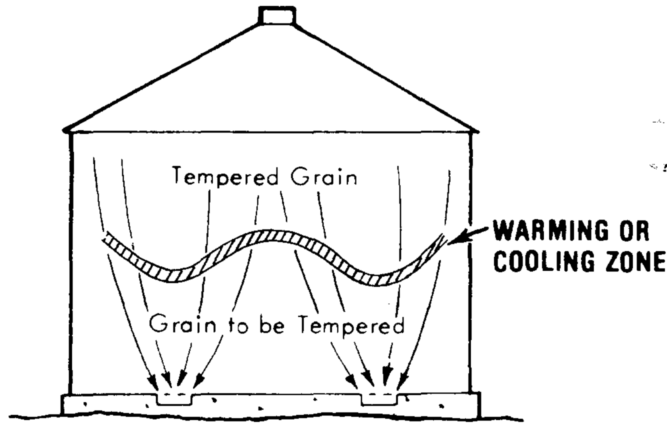
You can estimate when a cooling or warming cycle has passed through the crop by measuring the temperature. With a suction aeration system, measure the temperature of the air exhausting from the fan. Because air passes around a pocket of fines, the air exhausting from the fan may be cool even though there is still a hot spot in the crop. Run the fan about a day after the temperature of the air from the fan reaches the outdoor temperature to reduce the possibility of any hotspots. Probe with a thermometer to be sure all the crop has been cooled. With a pressure aeration system, place a thermometer 6 to 12 inches into the crop at the top of the bin. When a cooling zone has passed through the crop, the temperature will drop. Check the temperature at several locations.

If you warm the stored crop in the spring, start warming as soon as the average air temperature is about 10 F warmer than the crop. Larger temperature differences between the air and crop increase the quantity of condensation on the crop. Do not warm the grain to temperatures above 50 F. Continue to aerate until all the crop has been warmed or cooled (Figure 5).

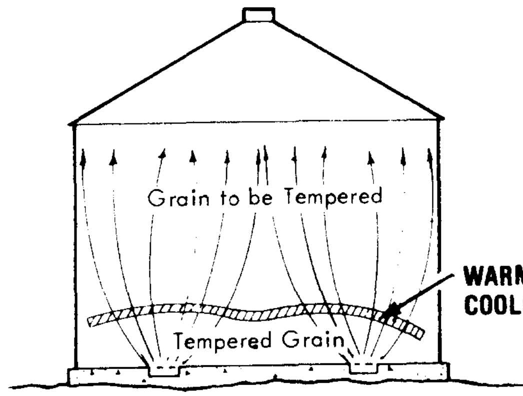
Air may be forced up or pulled down through the crop (either is acceptable if properly used). Pulling air down prevents condensation of moisture on the bin roof, but the crop at the bottom will be the last to cool and will be difficult to monitor. Upward airflow cools the crop on top last, so layers of warm crop can be added to existing crop without causing a rewarming of the lower layers.

Rewetting or drying is usually insignificant (about 0.5 percentage points) during crop aeration. The cooling front moves through the crop about 50 times faster than a wetting or drying front, so only a small fraction of the crop is rewetted during an aeration cycle, even with high humidities. However, if several days of foggy weather are expected, the aeration can normally be delayed until the weather improves.

Cover the fan when not operating. This limits excessive cooling in winter, rapid warming in the spring and excessive warming in the summer. Moisture may condense on the aeration ducts if warm moist air is allowed to contact cold crop near the duct. Also, keep water, debris, rodents and insects out of the aeration ducts.



Negative pressure - cooling or warming zone moves down through the grain.



Positive pressure - cooling or warming zone moves up through the grain.

Figure 5. Aerating to change grain temperature. Grain behind the zone of cooling or warming has been tempered. Grain in the zone is changing and approaching outside air conditions. Grain in front of the zone has changed very little. One temperature change or cycle is the time needed to move the tempering zone completely through the stored grain mass.

Fans

Axial (propeller) fans are the most common type fan used for aeration. They require a relatively low initial investment and operate well at static pressures below 3 to 4 inches water gage. Centrifugal (squirrel-cage) fans deliver a fairly consistent airflow over a wide range of static pressures but require a higher initial investment than axial fans.

Static pressure is the pressure against which the fan must work (force air). Static pressure increases for increasing crop depths and increasing airflow rates and varies in value for different crops. Table 2 lists the approximate static pressure for some crops and depths at various airflow rates.

Select a fan according to manufacturer's rating tables or curves to deliver the required air volume at the expected static pressure. There are some differences between fans, but generally a larger diameter axial flow fan will move more air at low static pressures, below 2 inches, and for the same horsepower a smaller diameter axial fan will move more air at higher static pressures. Table 3 shows typical axial flow fan performance for some fans.

