Extension Bulletion 35 (Revised)

NATURAL AIR / LOW TEMPERATURE
Crop Drying

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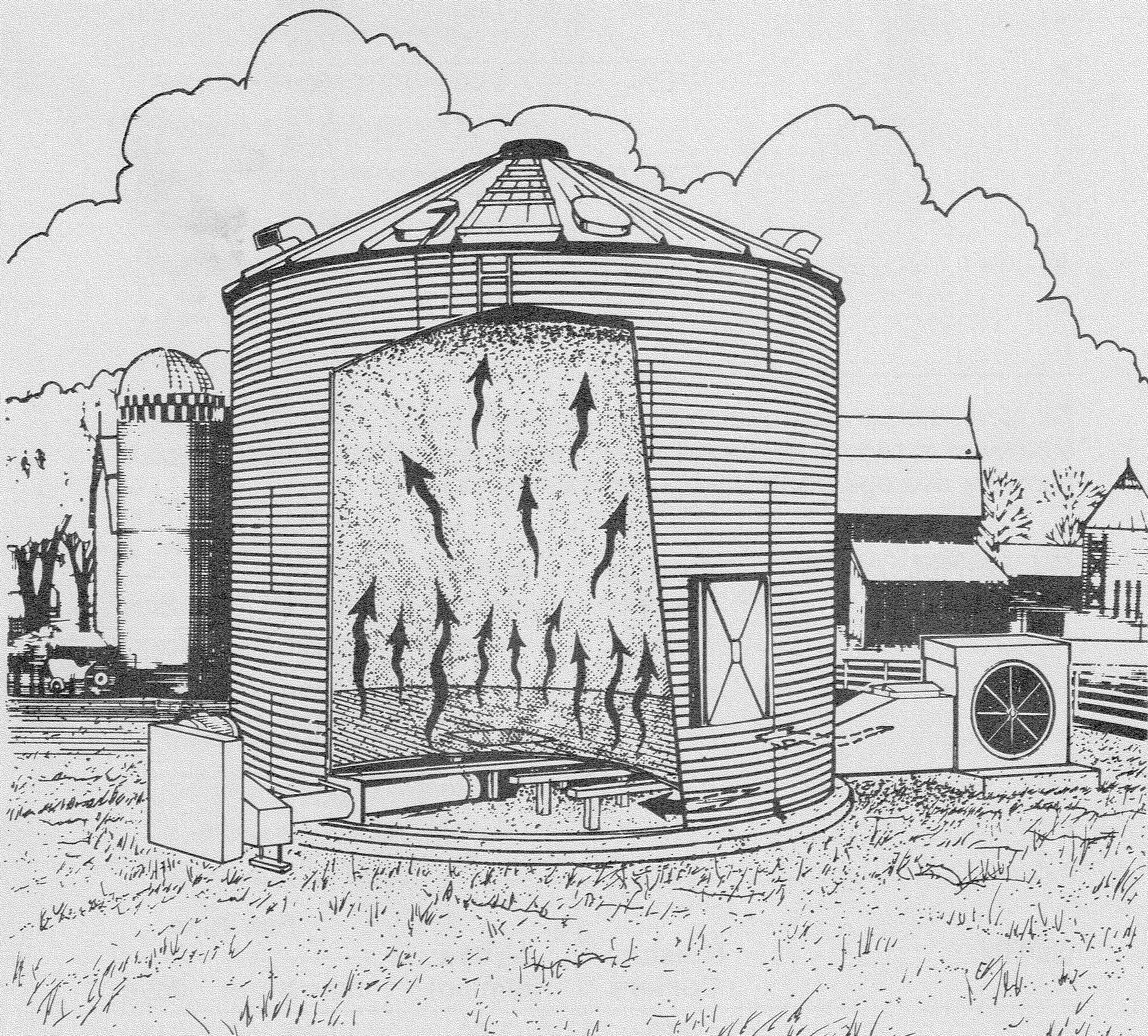

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Required airflow rates and drying times for natural air drying of wheat at various moisture contents using air at 69° F and 60% relative humidity, average North Dakota condition for August.

WHEAT	Moisture Content	Airflow (cfm/bu)	Fan Time hours	or	Fan Time days
	18%	1.25	480		20
		1.00	600		25
	17%	1.00	552		23
		0.75	744		31
	16%	1.00	504		21
		0.75	672		28
		0.50	1,008		42
	15%	1.00	480		20
		0.75	648		27
		0.50	960		40
	14%	1.00	408		17
		0.75	544		23
		0.50	816		34

Required airflow rates and drying times for natural air drying of corn and oil sunflower at various moisture contents using air at 47° F and 65% relative humidity, average North Dakota condition for October.

OIL SUNFLOWER	Moisture Content	Airflow (cfm/bu)	Fan time hours	or	Fan time days
	17%	1.00	648		27
	15%	1.00	480		20
		0.75	720		30
		0.50	960		40
	13%	1.00	336		14
		0.75	504		21
		0.50	672		28

CORN	Moisture Content	Airflow (cfm/bu)	Fan Time hours	or	Fan Time days
	21%	1.00	1,080		45
	19%	1.00	792		33
		0.75	1,056		44
	17%	1.00	672		28
		0.75	1,008		42
		0.50	1,344		56

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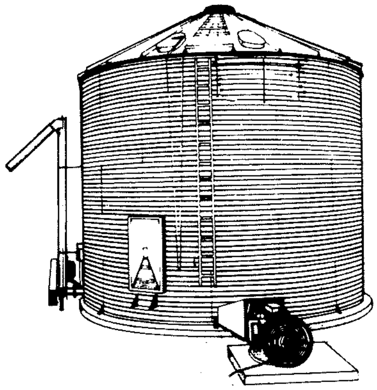

NATURAL AIR / LOW TEMPERATURE CROP DRYING

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NATURAL-AIR CROP DRYING

Natural-air drying is an in-storage drying system which utilizes unheated air to dry the crop. Air is forced upward through the grain, evaporating and carrying away the water. Drying takes place in a drying zone which advances upward through the grain (Figure 1). Grain above this drying zone remains at the initial moisture content or slightly above, while grain below the drying zone is at a moisture content in equilibrium with the drying air. The process may take several weeks depending on the airflow rate, climatic conditions and the amount of water to be removed. Natural-air drying requires enough airflow to complete drying within the allowable storage time, the time before significant quality deterioration takes place.

- **Advantages of natural-air drying include:**
  1. **No harvest bottle neck. The bins can be filled at the harvest rate.**
  2. **Economical. A properly sized system may dry the crop more economically than if dried in a high temperature dryer.**
- **Disadvantages of natural-air drying include:**
  1. **There is a limit on initial moisture content that can be effectively dried.**
  2. **Electrical power must be available at each bin for dryer fan motors.**

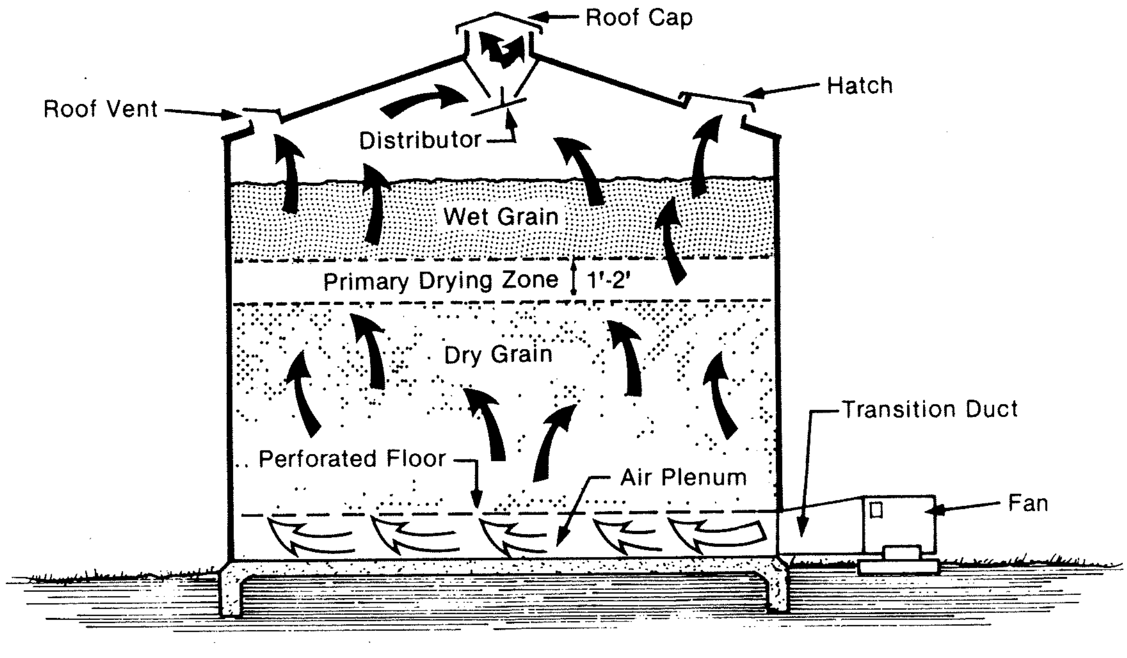
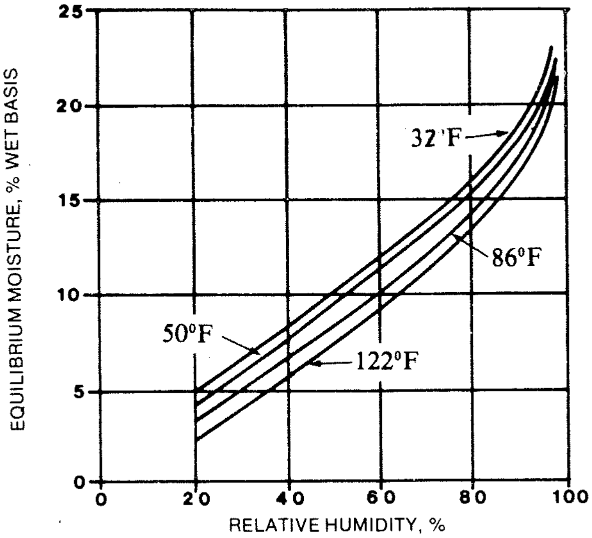


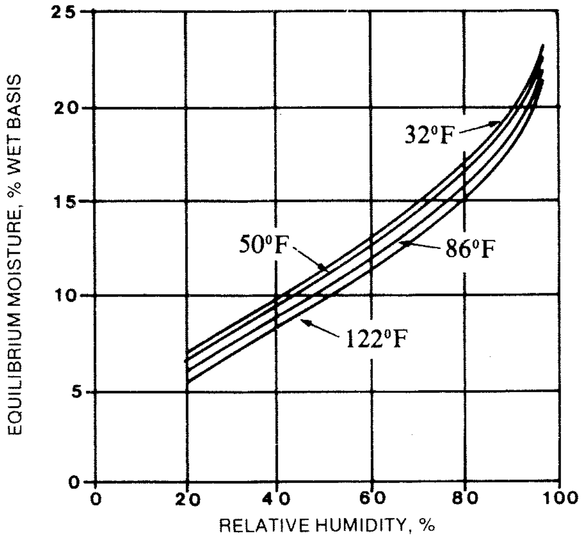
Figure 1. Three zones within grain during natural air drying in a typical bin.

EQUILIBRIUM MOISTURE CONTENT

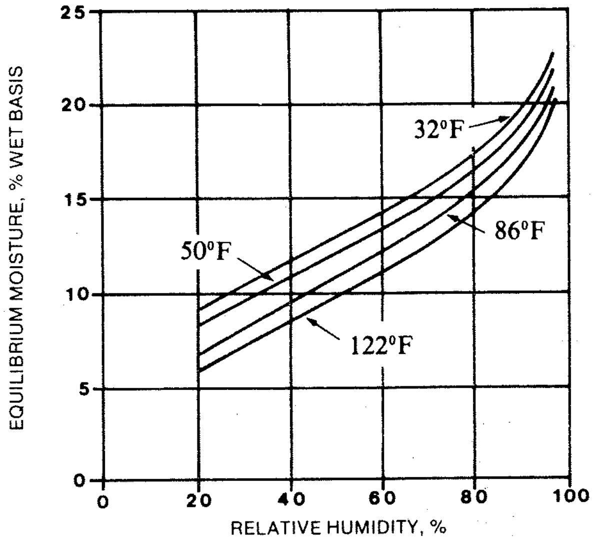
The moisture content of "dry" grain when natural-air drying fluctuates with the temperature and relative humidity conditions of the outside air. Table 1 illustrates the relationship between temperature, relative humidity and the equilibrium moisture content (EMC) for several crops. The EMC of corn at 50°F and 60 percent relative humidity is 13.7 percent moisture content. Complete graphs for some crops are shown in Figure 2.



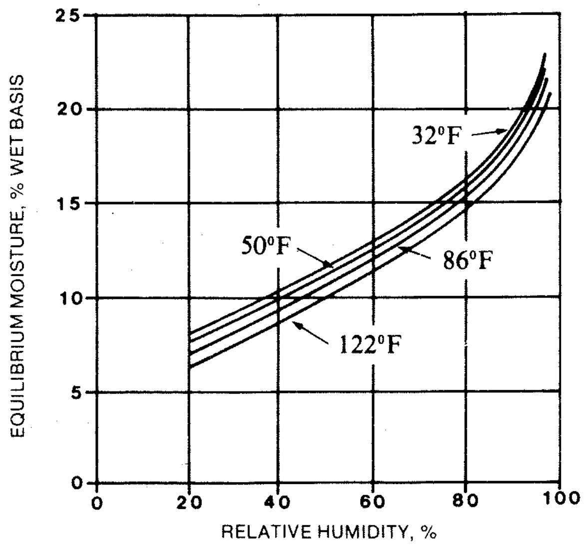
A—EQUILIBRIUM MOISTURE CONTENT, SOYBEAN



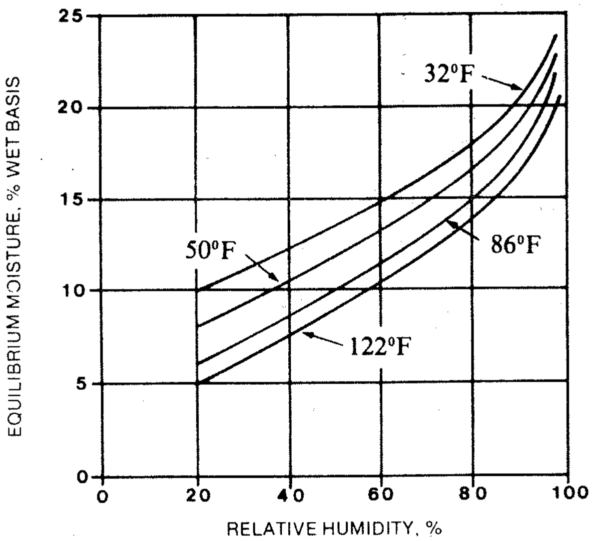
B—EQUILIBRIUM MOISTURE CONTENT, EDIBLE BEANS



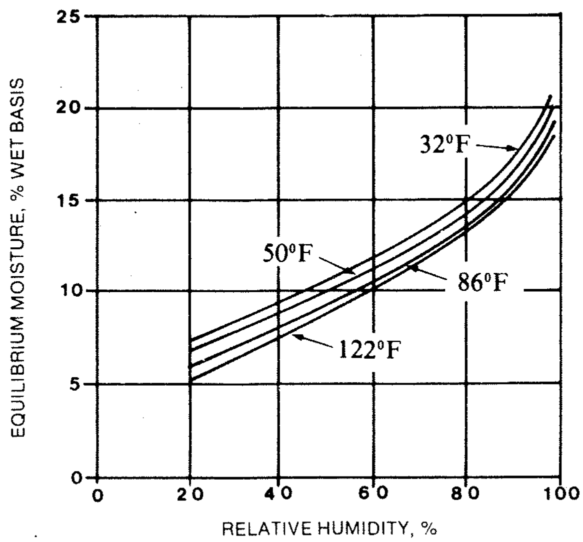
C—EQUILIBRIUM MOISTURE CONTENT, HARD WHEAT



D—EQUILIBRIUM MOISTURE CONTENT, DURUM WHEAT



E—EQUILIBRIUM MOISTURE CONTENT, YELLOW DENT CORN



F—EQUILIBRIUM MOISTURE CONTENT, BARLEY

FIGURE 2. EQUILIBRIUM MOISTURE CONTENT GRAPHS FOR SOME CROPS (ASAE D245.4)

TABLE 1. EQUILIBRIUM MOISTURE CONTENT OF SOME CROPS
(Wet Basis)

Crop	Temperature °F	Relative Humidity (%) 20	40	60	80	90
Barley	32	7.4	10.0	12.3	15.3	18.0
Oats	50	6.9	9.3	11.7	14.8	17.5
Rye	86	6.0	8.6	11.1	14.0	16.3
Edible Beans	32	7.7	10.5	13.7	17.7	20.3
	50	7.2	10.2	13.2	17.2	20.0
	86	6.7	9.5	12.5	16.5	19.2
Corn	32	9.8	12.5	15.0	18.7	21.3
	50	8.5	11.2	13.7	17.5	20.2
	86	6.5	9.2	11.8	16.0	18.5
Soybean	32	5.0	8.3	12.0	16.7	20.0
	50	4.2	7.7	11.3	16.0	19.2
	86	3.3	6.8	10.2	15.0	18.3
Durum	32	8.2	10.8	13.5	17.0	19.8
	50	7.8	10.3	13.0	16.3	19.2
	86	7.2	9.7	12.5	15.8	18.5
Hard Wheat	32	9.3	12.0	14.5	17.8	20.7
	50	8.5	11.2	13.8	17.0	20.0
	86	7.0	9.8	12.7	16.2	19.0
Confectionary Sunflower	32	5.6	8.6	11.4	14.9	17.6
	50	5.1	7.8	10.5	13.7	16.2
	86	4.4	6.8	9.1	12.0	14.2
Oil Sunflower	32	4.8	6.8	8.5	10.7	12.3
	50	4.5	6.3	8.0	10.0	11.5
	86	4.0	5.6	7.1	8.9	10.3
Flaxseed	77	5.0	6.1	7.7	11.2	14.9

Variability in weather conditions results in varying crop moisture contents. Equilibrium moisture content generally increases as the fall season progresses due to decreasing temperatures and increasing relative humidities. Climatic conditions for North Dakota are listed in Table 2. Although these can be used as a guide, actual weather conditions dictate the specific moisture content. Table 3 lists the maximum recommended moisture content for storage of some North Dakota crops.

TABLE 2. NORTH DAKOTA CLIMATIC CONDITIONS. (TEMPERATURE AND RELATIVE HUMIDITY)

Month	State		Bismarck		Devils Lake		Fargo		Williston	
	°F	%RH	°F	% RH	°F	%RH	°F	% RH	°F	% RH
January	6	72	10	68	5	75	7	71	9	74
February	10	74	13	71	9	76	11	73	13	76
March	24	73	26	67	22	77	25	76	25	72
April	42	65	44	61	40	68	42	71	43	63
May	56	60	56	60	53	63	56	63	55	57
June	64	66	65	66	62	67	65	68	63	64
July	71	64	72	62	69	67	72	69	71	62
August	69	60	70	58	67	66	70	66	69	56
September	58	65	59	62	56	68	59	72	57	60
October	47	65	42	59	44	69	47	71	46	64
November	27	73	29	67	25	78	28	76	28	73
December	13	75	18	70	12	77	15	76	18	75

TABLE 3. MAXIMUM RECOMMENDED MOISTURE CONTENT FOR STORAGE WITH AERATION OF SOME NORTH DAKOTA CROPS.

Crop	Short Term (less than 6 months)	Long Term (more than 6 months)
Barley	13%	12%
Corn	15.5%	13.5%
Durum	13.5%	12.5%
Edible Beans	14%	12%
Flaxseed	9%	7%
Millet	10%	9%
Oats	13%	12%
Rye	13%	12%
Sorghum	13.5%	13%
Soybean	13%	11%
Confectionary Sunflower	10%	9%
Oil Sunflower	10%	8%
Wheat	13.5%	12.5%

Natural-air drying requires that the drying zone be moved up and through the top of the grain within the allowable storage time (before significant deterioration occurs). The more air that is delivered, the faster the drying zone moves through the grain. The grain at the bottom of the bin will overdry in good drying weather and rewet during cool damp weather. Even though the bottom is rewetting, the drying zone continues to move upward, so operate the fan continuously until the drying zone moves through the top of the grain. Since the grain at the top of the bin is the last to dry, it is the most critical.

ALLOWABLE STORAGE OR DRYING TIME

To select an airflow rate for a natural-air drying system, information on allowable storage or drying time is used. The allowable storage time for corn is the time until 0.5 percent dry matter decomposition is reached. At that point there will be a reduction of one grade. The allowable storage time for corn is shown in Table 4 for different temperatures and moisture conditions. These data show that as moisture content or temperature increases, the allowable time for drying and storage decreases. This means that wetter or warmer grain requires higher airflow rates in order to accomplish drying within the allowable time.

Allowable storage time is cumulative. Corn at 20 percent moisture content and 60°F has an allowable storage time of 28 days (Table 4). If after five days,the corn is dried to 18 percent, the allowable storage time at 18 percent and 60°F is: $\left(\frac{28-5}{28}\right) \times 56 = 46$ **days, not 56 days.**

TABLE 4.

ALLOWABLE STORAGE TIME FOR SHELLED CORN. (DEVELOPED FROM THOMPSON, TRANSACTIONS OF ASAE 333-337, 1972.)

Grain temp. deg. F	Corn moisture, percent						
	18	20	22	24	26	28	30
				<------days---->			
30	648	321	190	127	94	74	61
35	432	214	126	85	62	49	40
40	288	142	84	56	41	32	27
45	192	95	56	37	27	21	18
50	128	63	37	25	18	14	12
55	85	42	25	16	12	9	8
60	56	28	17	11	8	7	5
65	42	21	13	8	6	5	4
70	31	16	9	6	5	4	3
75	23	12	7	5	4	3	2
80	17	9	5	4	3	2	2

The allowable storage or drying time for wheat is shown in Table 5. The same relationships exist between moisture content, temperature and allowable storage time, but the values are not the same. There should not be any serious losses during the indicated allowable storage time, but the stated times should be considered as **guidelines**, not as absolute values.

"Approximate" allowable storage time (days) for cereal grains.

	Temperature					
M.C.	30°	40°	50°	60°	70°	80°
(%)						
14	*	*	*	*	200	140
15	*	*	*	240	125	70
16	*	*	230	120	70	40
17	*	280	130	75	45	20
18	*	200	90	50	30	15
19	*	140	70	35	20	10
20	*	90	50	25	14	7
22	190	60	30	15	8	3
24	130	40	15	10	6	2
26	90	35	12	8	5	2
28	70	30	10	7	4	2
30	60	25	5	5	3	1

Based on composite of 0.5 percent maximum dry matter loss calculated on the basis of USDA research at Iowa State University; Transactions of ASAE 333-337, 1972; and "Unheated Air Drying," Manitoba Agriculture Agdex 732-1, rev. 1986.
* Approximate allowable storage time exceeds 300 days.

Allowable storage times have not been established for other crops, but estimates can be made based on the values for corn and wheat. The estimate is made by examining the equilibrium moisture content for the crop being considered and comparing that to corn or wheat. For example, the equilibrium moisture content at 50°F and 60 percent relative humidity for corn is 13.7 percent and for oil sunflower is 8.0 percent. The difference in moisture contents between the two crops is about 6 percent. As an estimate of allowable storage time for oil sunflower, add 6 percent to the corn moisture chart value. The allowable drying or storage time for oil sunflower at 14 percent and 50°F is comparable to corn at 20 percent. Checking the allowable storage time table for corn, the allowable storage time is 63 days. Therefore, the estimate of allowable storage time for oil sunflower at 50°F and 14 percent moisture content is 63 days. Wet crops may heat, so airflow and continual monitoring are required.

AIRFLOW RATES, FANS AND HORSEPOWER

Airflow is the key to natural-air drying. Airflow rates are specified in cubic feet of air per minute per bushel of grain (cfm/bu). If a fan moves 10,000 cfm through a 10,000 bushel bin of shelled corn, the airflow rate is 1 cfm/bu. Since airflow rate determines drying rate, if the airflow rate is doubled, the drying rate is doubled for the same conditions. It will take only half as long to dry.

Since the allowable storage time decreases and the amount of water to be removed increases with increased moisture content, the required airflow rate increases rapidly with increasing crop moisture contents. Also, since earlier harvest means warmer temperatures and therefore less allowable storage time, the required airflow rate for a given moisture content is higher earlier in the season. For example, 21 percent moisture content corn can be dried with 1 cfm/bu airflow, but 17 percent is the maximum for wheat at that same airflow rate. Minimum airflow rates for some crops in North Dakota are listed in Table 6.

TABLE 6.
MINIMUM RECOMMENDED AIRFLOW RATES FOR NATURAL AIR-LOW TEMPERATURE DRYING SOME CROPS IN NORTH DAKOTA.

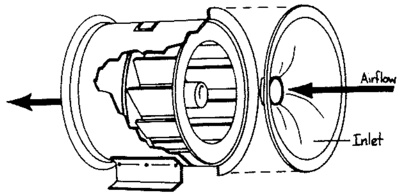
Crop	Moisture Content	cfm/bu
Barley	18%	1
Beans	20%	1
Corn	21% 23%	1 2
Oats	19%	1
Rye	17%	1
Sunflower	15% 17%	½ 1
Wheat		See inside cover

Estimated fan motor horsepowers required for various crops in various size bins at various airflow rates are shown in Appendix A. For example, at an airflow rate of 1 cfm/bu through wheat 12.5 feet deep in a 30 ft. diameter bin, the air volume is 7,069 cfm, estimated static pressure is 4.81 inches of water, and the estimated fan motor horsepower is 10.8 hp. The tables for barley can be used for oats, rye, and sunflower. The corn tables can be used for beans. Actual fan motor power required will vary depending on fan type, design, and other specifications. Find the actual airflow rate of the fan being considered from the manufacturer. Static pressure affects the airflow rate, so check the airflow rate at the static pressure estimated in the tables of Appendix A.

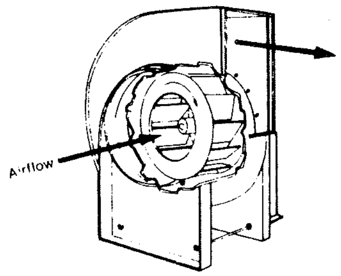
An axial-flow fan is more efficient than a centrifugal fan below about 4 inches of water static pressure while a centrifugal fan is more efficient above 4 inches of static pressure, Figure 3 and Table 7. Static pressure is the resistance to airflow measured in inches of water column. Figure 4 shows how to make a manometer for measuring static pressure. Centrifugal fans are sometimes used because they are less noisy than an axial flow fan, but centrifugal fans are more expensive.

It is not practical to move air through deep bins or at high airflow rates per bushel. Doubling the airflow rate increases the power required by about five. A 9 hp fan motor is required to move 1 cfm/bu through 12.5 feet of wheat in a 27 feet diameter bin, but a 40 hp fan motor is required to move 2 cfm/bu through the 12.5 feet of wheat in the same bin. Increasing the depth of grain also greatly increases the power required. If the depth in the previous example is increased just 2.5 feet to 15 feet, the horsepower requirement increases from 9 hp to 15 hp to move 1 cfm/bu of air. High airflow rates are only reasonable for shallow grain depths. Use large diameter, shallow bins to keep static pressure low and reduce the amount of fan power required (Figure 5).

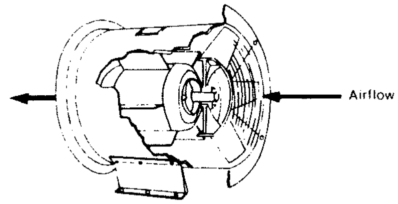
COMMON FANS USED ON GRAIN SYSTEMS



In-line centrifugal fans develop higher pressures than an axial-fan at a lower cost than a normal centrifugal fan.



Centrifugal fans require higher investment than axial-flow fans, but are more efficient at higher static pressures and are quieter. They normally operate at 1,750 or 3,500 rpm.



Axial-flow fans operate most efficiently at static pressures below 3 to 4 inches of water. Noise can be a problem.

Typical Fan Performance.

	Fan			Static Pressure (Inches of Water)									
Type	Hp	Dia.	RPM	1	2	3	4	5	6	7	8	9	10
		(in.)		Airflow Rate (cfm)									
Axial	3.0	18	3450	5700	4600	2650	1400						
LS Cent.	3.0	24	1750	4580	4230	3820	3350	2550					
HS Cent.	3.0	16	3500		2950		2550		2120		1650		1000
IL Cent.	3.0	18	3450	3800	3600	3400	3000	2500	1900				
IL Cent.	3.0	24	3450	4100	4000	3750	3500	3250	2950	2650			
Axial	5.0	24	3450	10500	9000	7000	4600	2900					
LS Cent.	5.0	24	1750	7800	7000	6250	5550	4600	3300				
HS Cent.	5.0	13	3500		4350		3850		3200		2200		1800
IL Cent.	5.0	24	3450	5500	5000	4400	4100	3900	3600	2800	1800		
Axial	7.5	24	3450	12500	11100	9450	6550	3900					
LS Cent.	7.5	24	1750	10550	9750	8950	8000	7400	6100				
HS Cent.	7.5	15	3500		5700		5100		4500		3800		2900
IL Cent.	7.5	28	3450	6200	6000	5700	5500	5200	4800	4500	4000	3500	3000
Axial	10.0	26	3450	15500	14000	12250	9500	5800	3400				
LS Cent.	10.0	27	1750	13300	12400	11550	10500	9550	8500	7300			
HS Cent.	10.0	18	3500		6800		6300		5750		5100		4450
IL Cent.	10.0	28	3450	7700	7300	6800	6500	6300	6000	5400	5100	4800	4400

LS = Low Speed Centrifugal Fan
HS = High Speed Centrifugal Fan
IL = In-Line Centrifugal Fan

* Consult a comparable table for the actual fan being selected.

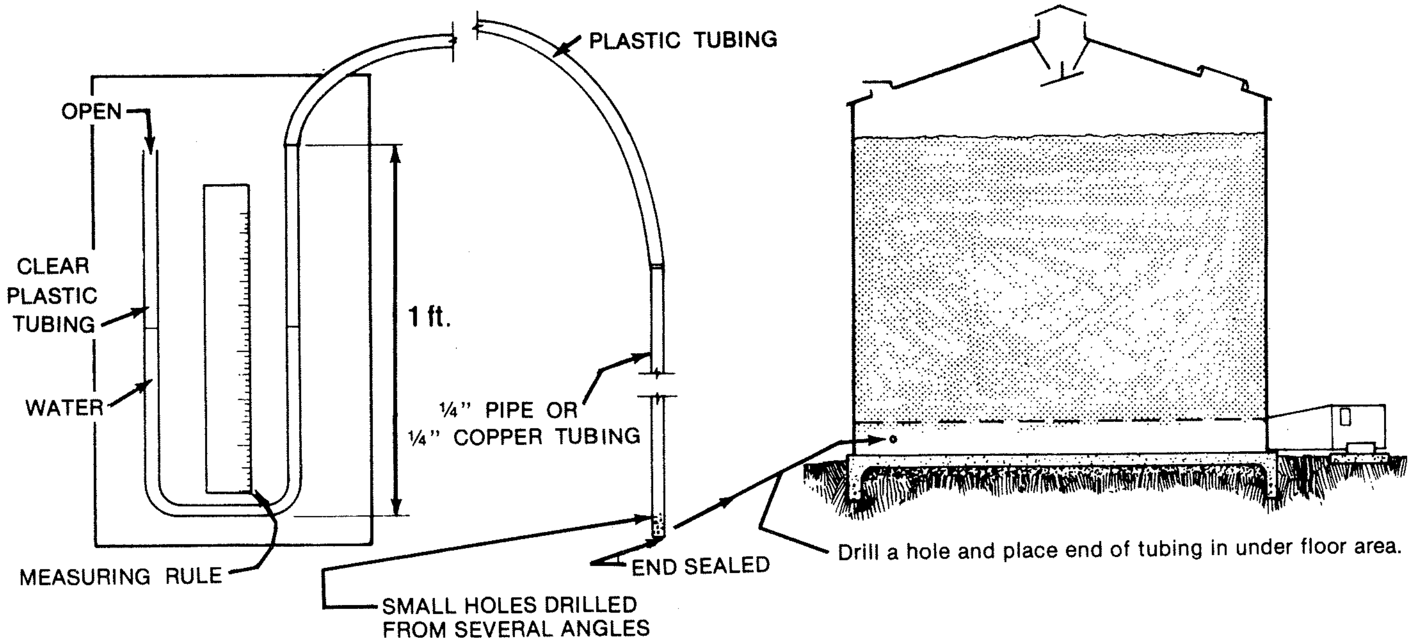
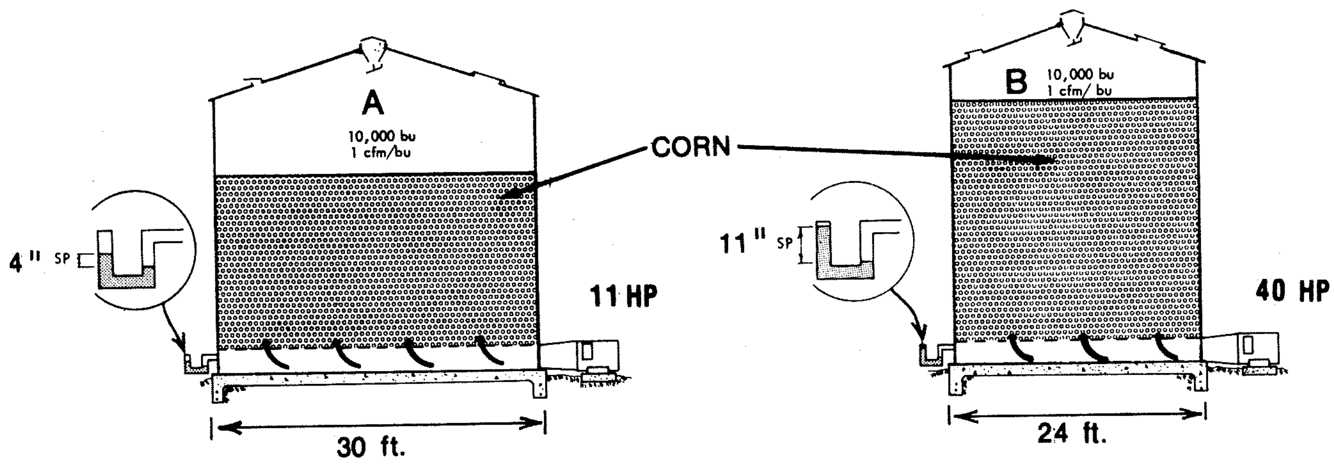


FIGURE 4. A U-TUBE MANOMETER USED FOR MEASURING STATIC PRESSURE.