Table 2. Approximate static pressure

Stored	Crop Depth (feet)	Static pressure when airflow rate in CFM/bu is: 1/20	1/10	1/5	1/2	3/4	1
		inches of water					
Wheat	10	0.62	0.74	0.98	1.70	2.45	3.20
	15	0.77	1.02	1.58	3.31	5.11	6.58
	20	0.98	1.45	2.39	5.90	8.90	12.2
	25	1.25	2.00	3.50	9.13	14.8	20.4
	30	1.82	2.66	4.91	12.6	23.0	31.1
Barley	10	0.57	0.62	0.76	1.19	1.55	2.00
Oats	15	0.65	0.79	1.10	2.08	3.20	4.10
Sunflower	20	0.76	1.01	1.61	3.50	5.30	7.40
	25	0.91	1.31	2.21	5.56	8.75	12.5
	30	1.09	1.69	3.07	7.70	13.6	18.7
Corn	10	0.53	0.56	0.61	0.83	1.03	1.28
Soybeans	15	0.56	0.62	0.77	1.31	1.85	2.17
Edible Beans	20	0.61	0.73	1.01	2.06	3.08	4.40
	25	0.67	0.86	1.31	3.09	5.26	7.25
	30	0.75	1.04	1.72	4.40	7.50	11.3

Static Pressure = (Shedd x 1.5) + 0.5 1 inch water = 250 Pa (pascals) 1 ft. = 0.3408 meter
1 CFM = 0.47 L/S

Table 3. Typical Axial Fan Performance*

HP	Fan Diameter (inches)	RPM	Airflow (cfm) Static Pressure (Inches of Water) 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.5	12	3450	1500	870	630	350					
0.75	12	3450	1700	1000	750	350					
1.0	14	3450	2880	1850	1050	780					
1.5	12	3450	2200	1400	950	500					
1.5	14	3450	2800	2100	1300	800					
1.5	16	3450	3500	3000	2400	1800	1300				
1.5	18	3450	4350	3800	3000	2000	1400	790			
3	18	3450	5700	5200	4600	3500	2650	1850	1400		
5	24	3450	10500	9800	9000	8150	7000	5900	4600	3450	2900

* Consult a comparable table for the actual fan being selected.
1 inch water = 250 Pa (pascals) 1 CFM = 0.47 L/S 1 Hp = 746 watts 1 inch = 25.4 mm

Duct Sizing and Spacing

There are many types of ducts and duct arrangements. The objective is to get airflow through the crop to maintain a uniform temperature. Ideally a perforated floor would be used, but this may not be necessary. Since most problems develop in the center of the storage and the crop will cool naturally near the wall, the aeration system must at least provide good airflow in the center. If ducts placed directly on the floor are to be held in place by the crop, be sure the crop flow is directly on top of the duct to prevent movement and damage to the ducts. Flush floor systems work well in storages with sweep augers and unloading equipment. Install ducts so they can be easily removed for cleaning. The duct spacing should not exceed the depth of the crop and the distance between the duct and storage structure wall should not exceed one-half the depth of the crop for bins and flat storages. Figure 6 shows common duct patterns for round bins. Figure 7 shows duct spacing for flat storages.

The duct must be large enough to properly carry the air. Typically, air velocities are kept at or below 1,500-2,000 feet per minute (fpm) in the duct. High air velocities increase the fan power required and may cause non-uniform airflow from the duct. Short ducts in deep bins may be sized for the faster air velocity while long ducts in shallow storages may require velocities less than 1,500 fpm for uniform air distribution. Fans should push the air into long ducts. There will be more air discharged from the duct near the fan than at the far end of the duct. Table 4 shows the cross-sectional area of some round ducts. There must also be enough perforated area to limit the air velocity leaving the duct. Provide about one square foot of perforated area for each 25 cfm. Finally, there must be at least 1 square foot of opening in the bin roof for each 1,000 cfm airflow. Air must have an unrestricted path into and out of the storage.

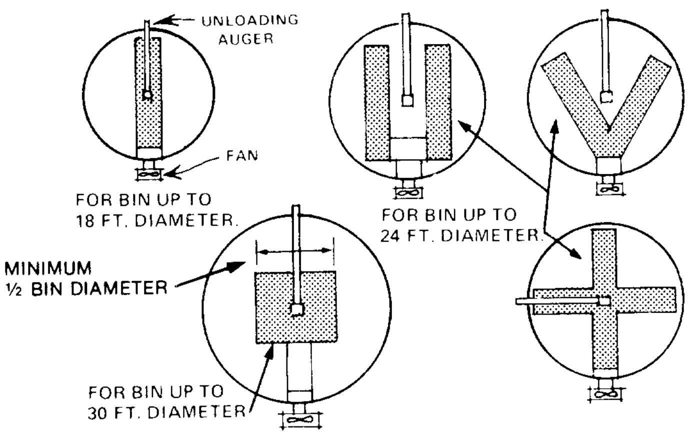
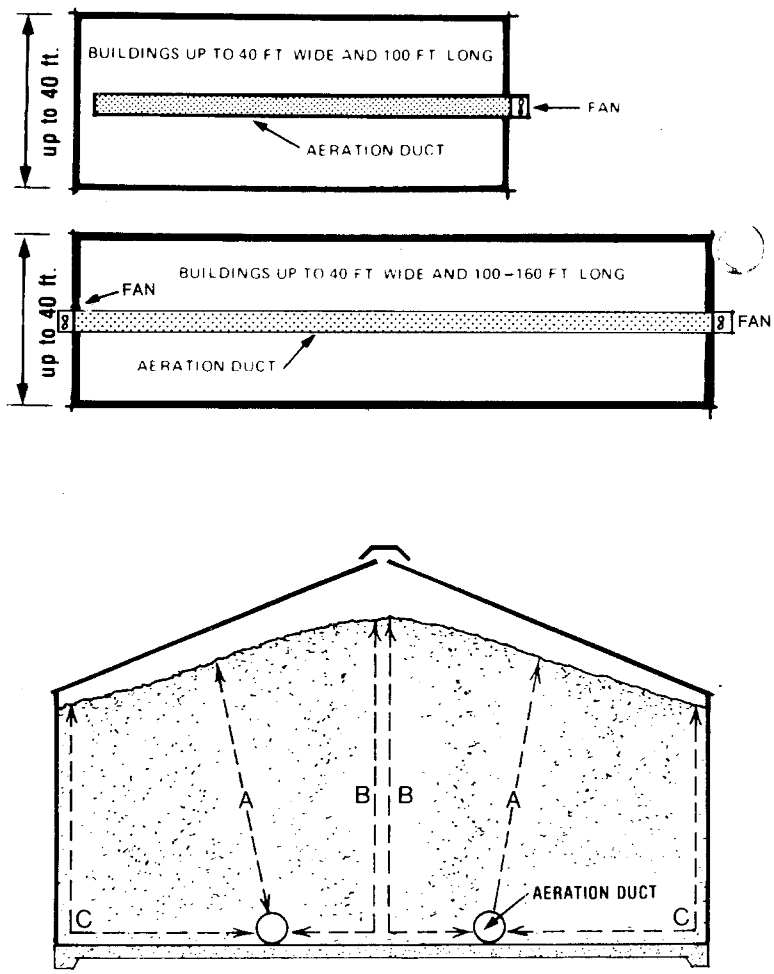


Figure 6. Common duct patterns for round grain bins. Duct arrangement may also be affected by grain depth.



(A) IS THE SHORTEST AIR PATH.
(B) AND (C) ARE LONGER AIR PATHS THAN (A).
(B) OR (C) SHOULD BE NO LONGER THAN 1½ TIMES (A).

Figure 7. Duct arrangements which may be used with large flat storages. On buildings up to 40 feet wide one properly sized duct may be used if the grain is peaked. The duct spacing should not exceed the depth of the grain.

Table 4. Round Duct Cross-sectional Areas

Diameter (inches)	8	10	12	14	16	18
Area (sq. ft.)	0.35	0.55	0.79	1.07	1.40	1.77

Example: Select an aeration system for 10,000 bushels of wheat 20 feet deep in a 30 ft. diameter bin with an airflow rate of 1/10 cfm/bushel.

Airflow = 10,000 bushels x 1/10 cfm/bu = 1,000 cfm
Static Pressure = 1.45 inches of water (Table 2)
Fan = ¾ horsepower 12" diameter (Table 3)

$$\text{Minimum Duct Cross-sectional Area} = \frac{1000 \text{ cfm}}{1500 \text{ fpm}} = 0.667 \text{ sq. ft.}$$

Use a 12-inch circular duct or a rectangular duct with the same cross-sectional area such as one 2 feet wide and 4 inches high (Table 4).

$$\text{Minimum Perforated Surface Area} = \frac{1000 \text{ cfm}}{25 \text{ fpm}} = 40 \text{ sq. ft.}$$

This would be a pad 6 x 7 ft. This is too small for the 30 ft. diameter bin, because there would be 12 feet of wheat between the pad and wall that would not get aerated. A 15 ft. x 15 ft. pad or larger is preferred.

$$\text{Open Area in the Bin Roof} = \frac{1000 \text{ cfm}}{1000 \text{ cfm/ft}^2} = 1 \text{ sq. ft.}$$

Checking the Crop

Check stored crop bi-weekly during the critical fall and spring months when outside air temperatures are changing rapidly and during the summer. Check at least every month during the winter after a storage history without problems.

Get into the bin to check the stored crop. Search for small changes that are indicators of potential problems. Check for indications of moisture such as crusting on the crop or condensation on the bin roof, or check the moisture content of the crop with a moisture meter. Check and record the temperature at several points in the stored crop. Any increase in temperature indicates a problem, unless outdoor temperatures are warmer than the crop. Probe the crop to check for insects or other problems. If problems are noticed, cool the crop by aeration since mold growth is practically nil at freezing temperatures and insects will be dormant as well. Fumigation is not recommended at grain temperatures below 60 F.

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