For the same amount of grain and cfm/bu airflow, the larger diameter Bin A offers less resistance than the smaller diameter Bin B and requires much less fan motor power.

FIGURE 5. AIRFLOW THROUGH NARROW TALL BINS VS. WIDE SHALLOW BINS

Aeration airflow rates of 1/10 cfm/bu are also listed in the fan tables in Appendix A. This is listed just for a comparison of the motor size of drying fans versus aeration fans. Aeration is totally inadequate for drying. At 1 cfm/bu, it will take about 21 days to dry wheat in August from 17 percent to 13.5 percent. The allowable storage time for 17 percent wheat at the average August temperature of 69°F is about 38 days (Table 5). If an aeration system was used to dry the wheat with an airflow of 1/10 cfm/bu, it would take 10 times as long or 210 days. Even to remove one percentage point of moisture would take about 60 days of continuous fan operation. A detailed discussion of estimating the drying time and sizing of fans is covered in the sections titled "Estimating Drying Time" and "Selecting Fans For Situations Not Included In Fan Tables."

NATURAL AIR DRYING MANAGEMENT

Air is usually pushed up through the grain, but airflow direction does not affect drying characteristics. The reason for pushing the air up through the grain is so the drying front moves upward with the last grain to dry on the top of the bin where it is easy to monitor. The grain on the bottom of the bin would be the last dried if air was pulled down through the grain. It is more difficult to monitor wet grain in several locations on the bottom of the bin than on the top. Also, by pushing the air up, wet grain can be added to the top without rewetting all the grain below as would happen if the air was pulled through the wet grain and then through the dry grain.

Experience has shown that the best drying procedure is to operate fans continuously until the drying front has moved through the top of the grain. Do not shut the fan off in the fall during periods of rainy weather or high relative humidity. Fan operation during these periods will continue to move the drying front through the crop, plus air movement will control heating of the grain. The fan can be shut off when the drying front has moved through the top of the grain or when all the grain has been cooled to about 25°F. Air has little drying ability at temperatures near or below freezing.

The crop can be held over winter with above normal storage moisture contents by keeping it cold with aeration and with weekly observation. Check for any changes in moisture content or increase in grain temperature. Moisture migration may cause a moisture increase in the top central area of the storage. Run the drying fan a total of six to eight hours about every two weeks when the outdoor temperature is between 20 and 30°F. This is particularly important following an extended below-zero period to provide uniform grain temperatures and limit moisture migration. Cover the fan after it has been shut off to prevent air currents from flowing through the bin.

Drying can normally be safely completed in the spring, if needed. About a month is required, so the allowable storage time should be checked for spring conditions. Start drying in the spring when the equilibrium moisture content, based on climatic conditions, is slightly drier than the moisture content of the crop.

As drying progresses in the spring, temperatures become warmer and relative humidities lower, drying the crop below the drying zone to lower moisture contents. In effect, a series of drying zones passes through the crop as drying conditions improve. It may be necessary to overdry the crop in the bottom of the bin to complete drying to the desired level at the top. This is more of a problem if drying is delayed in the spring.

DRYING ZONE MOVEMENT

Since weather conditions change throughout the drying season, it is useful to look in more detail at how a drying zone progresses through the crop during the drying process. An example of the crop drying pattern for average weather conditions is shown in Figure 6. For this example, an air-flow rate of one-half cubic foot of air per minute per bushel (½ cfm/bu) or 1.5 cfm/CWT of sunflower and North Dakota climatic conditions are assumed.

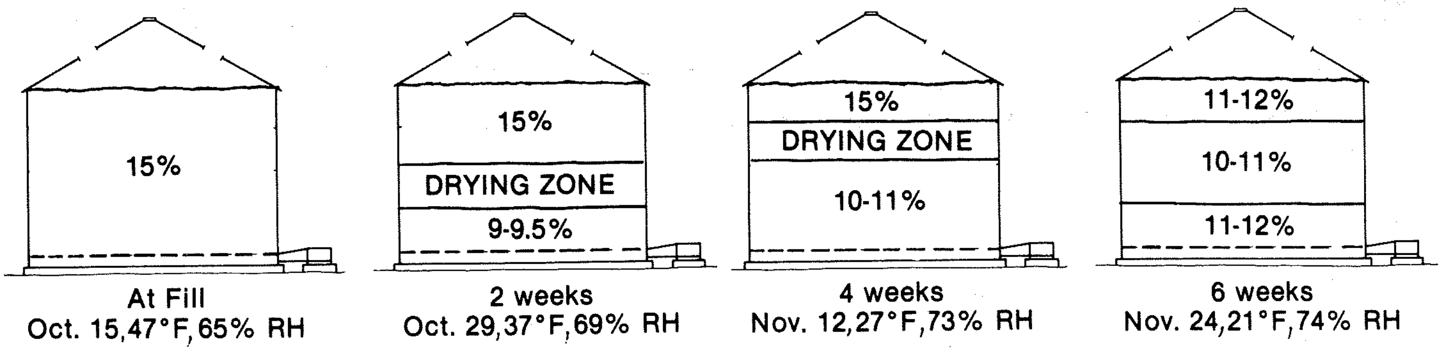


Figure 6. Oil Sunflower — Fall Drying under average weather conditions using an airflow rate of 1.5 cfm per hundredweight.

The bin is filled on a single day in the middle of October with 15 percent moisture content oil sunflower. Two weeks after the fill date the drying zone has progressed approximately one-third of the way through the sunflower with the sunflower below the drying zone at 9 to 9.5 percent moisture content. Four weeks after the fill date the drying zone is approximately two-thirds of the way through the sunflower with the sunflower below the drying zone at the 10-11 percent level. This increase in moisture content of the sunflower below the drying zone is due to changes in climatic conditions as the fall drying season progresses, leading to increased equilibrium moisture contents. About six weeks after filling, the drying zone has moved through the top of the sunflower. Note that the sunflower at the bottom of the bin has undergone additional rewetting to the 11-12 percent range due to decreasing temperatures and increasing relative humidities of the air flowing through the sunflower. It is likely that the driest sunflower will be in the middle of the bin because of the rewetting that has taken place at the bottom.

Since the drying zone has moved through the top of the sunflower, the fan is shut off for winter storage. Continued fan operation under typical late November and December weather conditions would result in further rewetting of the sunflower at the bottom of the bin with little or no useful drying at the top.

To hold the sunflower past early spring or into the summer, additional drying is necessary. Figure 7 illustrates the movement of a spring drying zone through the sunflower to complete drying. In this example, spring drying is started around April 1 with the same sunflower moisture conditions as at the end of fall drying. The equilibrium moisture content of sunflower for North Dakota climatic conditions about April 1 is 10 percent which is drier than the moisture content of the sunflower held over winter after fall drying. A spring drying zone is moving through the sunflower two weeks after spring start-up. After three weeks, the drying zone is almost two-thirds of the way through the sunflower. Five weeks after spring start-up, the drying zone has moved through the top of the sunflower to complete the spring drying.

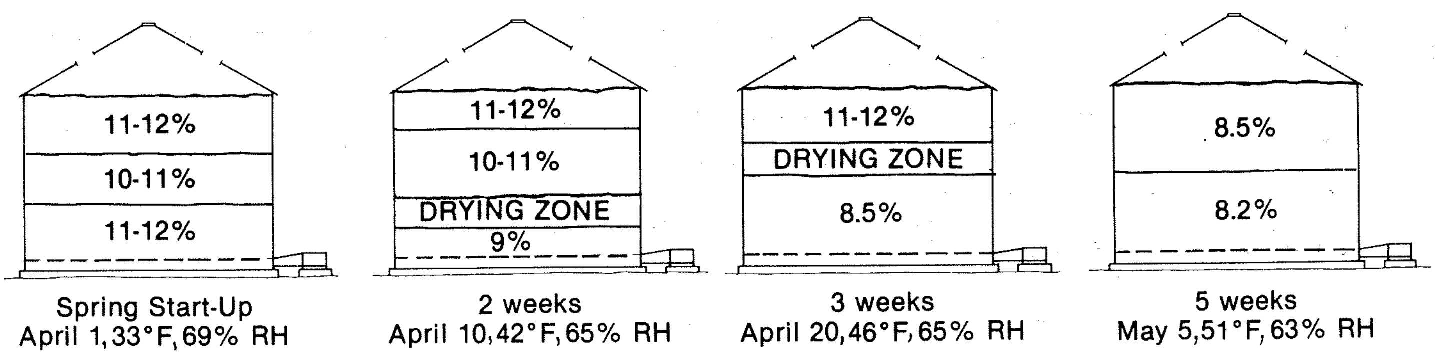


Figure 7. Oil Sunflower — Spring Drying under average weather conditions using an airflow rate of 1.5 cfm per hundredweight.

The process is the same for other crops, but the moisture contents will be different because of differences in equilibrium moisture contents. Drying corn is illustrated in Figures 8 and 9.

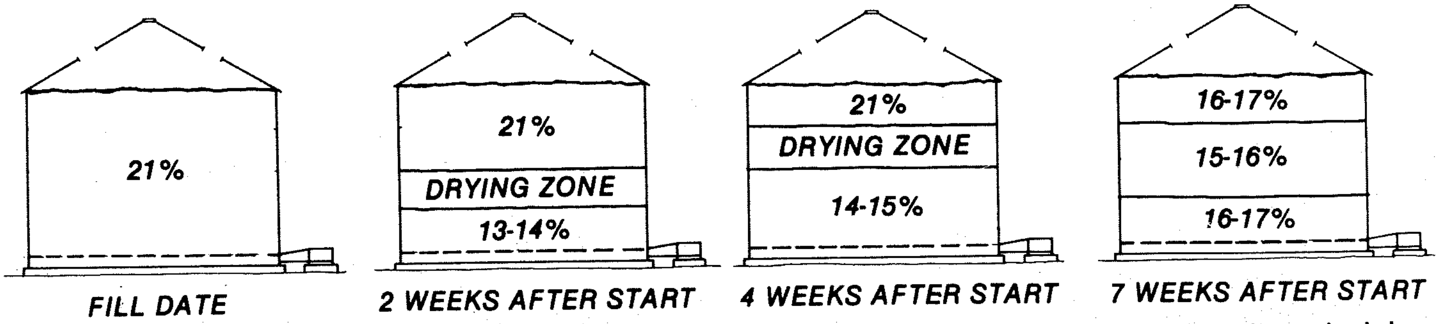


Figure 8. Example of fall drying progress for corn under average weather conditions using an airflow rate of 1.0 cfm per bushel.

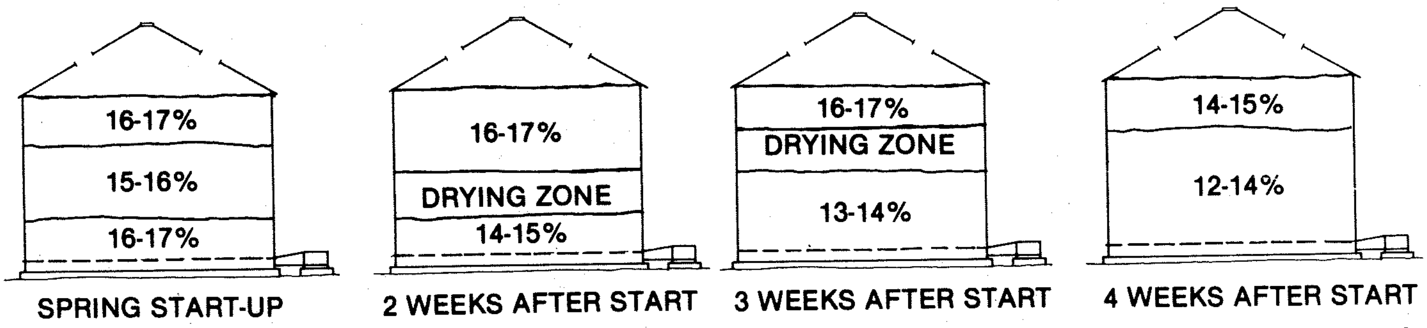


Figure 9. Example of spring drying progress for corn under average weather conditions using an airflow rate of 1.0 cfm per bushel.

SELECTING EQUIPMENT

A totally perforated floor with at least 10 percent open area or perforation is necessary to provide uniform airflow for drying. Crop that does not receive adequate airflow because the airflow is not uniform will dry much slower and may not get dry. It is difficult to get uniform airflow using ducts. Drying in a flat storage is discussed later.

It is important to locate the fan and unloading auger so airflow is not restricted (Figure 10). Especially when drying sunflower, fines may accumulate under the floor and create a fire hazard. Because of this, the underfloor area needs to be cleaned regularly. A door in the underfloor area may allow at least some of the fines under the floor to be blown out. It will also provide access to that area.

One square foot of duct cross-sectional area should be provided for each 1,500 cfm of airflow. The area under the perforated floor also needs to be sized to provide 1 square foot of cross-sectional area for each 1,500 cfm airflow. One square foot of bin exhaust opening should be provided for each 1,000 cfm of airflow. This area is required to prevent restricting the airflow. For 10,000 cfm, 10 square feet of bin exhaust opening is needed. This includes vents and eave openings.

If the ducts or openings in the bin are too small, some of the fan motor power is used to move the air through the ducts rather than through the grain, resulting in a reduced airflow rate and slower drying.

Various size transition ducts of 4 feet length were used to determine the effect on the power required for a 30 ft. diameter bin filled with 8,482 bushels of corn. The results are shown in Table 8.

TABLE 8. HORSEPOWER CHANGE DUE TO CHANGE IN DUCT AREA.

4 Feet Long Duct					
Duct Area (ft^2)	Air Velocity (cfm/ft^2)	Pressure Loss through Duct (In. H_2O)	Pressure Loss Through Grain (In. H_2O)	Hp	Hp Change (%)
5.33	1590	0.195	2.00	5.87	—
3.89	2181	0.364	2.00	6.32	7.7
3.17	2679	0.560	2.00	6.85	16.7

The horsepower required increased about 1 percent for each 50 cfm/ft² increase in velocity due to a smaller duct. The horsepower change from 5.87 to 6.85 did not increase the airflow rate through the corn because all the additional power was used to move the air through a smaller duct.

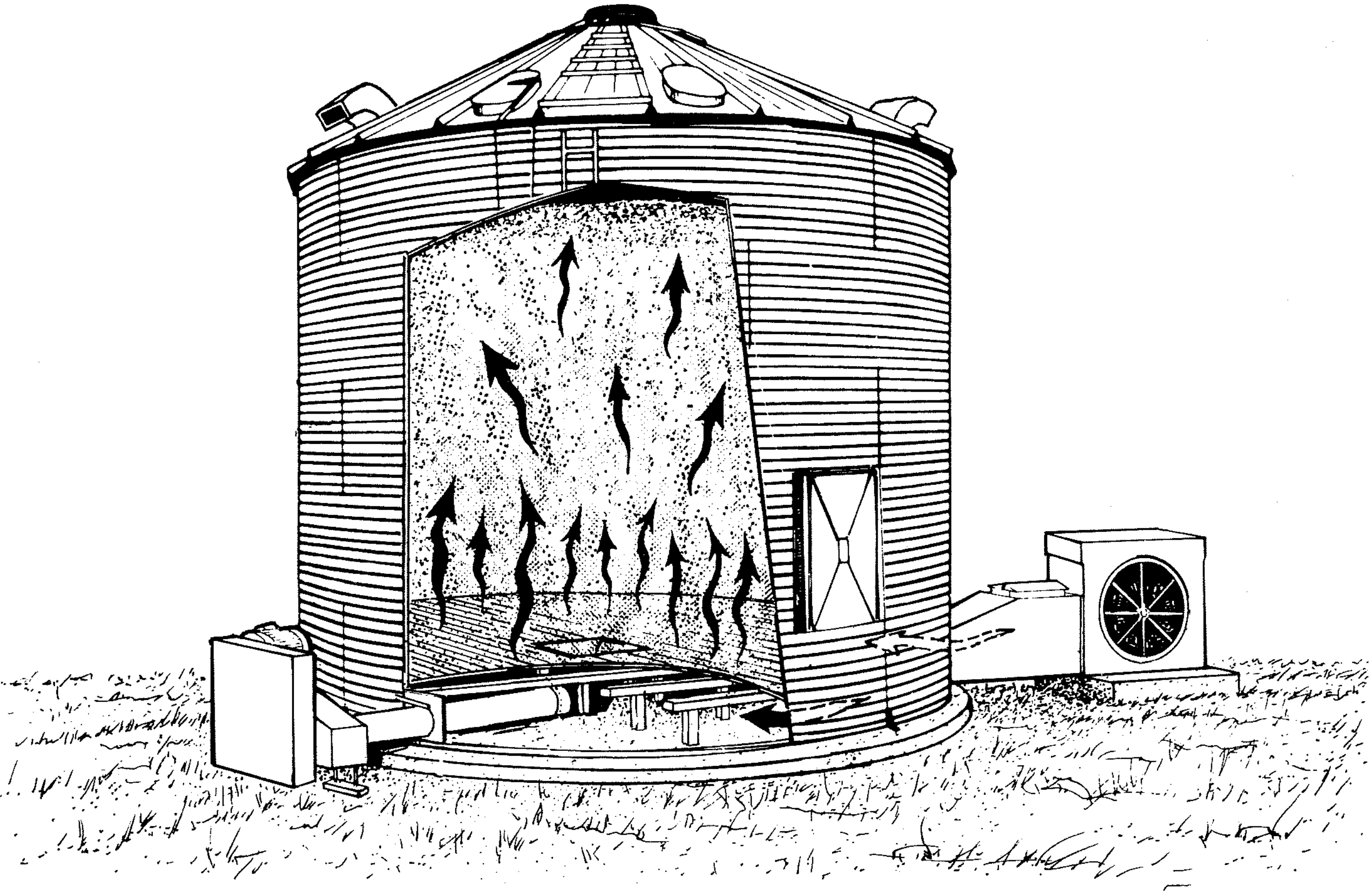


Figure 10. Drying Bin Showing Equipment.

SUPPLEMENTAL HEAT

Addition of supplemental heat to the air decreases the final moisture content of the grain. The airflow rate affects the time required to dry or the drying rate.

The effect of heating the air can be determined. Heating the air 10°F will reduce the relative humidity about one-fourth and heating the air 5°F will reduce the relative humidity about one-eighth. If air is 40°F and 80 percent relative humidity, heating it 10° to 50°F will reduce the relative humidity to about 60 percent; $80 \div 4 = 20$, $80 - 20 = 60$. Using the air temperature and relative humidity of the air after it has been heated, the crop equilibrium moisture content (EMC) can be determined from Table 1 and Figure 2.

Based on the equilibrium moisture content, oil sunflower will natural-air dry to 10.7 percent if the air is 32°F and 80 percent relative humidity. If that air is heated to 42°F, the relative humidity will be reduced to about 55 percent. By using the heated air, the sunflower will dry to 7.5 percent, approximately the recommended storage moisture content. Hard wheat will dry to about 13.5 percent with air at 70°F and 60 percent relative humidity. If the air is heated to 80°F, the relative humidity will be reduced to 43 percent. The EMC of hard wheat for the heated air condition, 80°F and 43 percent relative humidity, is about 10 percent. By heating the air, the wheat will be greatly overdried.

Drying systems commonly available have an electric heater or a small propane burner capable of increasing the air temperature about 10-20°F. Generally, the temperature increase needed is about 5-10°F. Electricity used by the fan motor is also converted to heat and is utilized. The heat added due to the electricity input to the fan motor usually results in a 1-3°F temperature rise in the drying air.

The amount of heat required can be determined from the equation: BTU/hr. = cfm x 1.08 x temperature increase desired, °F. To increase the temperature of 5,000 cfm by 10°F, a heater capable of delivering 5,000 cfm x 1.08 x 10°F = 54,000 BTU/hr is required. Since 1 KW = 3,413 BTU/hr., this would be equivalent to a 54,000 ÷ 3,413 = 16 KW electric heater.

There are two ways to dry the crop to the desired moisture content when drying cannot be done using natural air in the fall:

1. Add just enough heat as the weather conditions change in the fall to achieve the desired moisture content based on the EMC.

2. Finish drying to the long term storage moisture content in the spring. The allowable storage time will indicate how wet the crop can be to be stored during cold temperatures as well as the time available for spring drying.

The cost to dry is comparable for the two methods. Corn dried near Bismarck, North Dakota in 1972, a poorer than average year for drying, required 1542 BTU per pound of water removed. Only enough heat was added **when needed** to dry the corn from 20 to 15½ percent. Corn dried without heat was held over winter at 16 percent and drying completed in the spring. Drying this corn required 1459 BTU per pound of water removed. The electric use for fan and heater was 1.78 KWH per bushel compared to 1.70 KWH per bushel for corn dried without a heater. At 5 cents per KWH this is a difference of 0.4 cent per bushel or $40 on 10,000 bushels of corn.

GRAIN CLEANING AND LEVELING

Fine material in the grain increases the resistance to airflow, which reduces total airflow and slows drying (Figure 11). Foreign material is usually wetter than the grain, so it may cause problem spots. Screening is highly desirable for natural-air drying. Since fines tend to accumulate in the center, unloading some grain from the center when the bin is full will be beneficial.

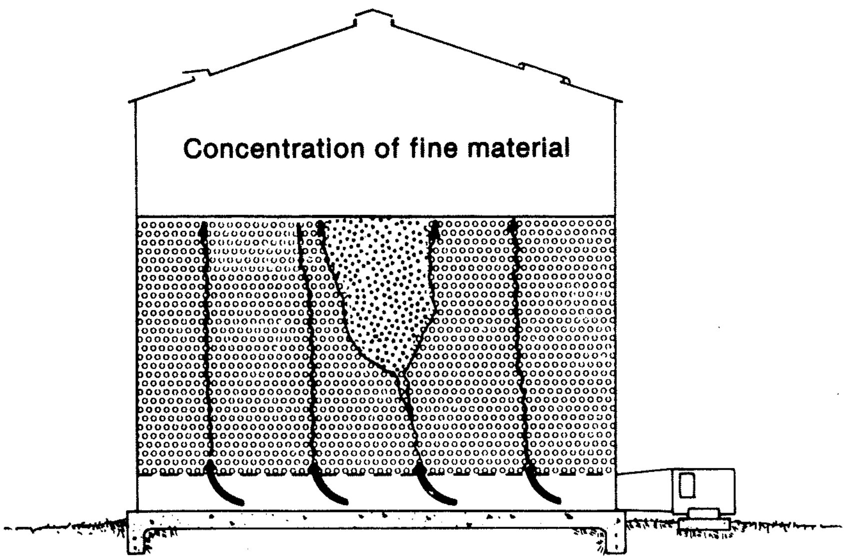


Figure 11. Broken grain and foreign material increase resistance. They concentrate under the spout and reduce airflow to the "dirty" area. Clean the grain and use a spreader to minimize this problem.

Keep the grain surface level to promote uniform airflow. Grain spreading devices can help distribute the grain and fines. Hand level when you have finished adding grain to the bin. In fact, because resistance to airflow is typically greater in the center of the bin than at the outer edges due to increased levels of fine material in the center, "dishing out" the center of the bin is usually beneficial. Where possible, drawing grain out of the center unloading hopper of the bin helps to reduce the amount of grain to be moved when leveling or "dishing out" the center. It also removes some of the fine material in the center of the bin.

STIRRING GRAIN FOR NATURAL AIR DRYING

In-bin stirring machines were originally developed for high-speed bin drying systems where drying air temperatures of 100-140°F were used with airflow rates of 10-20 cfm/bu. Recently these devices have been suggested for natural-air drying.

Advantages include:

—Reducing the deterioration rate of the grain at the top of the bin by mixing;
—providing a uniform moisture content throughout the bin which reduces the overdrying problem;
—increasing the airflow rate due to the loosening action during mixing.

Disadvantages of using stirring devices for natural air systems include:

—Increased investment, operating, and maintenance cost for the stirring device;
—unstirred portion along binwall may spoil if drying front does not advance rapidly enough to dry it within the allowable storage time because this area does not get as much airflow as the stirred grain;
—loss of storage space in the bin taken up by the stirring device;
—reduction in airflow if the crop is overstirred with fine material settling to the bottom.

It is questionable if the advantages of stirring outweigh the disadvantages when investing in new equipment. If natural-air drying is practiced in a bin already equipped with a stirring device, stirring every 7-14 days reduces deterioration at the top and redistributes moist grain. Periodic operation helps to avoid overstirring. Although stirring reduces the deterioration rate of the grain at the top of the bin, care is needed in handling higher moisture contents at natural air drying airflow rates. Remember to determine allowable storage time and monitor the drying closely. Problems may be encountered when attempting to start up the stirring device when the bin is full due to large starting torque and the pull of the stirring device.

SELECTING FANS FOR SITUATIONS NOT INCLUDED IN FAN TABLES

The fan tables in Appendix A do not include values for every situation, so it may be necessary to calculate an estimated fan motor size required. Two items are needed for the estimate; airflow rate and static pressure. Airflow rate is determined by the amount of crop being dried and the required airflow rate per bushel. If 10,000 bushels of 20 percent moisture content corn is being dried, then 10,000 cfm is required based on 1 cfm/bu (Table 6).

Static pressure, the resistance to airflow measured in inches of water column, can be estimated for some crops using the charts in Figures 12, 13 and 14. For example, the static pressure for an airflow rate of 1 cfm/bu airflow through 17.6 feet of corn is 3.4 inches of water (Figure 12). These charts are for uncleaned crops and include the static pressure normally caused by equipment such as ducts.

Estimated fan power is determined using the following equation: $Hp = \frac{\text{cfm} \times \text{total static pressure}}{6320 \times \text{fan efficiency}}$

Fan efficiency will vary but 50 percent is a good estimate. The estimated horsepower required for drying the 10,000 bushels of corn is $HP = \frac{10{,}000 \times 3.4}{6320 \times 0.50} = 11$ Hp. This compares to the 11.4 horsepower estimate from the fan table in Appendix A, for corn in a 30 ft. diameter bin, 17.5 ft. deep, at 1 cfm/bu. Actual fan performance will depend on fan design, so consult the manufacturer's airflow rating for each fan being considered.

If 10,000 bushels of sunflower are dried in that same bin, only 5,000 cfm are required at ½ cfm/bu. Referring to Figure 13 at ½ cfm/bu and 17.6 ft. of depth, the static pressure is 2.8 inches of water. The fan motor power required is: $HP = \frac{5000 \times 2.8}{6320 \times 0.50} = 4.4$ Hp. This compares to the 4.3 Hp listed in the barley fan table in Appendix A, for barley in a 30 ft. diameter bin, 17.5 ft. deep at ½ cfm/bu.

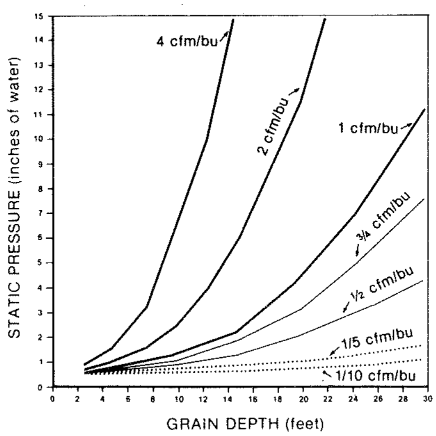


Figure 12. Static pressure for shelled corn at selected airflows. This may be used for beans. (Shedd × 1.5) + 0.5

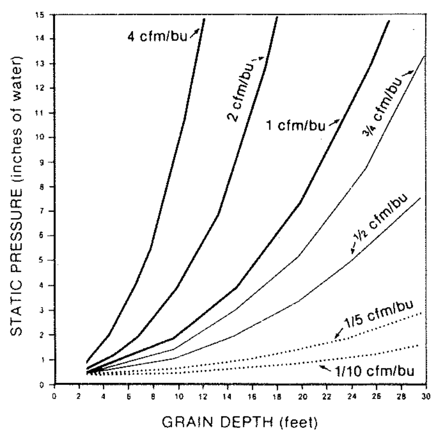


Figure 13. Static pressure for barley at selected airflows. This may be used for oats, rye, and sunflower. (Shedd × 1.5) + 0.5

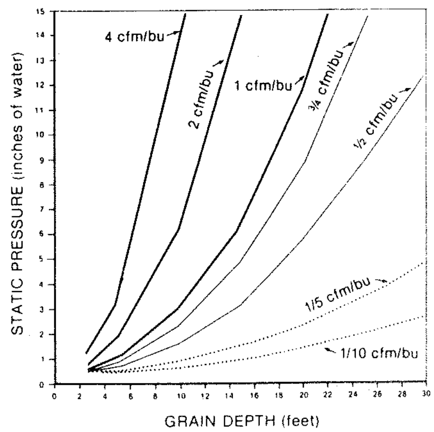


Figure 14. Static pressure for wheat at selected airflows. (Shedd × 1.5) + 0.5

SHRINKAGE

Drying removes water causing a reduction in both weight and volume which is referred to as shrinkage. The terminology of wet bushels and dry bushels are used to refer to the volume before and after drying. The term bushel may be confusing because by definition, a bushel is 1.244 ft^3; a standard volume, but also a bushel is a standard weight. Corn is marketed at 56 pounds per bushel at 15.5 percent moisture content. However, if the corn is at 20 percent moisture, 1.244 ft^3 of corn will not weigh 56 pounds. That bushel, 1.244 ft^3, will weigh less than 56 pounds. Really what is needed is to know how many pounds of corn at 20 percent moisture content are needed to give a 56 pound bushel of corn after being dried to 15.5 percent. This information is given in Table 9.

For corn at 20 percent moisture content, 59.15 pounds of corn are needed, so that after drying to 15.5 percent one bushel will weigh 56 pounds.

The "wet" weights can be calculated for crops not listed or for different crop weights than listed in Table 9 by using Table 10. To determine the "wet" weight for 20 percent moisture content corn, find the factor listed in Table 10 for an initial moisture content of 20 percent and final moisture content of 15.5 percent. The factor is 94.67. If corn weighs 56 pounds at 15.5 percent moisture content, the weight at 20 percent is

$\frac{56 \times 100}{94.67} = 59.15$ pounds. It will take 59.15 pounds of corn at 20 percent to equal one bushel or 56 pounds.

If the corn is dried to 10 percent, only 52.58 pounds is left of the 56 pound one bushel at 15.5 percent based on Table 9. This can also be calculated from Table 10 using the factor 93.88 found for initial moisture content of 15.5 percent and final 10 percent $(\frac{93.88 \times 56}{100} = 52.57)$.

Overdrying is costly. Corn at 10 percent moisture content is 56—52.58 = 3.42 pounds less than corn at 15.5 percent. Corn at $2.50 per bushel is 4.5 cents per pound, so there is a market loss of $4.5 \times 3.42 = 15.4$ cents per bushel. There is also the cost of drying which would be about 5 cents/bu for a total cost of overdrying of 20.4 cents per bushel.

ESTIMATING DRYING TIME

Drying time will be about 3 to 5 weeks using the recommended minimum airflow rates. For those that want to estimate the drying time, the process is described here.

Drying time is dependent on the amount of water removed, the airflow rate, and the condition of the air. Removing more water takes more time so this is very important in determining the amount of time rquired to dry the crop.

The equation for estimating drying time is: $\text{Drying time (days)} = \frac{3.47 \times \text{pounds of water removed} \times \text{air specific volume}}{(\text{air temperature in} - \text{air temperature out}) \times \text{cfm}}$

The following example determines estimated drying time for drying 5,000 bushels of 18 percent moisture content wheat in North Dakota in July.

Referring to Table 2, the climatic conditions for July in North Dakota are 71°F and 64 percent relative humidity. Based on those conditions, the equilibrium moisture content for hard wheat is about 14 percent, Table 1 or Figure 2. Therefore, the wheat will dry to about 14 percent moisture content. The amount of water removed is determined from Table 9. Wheat at 18 percent is 63.30 pounds and at 14 percent is 60.35 pounds. So 2.95 pounds of water are removed from each "dry" bushel of wheat. In drying 5,000 bushels, $5000 \times 2.95 = 14{,}750$ pounds of water must be removed. This is 1,771 gallons of water.

The specific volume of the air is found in **Figure 15, Example 1.** The air temperature is shown at the bottom with 71°F shown with an arrow. The relative humidities are shown as curved lines. 71°F and 64 percent relative humidity is the intersection of temperature and humidity shown as dot "A". The dot is between the lines for 13.5 ft^3/lb of air and 14.0 ft^3/lb of air which are circled at the bottom. The air specific voume is 13.6 ft^3 of air per pound of air.

The air temperature into the grain is the outside temperature of 71°F. The air temperature out of the grain, exit air temperature, is found in a two step process. First, the exit air relative humidity is found from Table 1 or Figure 2. The wheat is at 18 percent moisture content and 71°F. Eighteen percent moisture content at 71°F is about halfway between a relative humidity of 80 and 90 percent so the exit air relative humidity is about 85 percent. The second step in finding the exit air temperature is to follow the diagonal line on Figure 15, emphasized with dashes for example 1, from 71°F and 64 percent relative humidity to 85 percent relative humidity, dot "B". The exit air temperature of 66°F is then read by following the temperature line either up or down.

Now everything is known except the airflow. At 1 cfm/bu, the required airflow is 5,000 cfm. The drying time is now calculated from the equation: $\text{Time} = \frac{3.47 \times 14{,}750 \times 13.6}{(71\text{-}66) \times 5{,}000} = 27.8 \text{ days}$.

The estimated drying time is about 28 days. The allowable storage time from Table 5 is about 21 days. This shows that 1 cfm/bu for 18 percent moisture wheat is borderline. It would be safer to bin the wheat and start natural air drying at 17 percent moisture content. Adding heat would lower the final moisture content causing overdrying but reduce the drying time only slightly. Increasing the airflow rate from 1 cfm/bu to 1.5 cfm/bu would reduce the drying time to about 19 days but also increase the required fan horsepower from about 7.5 hp to 14 hp.

TABLE 9. WET WEIGHTS TO EQUAL A BUSHEL AT STANDARD MOISTURE CONTENTS.

Moisture Content	Wheat	Sunflower			Corn	Barley	Oats	Rye	Beans
		CWT	Oil	Confectionary					
5.0	54.63	94.73	28.42	22.74	49.81	43.20	30.78	50.69	54.95
5.5	54.92	95.24	28.57	22.86	50.07	43.43	30.94	50.96	55.24
6.0	55.21	95.74	28.72	22.98	50.34	43.66	31.11	51.23	55.53
6.5	55.51	96.26	28.88	23.10	50.61	43.89	31.27	51.51	55.83
7.0	55.81	96.78	29.03	23.23	50.88	44.13	31.44	51.79	56.13
7.5	56.11	97.30	29.19	23.35	51.16	44.37	31.61	52.07	56.43
8.0	56.42	97.83	29.35	23.48	51.44	44.61	31.78	52.35	56.74
8.5	56.72	98.36	29.51	23.61	51.72	44.85	31.96	52.63	57.05
9.0	57.03	98.90	29.67	23.74	52.00	45.10	32.13	52.92	57.36
9.5	57.35	99.45	29.84	23.87	52.29	45.35	32.31	53.22	57.68
10.0	57.67	100.00	30.00	24.00	52.58	45.60	32.49	53.51	58.00
10.5	57.99	100.56	30.17	24.13	52.87	45.85	32.67	53.81	58.32
11.0	58.31	101.12	30.34	24.27	53.17	46.11	32.85	54.11	58.65
11.5	58.64	101.69	30.51	24.41	53.47	46.37	33.04	54.42	58.98
12.0	58.97	102.28	30.68	24.55	53.77	46.64	33.23	54.73	59.32
12.5	59.31	102.86	30.86	24.67	54.08	46.90	33.42	55.04	59.65
13.0	59.65	103.46	31.04	24.83	54.39	47.17	33.61	55.36	60.00
13.5	60.00	104.05	31.21	24.97	54.71	47.45	33.80	55.68	60.35
14.0	60.35	104.66	31.40	25.12	55.02	47.72	34.00	56.00	60.70
14.5	60.70	105.26	31.58	25.26	55.35	48.00	34.20	56.33	61.06
15.0	61.06	105.89	31.77	25.41	55.67	48.28	34.40	56.66	61.41
15.5	61.43	106.52	31.96	25.56	56.00	48.57	34.61	57.00	61.78
16.0	61.79	107.15	32.14	25.72	56.33	48.86	34.81	57.34	62.14
16.5	62.16	107.79	32.34	25.87	56.67	49.15	35.02	57.68	62.52
17.0	62.53	108.44	32.53	26.02	57.01	49.45	35.23	58.03	62.89
17.5	62.91	109.10	32.73	26.18	57.36	49.75	35.44	58.38	63.28
18.0	63.30	109.76	32.93	26.34	57.71	50.05	35.66	58.74	63.66
18.5	63.69	110.44	33.13	26.50	58.06	50.36	35.88	59.10	64.05
19.0	64.08	111.11	33.33	26.67	58.42	50.67	36.10	59.46	64.45
19.5	64.47	111.81	33.54	26.83	58.78	50.98	36.32	59.83	64.85
20.0	64.88	112.51	33.75	27.00	59.15	51.30	36.55	60.20	65.25
21.0	65.70	113.93	34.18	27.34	59.90	51.95	37.01	60.96	66.08
22.0	66.54	115.39	34.62	27.69	60.67	52.62	37.49	61.75	66.93
23.0	67.41	116.89	35.07	28.05	61.45	53.30	37.98	62.55	67.80
24.0	68.29	118.43	35.53	28.42	62.26	54.01	38.47	63.37	68.69
25.0	69.20	120.00	36.00	28.80	63.09	54.73	38.99	64.22	69.61
26.0	70.14	121.62	36.49	29.19	63.95	55.47	39.52	65.09	70.55
27.0	71.10	123.29	36.99	29.59	64.82	56.22	40.06	65.98	71.51
28.0	72.10	125.00	37.50	30.00	65.72	57.00	40.61	66.89	72.51
29.0	73.10	126.77	38.03	30.43	66.65	57.80	41.19	67.84	73.53
30.0	74.15	128.58	38.58	30.86	67.60	58.63	41.77	68.80	74.58

TABLE 10. SHRINKAGE FACTORS (NDSU EXTENSION CIRCULAR AE-94 GRAIN DRYING TABLES)

Initial Moisture	Final Moisture Content 9	9.5	10	10.5
35	71.43	71.82	72.22	72.62
34	72.52	72.92	73.33	73.74
33	73.62	74.03	74.44	74.86
32	74.72	75.13	75.55	75.97
31	75.82	76.24	76.66	77.09
30	76.92	77.34	77.77	78.21
29	78.02	78.45	78.88	79.32
28	79.12	79.55	80.00	80.44
27	80.21	80.66	81.11	81.56
26	81.31	81.76	82.22	82.68
25	82.41	82.87	83.33	83.79
24	83.51	83.97	84.44	84.91
23	84.61	85.08	85.55	86.03
22	85.71	86.18	86.66	87.15
21	86.81	87.29	87.77	88.26
20	87.91	88.39	88.88	89.38
19.5	88.46	88.95	89.44	89.94
19	89.01	89.50	90.00	90.50
18.5	89.56	90.05	90.55	91.06
18	90.10	90.60	91.11	91.62
17.5	90.65	91.16	91.66	92.17
17	91.20	91.71	92.22	92.73
16.5	91.75	92.26	92.77	93.29
16	92.30	92.81	93.33	93.85
15.5	92.85	93.37	93.88	94.41
15	93.40	93.92	94.44	94.97
14.5	93.95	94.47	95.00	95.53
14	94.50	95.02	95.55	96.08
13.5	95.05	95.58	96.11	96.64
13	95.60	96.13	96.66	97.20
12.5	96.15	96.68	97.22	97.76
12	96.70	97.23	97.77	98.32

Initial Moisture	Final Moisture Content 11	11.5	12	12.5
35	73.03	73.44	73.86	74.28
34	74.15	74.57	75.00	75.42
33	75.28	75.70	76.13	76.57
32	76.40	76.83	77.27	77.71
31	77.52	77.96	78.40	78.85
30	78.65	79.09	79.54	80.00
29	79.77	80.22	80.68	81.14
28	80.89	81.35	81.81	82.28
27	82.02	82.48	82.95	83.42
26	83.14	83.61	84.09	84.57
25	84.26	84.74	85.22	85.71
24	85.39	85.87	86.36	86.85
23	86.51	87.00	87.50	88.00
22	87.64	88.13	88.63	89.14
21	88.76	89.26	89.77	90.28
20	89.88	90.39	90.90	91.42
19.5	90.44	90.96	91.47	92.00
19	91.01	91.52	92.04	92.57
18.5	91.57	92.09	92.61	93.14
18	92.13	92.65	93.18	93.71
17.5	92.69	93.22	93.75	94.28
17	93.25	93.78	94.31	94.85
16.5	93.82	94.35	94.88	95.42
16	94.38	94.91	95.45	96.00
15.5	94.94	95.48	96.02	96.57
15	95.50	96.04	96.59	97.14
14.5	96.06	96.61	97.15	97.71
14	96.62	97.17	97.72	98.28
13.5	97.19	97.74	98.29	98.85
13	97.75	98.30	98.86	99.42
12.5	98.31	98.87	99.43	—
12	98.87	99.43	—	—

Initial Moisture	Final Moisture Content 13	13.5	14	14.5
35	74.71	75.14	75.58	76.20
34	75.86	76.30	76.74	77.19
33	77.01	77.45	77.90	78.36
32	78.16	78.61	79.06	79.53
31	79.31	79.76	80.23	80.70
30	80.45	80.92	81.39	81.87
29	81.60	82.08	82.55	83.04
28	82.75	83.23	83.72	84.21
27	83.90	84.39	84.88	85.38
26	85.05	85.54	86.04	86.54
25	86.20	86.70	87.20	87.71
24	87.35	87.86	88.37	88.88
23	88.50	89.01	89.53	90.05
22	89.65	90.17	90.69	91.22
21	90.80	91.32	91.86	92.39
20	91.95	92.48	93.02	93.56
19.5	92.52	93.06	93.60	94.15
19	93.10	93.64	94.18	94.73
18.5	93.67	94.21	94.76	95.32
18	94.25	94.79	95.34	95.90
17.5	94.82	95.37	95.93	96.49
17	95.40	95.95	96.51	97.07
16.5	95.97	96.53	97.09	97.66
16	96.55	97.10	97.67	98.24
15.5	97.12	97.68	98.25	98.83
15	97.70	98.26	98.83	99.41
14.5	98.27	98.84	99.41	—
14	98.85	99.42	—	—
13.5	99.42	—	—	—
13	—	—	—	—
12.5	—	—	—	—
12	—	—	—	—

Initial Moisture	Final Moisture Content 15	15.5	16	16.5
35	76.47	76.92	77.38	77.84
34	77.64	78.10	78.57	79.04
33	78.82	79.28	79.76	80.23
32	80.00	80.47	80.95	81.43
31	81.17	81.65	82.14	82.63
30	82.35	82.84	83.33	83.83
29	83.52	84.02	84.52	85.02
28	84.70	85.20	85.71	86.22
27	85.88	86.39	86.90	87.42
26	87.05	87.57	88.09	88.62
25	88.23	88.75	89.28	89.82
24	89.41	89.94	90.47	91.01
23	90.58	91.12	91.66	92.21
22	91.76	92.30	92.85	93.41
21	92.94	93.49	94.04	94.61
20	94.11	94.67	95.23	95.80
19.5	94.70	95.26	95.83	96.40
19	95.29	95.85	96.42	97.00
18.5	95.88	96.44	97.02	97.60
18	96.47	97.04	97.61	98.20
17.5	97.05	97.63	98.21	98.80
17	97.64	98.22	98.80	99.40
16.5	98.23	98.81	99.40	—
16	98.82	99.40	—	—
15.5	99.41	—	—	—

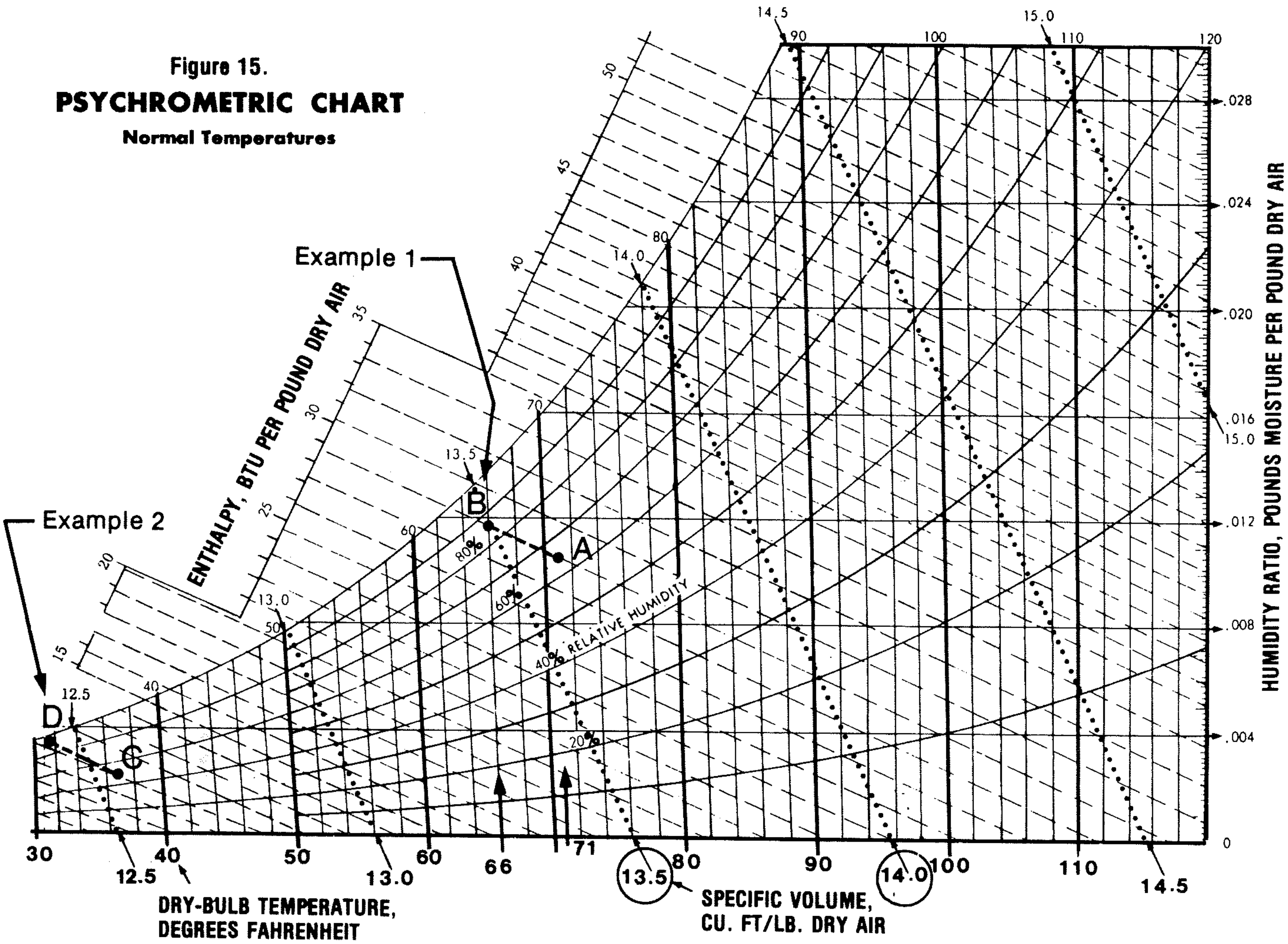
Initial Moisture	Final Moisture Content 17	17.5	18	18.5
35	78.31	78.78	79.26	79.75
34	79.51	80.00	80.48	80.98
33	80.72	81.21	81.70	82.20
32	81.92	82.42	82.92	83.43
31	83.13	83.63	84.14	84.66
30	84.33	84.84	85.36	85.88
29	85.54	86.06	86.58	87.11
28	86.74	87.27	87.80	88.34
27	87.95	88.48	89.02	89.57
26	89.15	89.69	90.24	90.79
25	90.36	90.90	91.46	92.02
24	91.56	92.12	92.68	93.25
23	92.77	93.33	93.90	94.47
22	93.97	94.54	95.12	95.70
21	95.18	95.75	96.34	96.93
20	96.38	96.96	97.56	98.15
19.5	96.98	97.57	98.17	98.77
19	97.59	98.18	98.78	99.38
18.5	98.19	98.78	99.39	—
18	98.79	99.39	—	—
17.5	99.39	—	—	—
17	—	—	—	—
16.5	—	—	—	—
16	—	—	—	—
15.5	—	—	—	—

Initial Moisture	Final Moisture Content 19	19.5
35	80.24	80.74
34	81.48	81.98
33	82.71	83.22
32	83.95	84.47
31	85.18	85.71
30	86.41	86.95
29	87.65	88.19
28	88.88	89.44
27	90.12	90.68
26	91.35	91.92
25	92.59	93.16
24	93.82	94.40
23	95.06	95.65
22	96.29	96.89
21	97.53	98.13
20	98.76	99.37
19.5	99.38	—
19	—	—
18.5	—	—
18	—	—
17.5	—	—
17	—	—
16.5	—	—
16	—	—
15.5	—	—

Figure 15.

PSYCHROMETRIC CHART

Normal Temperatures



Example 2:

Dry 5,000 bushels of oil sunflower at 15 percent moisture content in November in North Dakota.

Table 2 . . . 27°F . . . 73% Rh **Table 1 . . . Equilibrium Moisture Content . . . 10%**

This is above the recommended safe moisture content for long term storage of oil sunflower. The moisture content can be changed by heating the air. Heating the air 10°F reduces the relative humidity about one-fourth. (See section on supplemental heat). Heated air conditions are then 37°F and 50 percent relative humidity; dot "C" on Figure 15.

Equilibrium Moisture Content = 8%

Table 10. . . 15% = 31.77 lbs.
− 8% = 29.35 lbs.

2.42 × 5,000 bu. = 12,100 pounds of water

Figure 15 indicates air volume is based on the air conditions going through the fan, not after the heater. Specific Volume = 12.3 ft³ per pound of air for 27°F and 73% relative humidity.

Table 1. Exit Air Relative Humidity 95%

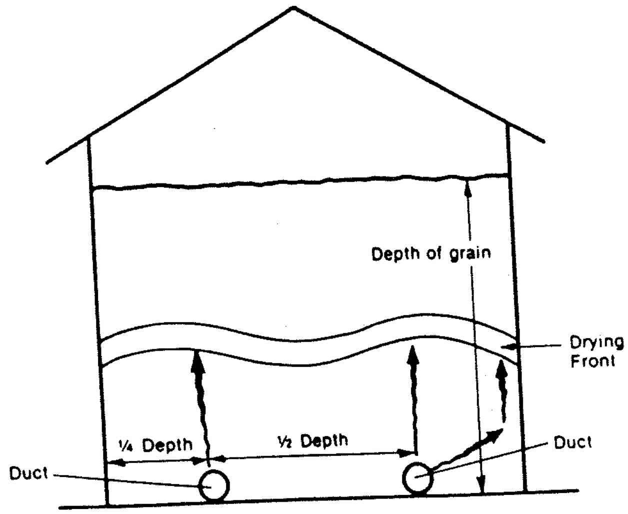
Figure 15. Exit air temperature 31°F, dot "D". Airflow rate ½ cfm/bu = 2500 cfm

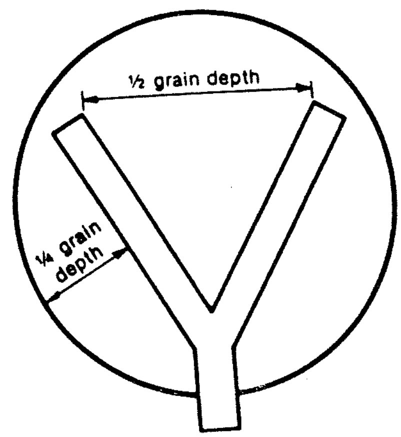
$$t = \frac{3.47 \times 12{,}100 \times 12.3}{(37\text{-}31) \times 2{,}500} = 34.4 \text{ days}$$

Table 4. Allowable storage time = 84 days
15% sunflower is about equivalent to 22 percent corn. (See discussion on allowable storage time.)

Drying with Ducts

Use the recommendations for duct placement as shown in the figure below. Provide one square foot of duct cross-sectional area for each 2,000 cfm and one square foot of perforated area for each 30 cfm in bins. In flat storage, provide at least one square foot of duct cross-sectional area for each 1,500 cfm. A fan blowing into the duct creates better airflow distribution uniformity than when the fan pulls the air from the duct in flat storage. However, there will still be considerable variation in airflow from the duct with as much as twice as much air coming from some areas as from other areas. This airflow variation will cause corresponding drying rate variations. Provide one square foot of exhaust vent area for each 1,200 cfm.





CONTROLLED FILLING FOR WETTER CROPS

Limiting grain depth to get a higher airflow rate is one way to dry a crop at higher moisture contents than the system can handle on a full-bin basis. Airflow is higher in a partially filled bin because of lower grain depth and static pressure. The actual airflow rate depends on individual fan performance, but in a bin designed for 1 cfm/bu on a full-bin basis, the airflow rate is at least 4 cfm/bu if the bin is ¼ full.

The airflow rate needs to be increased about ½ cfm/bu for each percentage increase in moisture content. For example, the recommended airflow rate to dry 21 percent corn is 1 cfm/bu, but to dry 23 percent moisture content corn the recommended airflow rate is 2 cfm/bu. So if a full-bin drying system is designed for 1 cfm/bu, but the corn is at 23 percent, then the bin should only be filled half full, Figure 17. More corn can be added when the grain in the bin has been dried. Increase the airflow rate ¼ cfm/bu or ¾ cfm/CWT for each percentage increase in moisture content for sunflower. Due to sunflower weighing only half as much as corn, only half as much water is removed in drying one percent moisture content. Therefore, only half the airflow rate is needed to dry sunflower as to dry corn.

The drying front may be found by probing and measuring the moisture content at various levels. Several points should be checked, since progress of the drying front may not be uniform throughout the bin because of fines accumulation and reduced airflow. Often it moves slower through the center of the bin. During filling, you can vary the thickness of a layer slightly to encourage uniform progress of the front. The probe can also be used for checking storages to properly manage grain in storage.

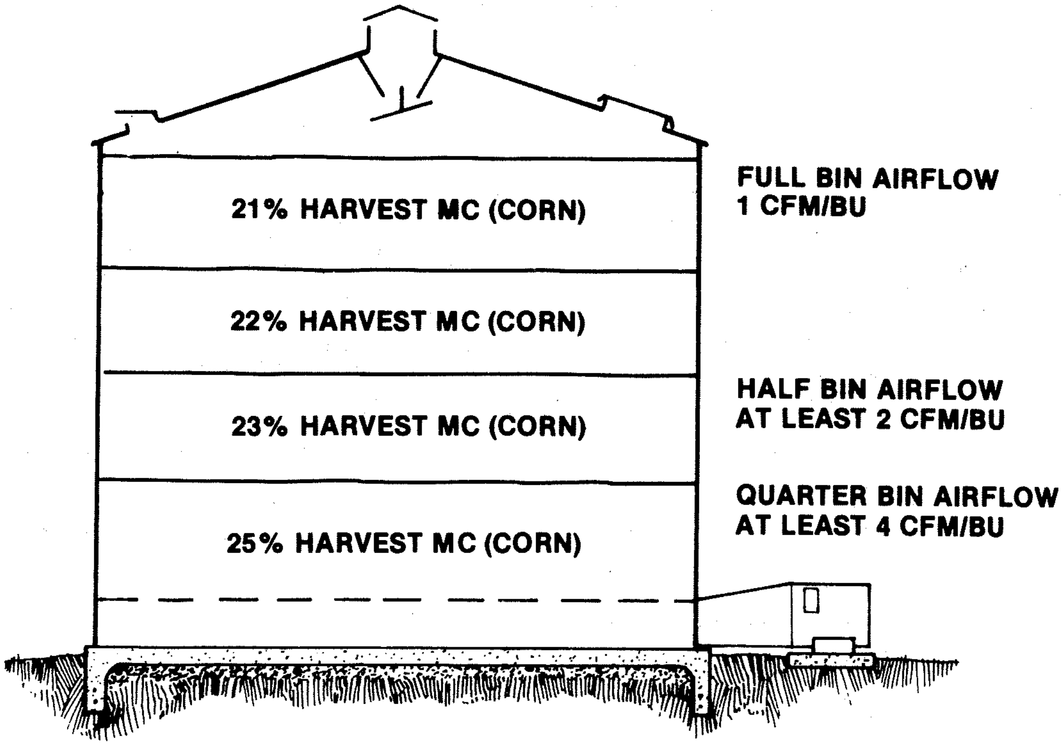


Figure 17. Example of Layer Filling. The Higher Airflow Rates on a Per Bushel Basis Early in the Filling Permit a Higher Initial Moisture Content to be Loaded.

◇ ◇ ◇

METRIC CONVERSIONS

meter = 0.3048 × foot
meter = 0.0254 × inch
$\text{meter}^3 = 0.0283 \times \text{foot}^3$
$\text{Newton/meter}^2 = 0.004015 \times \text{inches water}$
$t_C = 5/9\,(t_F - 32)$

kilopascal = 0.24884 × inches water
watt = 745.70 × horsepower
$\text{meter}^3 = 0.03524 \times \text{bushel}$
Joule = 1055.056 × British Thermal Unit (BTU)

$$\frac{\text{kilogram}}{\text{meter}^3} = 12.87658 \times \frac{\text{pound}}{\text{bushel}}$$

$$\frac{\text{liter}}{\text{second-meter}^3} = 13.3927 \times \frac{\text{foot}^3}{\text{minute-bushel}}$$

$$\frac{\text{meter}^3}{\text{minute-meter}^3} = 0.80356 \times \frac{\text{foot}^3}{\text{minute-bushel}}$$

CALCULATING AREA AND VOLUME

$$\text{Circle Area} = \frac{\text{diameter}^2 \times 3.14}{4}$$

Rectangle Area = length × width

Volume = area × height

$1\ \text{ft}^2 = 144\ \text{in}^2$

$1\ \text{bushel} = 1.2444\ \text{ft}^3$

ADDITIONAL EXTENSION PUBLICATIONS

- AE-701 Grain Drying
- MWPS-22 Low Temperature and Solar Grain Drying Handbook
- MWPS-13 Planning Grain-Feed Handling
- AE-791 Crop Storage Management

Use a static pressure value that is 87% of table value.

Appropriate application of drying fans should result in about a 65% efficiency. Use 77% of table value for fan motor horsepower.

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

WHEAT

SP = Shedd × 1.5 + 0.5

BIN DIA. (FT.)	GRAIN DEPTH (FT.)	GRAIN VOLUME (BU.)	AIR VOLUME (cfm) AT 1/10	1/5	½	¾	1	2
			(cfm per bushel)					
18 254.47 ft²	2.5	509	51	102	255	382	509	1,018
	5.0	1,018	102	204	509	764	1,018	2,036
	7.5	1,527	153	305	764	1,145	1,527	3,054
	10.0	2,036	204	407	1,018	1,527	2,036	4,072
	12.5	2,545	255	509	1,273	1,909	2,545	5,090
	15.0	3,054	305	611	1,527	2,291	3,054	6,108
	17.5	3,563	356	713	1,782	2,672	3,563	7,126
	20.0	4,072	407	814	2,036	3,054	4,072	8,144
	25.0	5,089	509	1,018	2,545	3,817	5,089	10,178
	30.0	6,107	611	1,221	3,054	4,580	6,107	12,214
	40.0	8,143	814	1,629	4,072	6,107	8,143	16,286
	50.0	10,179	1,018	2,036	5,090	7,634	10,179	20,358
21 346.36 ft²	2.5	693	69	139	346	520	693	1,386
	5.0	1,385	139	277	693	1,039	1,385	2,770
	7.5	2,078	208	416	1,039	1,559	2,078	4,156
	10.0	2,771	278	554	1,385	2,078	2,771	5,542
	12.5	3,464	346	693	1,732	2,598	3,464	6,928
	15.0	4,156	416	831	2,078	3,117	4,156	8,312
	17.5	4,849	485	970	2,425	3,637	4,849	9,698
	20.0	5,542	554	1,108	2,771	4,156	5,542	11,084
	25.0	6,927	693	1,385	3,464	5,195	6,927	13,854
	30.0	8,313	831	1,663	4,156	6,235	8,313	16,626
	40.0	11,084	1,108	2,217	5,542	8,313	11,084	22,168
	50.0	13,855	1,386	2,771	6,927	10,391	13,855	27,710
24 452.39 ft²	2.5	905	91	181	452	679	905	1,810
	5.0	1,810	181	362	905	1,357	1,810	3,619
	7.5	2,714	271	543	1,357	2,036	2,714	5,429
	10.0	3,619	362	724	1,810	2,714	3,619	7,238
	12.5	4,524	452	905	2,262	3,393	4,524	9,048
	15.0	5,429	543	1,086	2,714	4,072	5,429	10,857
	17.5	6,333	633	1,267	3,167	4,750	6,333	12,666
	20.0	7,238	724	1,448	3,619	5,429	7,238	14,477
	25.0	9,048	905	1,810	4,524	6,786	9,048	18,096
	30.0	10,857	1,086	2,171	5,429	8,143	10,857	21,714
	40.0	14,477	1,448	2,895	7,238	10,857	14,477	28,954
	50.0	18,096	1,810	3,619	9,048	13,572	18,096	36,192
27 572.56 ft²2	2.5	1,145	115	229	573	859	1,145	2,290
	5.0	2,290	229	458	1,145	1,718	2,290	4,580
	7.5	3,435	344	687	1,718	2,577	3,435	6,871
	10.0	4,580	458	916	2,290	3,435	4,580	9,161
	12.5	5,726	573	1,145	2,863	4,294	5,726	11,451
	15.0	6,871	687	1,374	3,435	5,153	6,871	13,741
	17.5	8,016	802	1,603	4,008	6,012	8,016	16,032
	20.0	9,161	916	1,832	4,580	6,871	9,161	18,322
	25.0	11,451	1,145	2,290	5,726	8,588	11,451	22,902
	30.0	13,741	1,374	2,748	6,871	10,306	13,741	27,482
	40.0	18,322	1,832	3,664	9,161	13,741	18,322	36,644
	50.0	22,902	2,290	4,580	11,451	17,177	22,902	45,804

BIN DIA. (FT.)	GRAIN DEPTH (FT.)	GRAIN VOLUME (BU.)	STATIC PRESSURE (inches of water) AT 1/10	1/5	½	¾	1	2	FAN MOTOR (hp) (50% Eff.) AT 1/10	1/5	½	¾	1	2
			cfm/bu.						cfm/bu.					
18 254.47 ft²	2.5	509	0.51	0.53	0.58	0.61	0.65	0.80	0.01	0.02	0.05	0.07	0.10	0.26
	5.0	1,018	0.56	0.62	0.80	0.95	1.10	1.85	0.02	0.04	0.13	0.23	0.35	1.19
	7.5	1,527	0.64	0.76	1.18	1.57	1.96	3.54	0.03	0.07	0.29	0.57	0.95	3.42
	10.0	2,036	0.74	0.98	1.70	2.45	3.20	6.50	0.05	0.13	0.55	1.18	2.06	8.38
	12.5	2,545	0.88	1.25	2.52	3.64	4.81	10.4	0.07	0.20	1.03	2.17	3.87	18.0
	15.0	3,054	1.02	1.58	3.31	5.11	6.58	15.8	0.10	0.31	1.60	3.70	6.36	30.5
	17.5	3,563	1.23	2.00	4.49	6.80	9.69	23.3	0.14	0.45	2.50	5.75	10.9	52.6
	20.0	4,072	1.45	2.39	5.90	8.90	12.2	28.4	0.19	0.62	3.80	8.60	15.7	73.2
	25.0	5,089	2.00	3.50	9.13	14.75	20.4	49.3	0.32	1.13	7.35	17.8	32.8	159
	30.0	6,107	2.66	4.91	12.65	23.00	31.1	--	0.51	1.90	12.2	33.3	60.1	--
	40.0	8,143	4.28	8.60	24.50	42.50	57.5	--	1.10	4.43	31.6	82.1	148	--
	50.0	10,179	6.50	14.00	40.25	68.0	98.0	--	2.09	9.02	64.8	164	316	--
21 346.36 ft²	2.5	693	0.51	0.53	0.58	0.61	0.65	0.80	0.01	0.02	0.06	0.10	0.14	0.35
	5.0	1,385	0.56	0.62	0.80	0.95	1.10	1.85	0.02	0.05	0.18	0.31	0.48	1.62
	7.5	2,078	0.64	0.76	1.18	1.57	1.96	3.54	0.04	0.10	0.39	0.77	1.29	4.66
	10.0	2,771	0.74	0.98	1.70	2.45	3.20	6.50	0.07	0.17	0.75	1.61	2.81	11.4
	12.5	3,464	0.88	1.25	2.52	3.64	4.81	10.4	0.10	0.27	1.38	2.99	5.27	22.9
	15.0	4,156	1.02	1.58	3.43	5.11	6.58	15.8	0.13	0.42	2.26	5.04	8.65	41.6
	17.5	4,849	1.23	2.00	4.44	6.80	9.69	23.3	0.19	0.61	3.41	7.83	14.9	71.6
	20.0	5,542	1.45	2.39	5.90	8.90	12.2	28.4	0.25	0.84	5.17	11.7	21.4	99.6
	25.0	6,927	2.00	3.50	9.13	14.8	20.4	49.3	0.44	1.53	10.0	24.3	44.7	189
	30.0	8,313	2.66	4.91	12.7	23.0	31.1	--	0.70	2.58	16.6	45.4	81.8	--
	40.0	11,084	4.28	8.60	24.5	42.5	57.5	--	1.50	6.03	43.0	111	177	--
	50.0	13,855	6.50	14.00	40.3	68.0	98.0	--	2.85	12.3	88.2	196	376	--
24 452.39 ft²	2.5	905	0.51	0.53	0.58	0.61	0.65	0.80	0.01	0.03	0.08	0.13	0.19	0.46
	5.0	1,810	0.56	0.62	0.80	0.95	1.10	1.85	0.03	0.07	0.23	0.41	0.63	2.12
	7.5	2,714	0.64	0.76	1.18	1.57	1.96	3.54	0.05	0.13	0.51	1.01	1.68	6.08
	10.0	3,619	0.74	0.98	1.70	2.45	3.20	6.50	0.08	0.22	0.97	2.10	3.66	14.9
	12.5	4,524	0.88	1.25	2.52	3.64	4.81	10.4	0.13	0.36	1.80	3.91	6.89	29.9
	15.0	5,429	1.02	1.58	3.31	5.11	6.58	15.8	0.18	0.54	2.84	5.58	11.3	54.3
	17.5	6,333	1.23	2.00	4.44	6.80	9.69	23.3	0.25	0.80	4.45	10.2	19.4	93.5
	20.0	7,238	1.45	2.39	5.90	8.90	12.2	28.4	0.33	1.10	6.76	21.0	27.9	130
	25.0	9,048	2.00	3.50	9.13	14.8	20.4	49.3	0.57	2.00	13.1	31.7	58.4	282
	30.0	10,857	2.66	4.91	12.7	23.0	31.1	--	0.91	3.37	21.7	59.3	106	--
	40.0	14,477	4.28	8.60	24.5	42.5	57.5	--	1.96	7.88	56.1	146	263	--
	50.0	18,096	6.50	14.00	40.3	68.0	98.0	--	3.72	16.0	115	292	561	--
27 572.56 ft²2	2.5	1,145	0.51	0.53	0.58	0.61	0.65	0.80	0.02	0.04	0.11	0.17	0.24	0.58
	5.0	2,290	0.56	0.62	0.80	0.95	1.15	1.85	0.04	0.09	0.29	0.52	0.80	2.68
	7.5	3,435	0.64	0.76	1.18	1.57	1.96	3.54	0.07	0.17	0.64	1.28	2.13	7.70
	10.0	4,580	0.74	0.98	1.70	2.45	3.20	6.50	0.11	0.28	1.23	2.66	4.64	18.8
	12.5	5,726	0.88	1.25	2.52	3.64	4.81	10.4	0.16	0.74	2.28	4.95	8.72	37.8
	15.0	6,871	1.02	1.58	3.31	5.11	6.58	15.8	0.22	0.69	3.60	8.33	14.3	68.7
	17.5	8,016	1.23	2.00	4.44	6.80	9.69	23.3	0.31	1.01	5.63	12.9	24.6	118
	20.0	9,161	1.45	2.39	5.90	8.90	12.2	28.4	0.42	1.39	8.55	19.4	35.4	165
	25.0	11,451	2.00	3.50	9.13	14.8	20.4	49.3	0.72	2.54	16.5	40.1	73.9	357
	30.0	13,741	2.66	4.91	12.7	23.0	31.3	--	1.16	4.27	27.5	75.0	135	--
	40.0	18,322	4.28	8.60	24.5	42.5	57.5	--	2.48	9.97	71.0	185	333	--
	50.0	22,902	6.50	14.0	40.3	68.0	98.0	--	4.70	20.3	146	370	710	--

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

WHEAT

SP = Shedd × 1.5 + 0.5

BIN DIA.	GRAIN DEPTH	GRAIN VOLUME	AIR VOLUME (cfm) AT						STATIC PRESSURE (inches of water) AT						FAN MOTOR (hp) (50% Eff.) AT					
			1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2
FT.	FT.	BU.	(cfm per bushel)						cfm/bu.						cfm/bu.					
30 706.86 ft^2	2.5	1,414	141	283	707	1,060	1,414	2,828	0.51	0.53	0.58	0.61	0.65	0.80	0.02	0.05	0.13	0.20	0.29	0.72
	5.0	2,827	283	565	1,414	2,121	2,827	5,654	0.56	0.62	0.80	0.95	1.10	1.85	0.05	0.11	0.36	0.64	0.98	3.31
	7.5	4,241	424	848	2,121	3,181	4,241	8,482	0.64	0.76	1.18	1.57	1.96	3.54	0.09	0.20	0.79	1.58	2.63	9.50
	10.0	5,655	566	1,131	2,827	4,241	5,655	11,310	0.74	0.98	1.70	2.45	3.20	6.50	0.13	0.35	1.52	3.29	5.73	23.3
	12.5	7,069	707	1,414	3,534	5,301	7,069	14,137	0.88	1.25	2.52	3.64	4.81	10.4	0.20	0.56	2.82	6.11	10.8	46.5
	15.0	8,482	848	1,696	4,241	6,362	8,482	16,965	1.02	1.58	3.31	5.11	6.58	15.8	0.27	0.85	4.44	10.3	17.7	84.8
	17.5	9,896	990	1,979	4,948	7,422	9,896	19,792	1.23	2.00	4.44	6.80	9.69	23.3	0.39	1.25	6.95	16.0	30.3	146
	20.0	11,310	1,131	2,262	5,655	8,482	11,310	22,620	1.45	2.39	5.90	8.90	12.2	28.4	0.52	1.71	10.6	23.9	43.7	203
	25.0	14,137	1,414	2,827	7,069	10,603	14,137	28,274	2.00	3.50	9.13	14.8	20.4	49.3	0.89	3.13	20.4	49.7	91.3	441
	30.0	16,965	1,697	3,393	8,482	12,724	16,965	33,930	2.66	4.91	12.7	23.0	31.1	--	1.43	5.27	34.1	92.6	167	--
	40.0	22,620	2,262	4,524	11,310	16,965	22,620	45,240	4.28	8.60	24.5	42.5	57.5	--	3.06	12.3	87.7	228	412	--
	50.0	28,274	2,827	5,655	14,137	21,206	28,274	56,548	6.50	14.0	40.3	68.0	98.0	--	5.82	25.1	180	456	877	--
36 1017.88 ft^2	2.5	2,036	204	407	1,018	1,527	2,036	4,072	0.51	0.53	0.58	0.61	0.65	0.80	0.03	0.07	0.19	0.29	0.42	1.03
	5.0	4,072	407	814	2,036	3,054	4,072	8,143	0.56	0.62	0.80	0.95	1.10	1.85	0.07	0.16	0.52	0.92	1.42	4.78
	7.5	6,107	611	1,221	3,054	4,580	6,107	12,215	0.64	0.76	1.18	1.57	1.96	3.54	0.12	0.29	1.14	2.28	3.79	13.7
	10.0	8,143	814	1,629	4,072	6,107	8,143	16,286	0.74	0.98	1.70	2.45	3.20	6.50	0.19	0.51	2.19	4.73	8.25	33.5
	12.5	10,179	1,018	2,036	5,089	7,634	10,179	20,358	0.88	1.25	2.52	3.64	4.81	10.4	0.28	0.81	4.06	8.79	15.5	67.0
	15.0	12,215	1,222	2,443	6,107	9,161	12,215	24,429	1.02	1.58	3.31	5.11	6.58	15.8	0.39	1.22	6.40	14.8	25.4	122
	17.5	14,250	1,425	2,850	7,125	10,688	14,250	28,500	1.23	2.00	4.44	6.80	9.69	23.3	0.55	1.80	10.0	23.0	43.7	210
	20.0	16,286	1,629	3,257	8,143	12,215	16,286	32,572	1.45	2.39	5.90	8.90	12.2	28.4	0.75	2.46	15.2	34.4	62.9	243
	25.0	20,358	2,036	4,072	10,179	15,269	20,358	40,715	2.00	3.50	9.13	14.8	20.4	49.3	1.29	4.51	29.4	71.5	131	635
	30.0	24,429	2,443	4,886	12,215	18,322	24,429	48,858	2.66	4.91	12.7	23.0	31.3	--	2.06	7.59	49.1	133	242	--
	40.0	32,572	3,257	6,514	16,286	24,429	32,572	65,144	4.28	8.60	24.5	42.5	57.5	--	4.41	17.7	126	329	593	--
	50.0	40,715	4,072	8,143	20,358	30,536	40,715	81,430	6.50	14.0	40.3	68.0	98.0	--	8.38	36.1	260	657	--	--
42 1385.44 ft^2	2.5	2,771	277	554	1,385	2,078	2,771	5,542	0.51	0.53	0.58	0.61	0.65	0.80	0.04	0.09	0.25	0.40	0.57	1.40
	5.0	5,542	554	1,108	2,771	4,156	5,542	11,084	0.56	0.62	0.80	0.95	1.10	1.85	0.10	0.22	0.70	1.25	1.93	6.49
	7.5	8,313	831	1,663	4,156	6,235	8,313	16,625	0.64	0.76	1.18	1.57	1.96	3.54	0.17	0.40	1.55	3.10	5.16	18.6
	10.0	11,084	1,108	2,217	5,542	8,313	11,084	22,167	0.74	0.98	1.70	2.45	3.20	6.50	0.26	0.69	2.98	6.45	11.2	45.6
	12.5	13,854	1,385	2,771	6,927	10,391	13,854	27,709	0.88	1.25	2.52	3.64	4.81	10.4	0.39	1.10	5.52	12.0	21.1	91.2
	15.0	16,625	1,663	3,325	8,313	12,469	16,625	33,250	1.02	1.58	3.31	5.11	6.58	15.8	0.54	1.66	8.71	20.2	34.6	166
	17.5	19,396	1,940	3,879	9,698	14,547	19,396	38,792	1.23	2.00	4.44	6.80	9.69	23.3	0.76	2.46	13.6	31.3	59.5	286
	20.0	22,167	2,217	4,434	11,084	16,625	22,167	44,334	1.45	2.39	5.90	8.90	12.2	28.4	1.02	3.35	20.7	46.8	85.6	398
	25.0	27,709	2,771	5,542	13,855	20,782	27,709	55,418	2.00	3.50	9.13	14.8	20.4	49.3	1.75	6.14	40.0	97.3	179	865
	30.0	33,250	3,325	6,650	16,625	24,938	33,250	66,500	2.66	4.91	12.7	23.0	31.1	--	2.80	10.3	66.8	182	327	--
	40.0	44,334	4,433	8,867	22,167	33,251	44,334	88,668	4.28	8.60	24.5	42.5	57.5	--	6.00	24.1	172	447	807	--
	50.0	55,418	5,542	11,084	27,709	41,564	55,418	110,836	6.50	14.0	40.3	68.0	98.0	--	11.4	49.1	353	894	--	--
50 1963.50 ft^2	2.5	3,927	393	784	1,964	2,945	3,927	7,854	0.51	0.53	0.58	0.61	0.65	0.80	0.06	0.13	0.36	0.57	0.81	1.99
	5.0	7,854	785	1,571	3,927	5,891	7,854	15,708	0.56	0.62	0.80	0.95	1.10	1.85	0.14	0.31	0.99	1.77	2.73	9.20
	7.5	11,781	1,178	2,356	5,891	8,836	11,781	23,562	0.64	0.76	1.81	1.57	1.96	3.54	0.24	0.57	2.20	4.39	7.31	26.4
	10.0	15,708	1,571	3,142	7,854	11,781	15,708	31,416	0.74	0.98	1.70	2.45	3.20	6.50	0.37	0.97	4.23	9.13	15.9	64.6
	12.5	19,635	1,964	3,927	9,818	14,726	19,635	39,270	0.88	1.25	2.52	3.64	4.81	10.4	0.55	1.55	7.83	17.0	29.9	129
	15.0	23,562	2,356	4,712	11,781	17,672	23,562	47,124	1.02	1.58	3.31	5.11	6.58	15.8	0.76	2.36	12.3	28.6	49.1	236
	17.5	27,489	2,749	5,498	13,745	20,617	27,489	54,978	1.23	2.00	4.44	6.80	9.69	23.3	1.07	3.48	19.3	44.4	84.3	405
	20.0	31,416	3,142	6,283	15,708	23,562	31,416	62,832	1.45	2.39	5.90	8.90	12.2	28.4	1.44	4.75	29.3	66.4	121	565
	25.0	39,270	3,927	7,854	19,635	29,453	39,270	78,540	2.00	3.50	9.13	14.8	20.4	49.3	2.49	8.70	56.7	138	254	--
	30.0	47,124	4,712	9,425	23,562	35,343	47,124	94,248	2.66	4.91	12.7	23.0	31.1	--	3.97	14.6	94.7	257	464	--
	40.0	62,832	6,283	12,566	31,416	47,124	62,832	125,664	4.28	8.60	24.5	42.5	57.5	--	8.51	34.2	244	634	--	--
	50.0	78,540	7,854	15,708	39,270	58,905	78,540	157,080	6.50	14.0	40.3	68.0	98.0	--	16.2	69.6	501	--	--	--

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

CORN

SP = Shedd × 1.5 + 0.5

BIN DIA.	GRAIN DEPTH	GRAIN VOLUME	AIR VOLUME (cfm) AT						STATIC PRESSURE (inches of water) AT						FAN MOTOR (hp) (50% Eff.) AT					
			1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2
FT.	FT.	BU.	(cfm per bushel)						cfm/bu.						cfm/bu.					
18 254.47 ft²	2.5	509	51	102	255	382	509	1,018	0.50	0.51	0.52	0.53	0.54	0.58	0.01	0.02	0.04	0.06	0.09	0.19
	5.0	1,018	102	204	509	764	1,018	2,036	0.51	0.53	0.57	0.62	0.67	0.88	0.02	0.03	0.09	0.15	0.21	0.57
	7.5	1,527	153	305	764	1,145	1,527	3,054	0.53	0.56	0.67	0.77	0.89	1.46	0.03	0.05	0.16	0.28	0.43	1.41
	10.0	2,036	204	407	1,018	1,527	2,036	4,072	0.56	0.61	0.83	1.03	1.28	2.45	0.04	0.08	0.27	0.49	0.82	3.16
	12.5	2,545	255	509	1,273	1,909	2,545	5,090	0.59	0.68	1.03	1.36	1.80	3.88	0.05	0.11	0.41	0.82	1.44	6.25
	15.0	3,054	305	611	1,527	2,291	3,054	6,108	0.62	0.77	1.31	1.85	2.17	5.90	0.06	0.15	0.63	1.33	2.09	11.4
	17.5	3,563	356	713	1,782	2,672	3,563	7,126	0.67	0.87	1.60	2.34	3.65	8.64	0.08	0.20	0.90	1.97	4.09	19.5
	20.0	4,072	407	814	2,036	3,054	4,072	8,144	0.73	1.01	2.06	3.08	4.40	11.6	0.09	0.26	1.32	2.96	5.64	29.9
	25.0	5,089	509	1,018	2,545	3,817	5,089	10,178	0.86	1.31	3.09	5.26	7.25	20.0	0.14	0.42	2.49	6.35	11.7	64.4
	30.0	6,107	611	1,221	3,054	4,580	6,107	12,214	1.04	1.72	4.40	7.50	11.3	32.0	0.20	0.66	4.23	10.8	21.7	124
	40.0	8,143	814	1,629	4,072	6,107	8,143	16,286	1.52	2.78	8.30	14.9	22.7	--	0.39	1.43	10.70	28.6	--	--
	50.0	10,179	1,018	2,036	5,090	7,634	10,179	20,358	2.11	4.33	14.0	26.0	39.5	--	0.68	2.79	22.4	62.8	--	--
21 346.36 ft²	2.5	693	69	139	346	520	693	1,386	0.50	0.51	0.52	0.53	0.54	0.58	0.01	0.02	0.06	0.09	0.12	0.25
	5.0	1,385	139	277	693	1,039	1,385	2,770	0.51	0.53	0.57	0.62	0.67	0.88	0.02	0.05	0.12	0.20	0.29	0.77
	7.5	2,078	208	416	1,039	1,559	2,078	4,156	0.53	0.56	0.67	0.77	0.89	1.46	0.03	0.07	0.22	0.38	0.58	1.92
	10.0	2,771	278	554	1,385	2,078	2,771	5,542	0.56	0.61	0.83	1.03	1.28	2.45	0.05	0.11	0.36	0.67	1.12	4.30
	12.5	3,464	346	693	1,732	2,598	3,464	6,928	0.59	0.68	1.03	1.36	1.80	3.88	0.06	0.15	0.56	1.11	1.96	8.51
	15.0	4,156	416	831	2,078	3,117	4,156	8,312	0.62	0.77	1.31	1.85	2.17	5.90	0.08	0.20	0.86	1.81	2.84	15.5
	17.5	4,849	485	970	2,425	3,637	4,849	9,698	0.67	0.87	1.60	2.34	3.65	8.64	0.10	0.27	1.22	2.68	5.57	26.5
	20.0	5,542	554	1,108	2,771	4,156	5,542	11,084	0.73	1.01	2.06	3.08	4.40	11.6	0.13	0.35	1.80	4.03	7.67	40.7
	25.0	6,927	693	1,385	3,464	5,195	6,927	13,854	0.86	1.31	3.09	5.26	7.25	20.0	0.19	0.57	3.39	8.65	15.9	87.7
	30.0	8,313	831	1,663	4,156	6,235	8,313	16,626	1.04	1.72	4.40	7.50	11.3	32.0	0.27	0.91	5.75	14.7	29.6	168
	40.0	11,084	1,108	2,217	5,542	8,313	11,084	22,168	1.52	2.78	8.30	14.9	22.7	--	0.53	1.95	14.5	39.0	79.6	--
	50.0	13,855	1,386	2,771	6,927	10,391	13,855	27,710	2.11	4.33	14.0	26.0	39.5	--	0.93	3.80	30.5	85.5	173	--
24 452.39 ft²	2.5	905	91	181	452	679	905	1,810	0.50	0.51	0.52	0.53	0.54	0.58	0.01	0.03	0.07	0.11	0.15	0.33
	5.0	1,810	181	362	905	1,357	1,810	3,619	0.51	0.53	0.57	0.62	0.67	0.88	0.03	0.06	0.16	0.26	0.38	1.01
	7.5	2,714	271	543	1,357	2,036	2,714	5,429	0.53	0.56	0.67	0.77	0.89	1.46	0.05	0.10	0.29	0.49	0.76	2.51
	10.0	3,619	362	724	1,810	2,714	3,619	7,238	0.56	0.61	0.83	1.03	1.28	2.45	0.06	0.14	0.47	0.88	1.46	5.61
	12.5	4,524	452	905	2,262	3,393	4,524	9,048	0.59	0.68	1.03	1.36	1.80	3.88	0.08	0.19	0.73	1.45	2.56	11.1
	15.0	5,429	543	1,086	2,714	4,072	5,429	10,857	0.62	0.77	1.31	1.85	2.17	5.90	0.11	0.26	1.12	2.37	3.71	20.3
	17.5	6,333	633	1,267	3,167	4,750	6,333	12,666	0.67	0.87	1.60	2.34	3.65	8.64	0.13	0.35	1.59	3.50	7.27	34.6
	20.0	7,238	724	1,448	3,619	5,429	7,238	14,477	0.73	1.01	2.06	3.08	4.40	11.6	0.17	0.46	2.35	5.26	10.0	53.1
	25.0	9,048	905	1,810	4,524	6,786	9,048	18,096	0.86	1.31	3.09	5.26	7.25	20.0	0.25	0.75	4.42	11.3	20.8	115
	30.0	10,857	1,086	2,171	5,429	8,143	10,857	21,714	1.04	1.72	4.40	7.50	11.3	32.0	0.36	1.18	7.52	19.2	38.6	220
	40.0	14,477	1,448	2,895	7,238	10,857	14,477	28,954	1.52	2.78	8.30	14.9	22.7	--	0.70	2.55	18.9	50.9	104	--
	50.0	18,096	1,810	3,619	9,048	13,572	18,096	36,192	2.11	4.33	14.0	26.0	39.5	--	1.21	4.96	39.9	112	226	--
27 572.56 ft²	2.5	1,145	115	229	573	859	1,145	2,290	0.50	0.51	0.52	0.53	0.54	0.58	0.02	0.04	0.09	0.14	0.19	0.42
	5.0	2,290	229	458	1,145	1,718	2,290	4,580	0.51	0.53	0.57	0.62	0.67	0.88	0.04	0.08	0.21	0.34	0.48	1.28
	7.5	3,435	344	687	1,718	2,577	3,435	6,871	0.53	0.56	0.67	0.77	0.89	1.46	0.06	0.12	0.36	0.62	0.96	3.17
	10.0	4,580	458	916	2,290	3,435	4,580	9,161	0.56	0.61	0.83	1.03	1.28	2.45	0.08	0.18	0.60	1.11	1.84	7.10
	12.5	5,726	573	1,145	2,863	4,294	5,726	11,451	0.59	0.68	1.03	1.36	1.80	3.88	0.11	0.25	0.93	1.84	3.24	14.1
	15.0	6,871	687	1,374	3,435	5,153	6,871	13,741	0.62	0.77	1.31	1.85	2.17	5.90	0.13	0.33	1.42	3.00	4.69	25.7
	17.5	8,016	802	1,603	4,008	6,012	8,016	16,032	0.67	0.87	1.60	2.34	3.65	8.64	0.17	0.44	2.02	4.43	9.21	43.8
	20.0	9,161	916	1,832	4,580	6,871	9,161	18,322	0.73	1.01	2.06	3.08	4.40	11.6	0.21	0.59	2.97	6.66	12.7	67.3
	25.0	11,451	1,145	2,290	5,726	8,588	11,451	22,902	0.86	1.31	3.09	5.26	7.25	20.0	0.31	0.95	5.60	14.3	26.3	145
	30.0	13,741	1,374	2,748	6,871	10,306	13,741	27,482	1.04	1.72	4.40	7.50	11.3	32.0	0.45	1.50	9.51	24.3	48.9	278
	40.0	18,322	1,832	3,664	9,161	13,741	18,322	36,644	1.52	2.78	8.30	14.9	22.7	--	0.88	3.22	23.9	64.4	132	--
	50.0	22,902	2,290	4,580	11,451	17,177	22,902	45,804	2.11	4.33	14.0	26.0	39.5	--	1.53	6.28	50.5	141	286	--

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

CORN

SP = Shedd x 1.5 + 0.5

BIN DIA.	GRAIN DEPTH	GRAIN VOLUME	AIR VOLUME (cfm) AT						STATIC PRESSURE (inches of water) AT						FAN MOTOR (hp) (50% Eff.) AT					
			1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2
FT.	FT.	BU.	(cfm per bushel)						cfm/bu.						cfm/bu.					
30 706.86 ft²	2.5	1,414	141	283	707	1,060	1,414	2,828	0.50	0.51	0.52	0.53	0.54	0.58	0.02	0.05	0.12	0.18	0.24	0.52
	5.0	2,827	283	565	1,414	2,121	2,827	5,654	0.51	0.53	0.57	0.62	0.67	0.88	0.05	0.09	0.25	0.41	0.60	1.57
	7.5	4,241	424	848	2,121	3,181	4,241	8,482	0.53	0.56	0.67	0.77	0.89	1.46	0.07	0.15	0.45	0.77	1.19	3.92
	10.0	5,655	566	1,131	2,827	4,241	5,655	11,310	0.56	0.61	0.83	1.03	1.28	2.45	0.10	0.22	0.74	1.37	2.28	8.77
	12.5	7,069	707	1,414	3,534	5,301	7,069	14,137	0.59	0.68	1.03	1.36	1.80	3.88	0.13	0.30	1.15	2.27	4.00	17.4
	15.0	8,482	848	1,696	4,241	6,362	8,482	16,965	0.62	0.77	1.31	1.85	2.17	5.90	0.17	0.41	1.75	3.70	5.79	31.7
	17.5	9,896	990	1,979	4,948	7,422	9,896	19,792	0.67	0.87	1.60	2.34	3.65	8.64	0.21	0.54	2.49	5.46	11.4	54.1
	20.0	11,310	1,131	2,262	5,655	8,482	11,310	22,620	0.73	1.01	2.06	3.08	4.40	11.6	0.26	0.72	3.67	8.22	15.7	83.0
	25.0	14,137	1,414	2,827	7,069	10,603	14,137	28,274	0.86	1.31	3.09	5.26	7.25	20.0	0.38	1.17	5.91	17.6	32.4	179
	30.0	16,965	1,697	3,393	8,482	12,724	16,965	33,930	1.04	1.72	4.40	7.50	11.3	32.0	0.56	1.85	11.7	30.0	60.3	344
	40.0	22,620	2,262	4,524	11,310	16,965	22,620	45,240	1.52	2.78	8.30	14.9	22.7	--	1.09	3.98	29.5	79.5	162	--
	50.0	28,274	2,827	5,655	14,137	21,206	28,274	56,548	2.11	4.33	14.0	26.0	39.5	--	1.89	7.75	62.3	174	353	--
36 1017.88 ft²	2.5	2,036	204	407	1,018	1,527	2,036	4,072	0.50	0.51	0.52	0.53	0.54	0.58	0.03	0.07	0.17	0.25	0.35	0.75
	5.0	4,072	407	814	2,036	3,054	4,072	8,143	0.51	0.53	0.57	0.62	0.67	0.88	0.07	0.14	0.37	0.60	0.86	2.27
	7.5	6,107	611	1,221	3,054	4,580	6,107	12,215	0.53	0.56	0.67	0.77	0.89	1.46	0.10	0.22	0.64	1.11	1.71	5.64
	10.0	8,143	814	1,629	4,072	6,107	8,143	16,286	0.56	0.61	0.83	1.03	1.28	2.45	0.14	0.31	1.06	1.98	3.28	12.6
	12.5	10,179	1,018	2,036	5,089	7,634	10,179	20,358	0.59	0.68	1.03	1.36	1.80	3.88	0.19	0.44	1.65	3.27	5.77	25.0
	15.0	12,215	1,222	2,443	6,107	9,161	12,215	24,429	0.62	0.77	1.31	1.85	2.17	5.90	0.24	0.60	2.52	5.33	8.34	45.6
	17.5	14,250	1,425	2,850	7,125	10,688	14,250	28,500	0.67	0.87	1.60	2.34	3.65	8.64	0.30	0.78	3.59	7.87	16.4	77.9
	20.0	16,286	1,629	3,257	8,143	12,215	16,286	32,572	0.73	1.01	2.06	3.08	4.40	11.6	0.38	1.04	5.28	11.8	22.6	120
	25.0	20,358	2,036	4,072	10,179	15,269	20,358	40,715	0.86	1.31	3.09	5.26	7.25	20.0	0.55	1.69	9.95	25.4	46.7	258
	30.0	24,429	2,443	4,886	12,215	18,322	24,429	48,858	1.04	1.72	4.40	7.50	11.3	32.0	0.80	2.66	16.9	43.2	86.9	495
	40.0	32,572	3,257	6,514	16,286	24,429	32,572	65,144	1.52	2.78	8.30	14.9	22.7	--	1.57	5.73	42.5	115	234	--
	50.0	40,715	4,072	8,143	20,358	30,536	40,715	81,430	2.11	4.33	14.0	26.0	39.5	--	2.72	11.2	90.2	251	509	--
42 1385.44 ft²	2.5	2,771	277	554	1,385	2,078	2,771	5,542	0.50	0.51	0.52	0.53	0.54	0.58	0.04	0.09	0.23	0.35	0.47	1.02
	5.0	5,542	554	1,108	2,771	4,156	5,542	11,084	0.51	0.53	0.57	0.62	0.67	0.88	0.09	0.19	0.50	0.82	1.18	3.09
	7.5	8,313	831	1,663	4,156	6,235	8,313	16,625	0.53	0.56	0.67	0.77	0.89	1.46	0.14	0.29	0.88	1.52	2.34	7.68
	10.0	11,084	1,108	2,217	5,542	8,313	11,084	22,167	0.56	0.61	0.83	1.03	1.28	2.45	0.20	0.43	1.46	2.71	4.49	17.2
	12.5	13,854	1,385	2,771	6,927	10,391	13,854	27,709	0.59	0.68	1.03	1.36	1.80	3.88	0.26	0.60	2.26	4.47	7.98	34.0
	15.0	16,625	1,663	3,325	8,313	12,469	16,625	33,250	0.62	0.77	1.31	1.85	2.17	5.90	0.33	0.81	3.45	7.30	11.4	62.1
	17.5	19,396	1,940	3,879	9,698	14,547	19,396	38,792	0.67	0.87	1.60	2.34	3.65	8.64	0.41	1.07	4.91	10.8	22.4	106
	20.0	22,167	2,217	4,434	11,084	16,625	22,167	44,334	0.73	1.01	2.06	3.08	4.40	11.6	0.51	1.42	7.23	16.2	30.9	163
	25.0	27,709	2,771	5,542	13,855	20,782	27,709	55,418	0.86	1.31	3.09	5.26	7.25	20.0	0.75	2.30	13.5	34.6	63.6	351
	30.0	33,250	3,325	6,650	16,625	24,938	33,250	66,500	1.04	1.72	4.40	7.50	11.3	32.0	1.09	3.62	23.1	59.2	119	673
	40.0	44,334	4,433	8,867	22,167	33,251	44,334	88,668	1.52	2.78	8.30	14.9	22.7	--	2.13	7.80	58.2	157	318	--
	50.0	55,418	5,542	11,084	27,709	41,564	55,418	110,836	2.11	4.33	14.0	26.0	39.5	--	3.70	15.2	123	342	693	--
50 1963.50 ft²	2.5	3,927	393	784	1,964	2,945	3,927	7,854	0.50	0.51	0.52	0.53	0.54	0.58	0.06	0.13	0.32	0.49	0.67	1.44
	5.0	7,854	785	1,571	3,927	5,891	7,854	15,708	0.51	0.53	0.57	0.62	0.67	0.88	0.13	0.26	0.71	1.16	1.67	4.37
	7.5	11,781	1,178	2,356	5,891	8,836	11,781	23,562	0.53	0.56	0.67	0.77	0.89	1.46	0.20	0.42	1.25	2.15	3.32	10.9
	10.0	15,708	1,571	3,142	7,854	11,781	15,708	31,416	0.56	0.61	0.83	1.03	1.28	2.45	0.28	0.61	2.07	3.84	6.36	24.4
	12.5	19,635	1,964	3,927	9,818	14,726	19,635	39,270	0.59	0.68	1.03	1.36	1.80	3.88	0.37	0.85	3.20	6.34	11.2	48.2
	15.0	23,562	2,356	4,712	11,781	17,672	23,562	47,124	0.62	0.77	1.31	1.85	2.17	5.90	0.46	1.15	4.88	10.3	16.2	88.0
	17.5	27,489	2,749	5,498	13,745	20,617	27,489	54,978	0.67	0.87	1.60	2.34	3.65	8.64	0.58	1.51	6.96	15.3	31.8	150
	20.0	31,416	3,142	6,283	15,708	23,562	31,416	62,832	0.73	1.01	2.06	3.08	4.40	11.6	0.73	2.01	10.2	23.0	43.7	231
	25.0	39,270	3,927	7,854	19,635	29,453	39,270	78,540	0.86	1.31	3.09	5.26	7.25	20.0	1.07	3.26	19.2	49.0	90.1	497
	30.0	47,124	4,712	9,425	23,562	35,343	47,124	94,248	1.04	1.72	4.40	7.50	11.3	32.0	1.55	5.13	32.8	83.9	169	954
	40.0	62,832	6,283	12,566	31,416	47,124	62,832	125,664	1.52	2.78	8.30	14.9	22.7	--	3.02	11.1	82.5	222	451	--
	50.0	78,540	7,854	15,708	39,270	58,905	78,540	157,080	2.11	4.33	14.0	26.0	39.5	--	5.24	21.5	174	485	982	--

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

BARLEY

SP = Shedd x 1.5 + 0.5

BIN DIA.	GRAIN DEPTH	GRAIN VOLUME	AIR VOLUME (cfm) AT						STATIC PRESSURE (inches of water) AT						FAN MOTOR (hp) (50% Eff.) AT					
			1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2
FT.	FT.	BU.	(cfm per bushel)						cfm/bu.						cfm/bu.					
18	2.5	509	51	102	255	382	509	1,018	0.51	0.52	0.54	0.56	0.58	0.67	0.01	0.02	0.04	0.07	0.09	0.22
	5.0	1,018	102	204	509	764	1,018	2,036	0.53	0.56	0.66	0.75	0.85	1.27	0.02	0.04	0.11	0.18	0.27	0.81
	7.5	1,527	153	305	764	1,145	1,527	3,054	0.57	0.65	0.87	1.07	1.29	2.19	0.03	0.06	0.21	0.39	0.62	2.12
	10.0	2,036	204	407	1,018	1,527	2,036	4,072	0.62	0.76	1.19	1.55	2.00	3.95	0.04	0.10	0.38	0.75	1.29	5.09
	12.5	2,545	255	509	1,273	1,909	2,545	5,090	0.69	0.90	1.61	2.23	3.03	6.50	0.06	0.14	0.65	1.35	2.44	10.5
	15.0	3,054	305	611	1,527	2,291	3,054	6,108	0.79	1.10	2.08	3.20	4.10	9.61	0.08	0.21	1.01	2.32	3.96	18.6
254.47 ft^2	17.5	3,563	356	713	1,782	2,672	3,563	7,126	0.88	1.34	2.73	4.10	5.75	14.2	0.10	0.30	1.54	3.47	6.48	32.0
	20.0	4,072	407	814	2,036	3,054	4,072	8,144	1.01	1.61	3.50	5.30	7.40	18.5	0.13	0.41	2.26	5.12	9.54	47.7
	25.0	5,089	509	1,018	2,545	3,817	5,089	10,178	1.31	2.21	5.56	8.75	12.5	35.0	0.21	0.71	4.48	10.6	20.1	113
	30.0	6,107	611	1,221	3,054	4,580	6,107	12,214	1.69	3.07	7.70	13.6	18.7	--	0.33	1.19	7.44	19.6	36.1	--
	40.0	8,143	814	1,629	4,072	6,107	8,143	16,286	2.66	5.00	14.3	24.8	36.5	--	0.69	2.58	18.4	47.9	94.1	--
	50.0	10,179	1,018	2,036	5,090	7,634	10,179	20,358	3.91	8.00	24.5	41.8	69.5	--	1.26	5.15	39.5	101	224	--
21	2.5	693	69	139	346	520	693	1,386	0.51	0.52	0.54	0.56	0.58	0.67	0.01	0.02	0.06	0.09	0.13	0.29
	5.0	1,385	139	277	693	1,039	1,385	2,770	0.53	0.56	0.66	0.75	0.85	1.27	0.02	0.05	0.14	0.25	0.37	1.10
	7.5	2,078	208	416	1,039	1,559	2,078	4,156	0.57	0.65	0.87	1.07	1.29	2.19	0.04	0.09	0.29	0.53	0.85	2.88
	10.0	2,771	278	554	1,385	2,078	2,771	5,542	0.62	0.76	1.19	1.55	2.00	3.95	0.05	0.13	0.52	1.02	1.75	6.93
	12.5	3,464	346	693	1,732	2,598	3,464	6,928	0.69	0.90	1.61	2.23	3.03	6.50	0.08	0.20	0.88	1.83	3.32	14.3
	15.0	4,156	416	831	2,078	3,117	4,156	8,312	0.79	1.10	2.08	3.20	4.10	9.61	0.10	0.29	1.37	3.16	5.39	25.3
346.36 ft^2	17.5	4,849	485	970	2,425	3,637	4,849	9,698	0.88	1.34	2.73	4.10	5.75	14.2	0.14	0.41	2.10	4.72	8.82	43.6
	20.0	5,542	554	1,108	2,771	4,156	5,542	11,084	1.01	1.61	3.50	5.30	7.40	18.5	0.18	0.56	3.07	6.97	13.0	64.9
	25.0	6,927	693	1,385	3,464	5,195	6,927	13,854	1.31	2.21	5.56	8.75	12.5	35.0	0.29	0.97	6.09	14.4	27.4	153
	30.0	8,313	831	1,663	4,156	6,235	8,313	16,626	1.69	3.07	7.70	13.6	18.7	--	0.44	1.62	10.1	26.8	49.2	--
	40.0	11,084	1,108	2,217	5,542	8,313	11,084	22,168	2.66	5.00	14.3	24.8	36.5	--	0.93	3.51	25.1	65.2	128	--
	50.0	13,855	1,386	2,771	6,927	10,391	13,855	27,710	3.91	8.00	24.5	41.8	69.5	--	1.71	7.02	53.7	137	305	--
24	2.5	905	91	181	452	679	905	1,810	0.51	0.52	0.54	0.56	0.58	0.67	0.01	0.03	0.08	0.12	0.17	0.38
	5.0	1,810	181	362	905	1,357	1,810	3,619	0.53	0.56	0.66	0.75	0.85	1.27	0.03	0.06	0.19	0.32	0.49	1.45
	7.5	2,714	271	543	1,357	2,036	2,714	5,429	0.57	0.65	0.87	1.07	1.29	2.19	0.05	0.11	0.37	0.69	1.11	3.76
	10.0	3,619	362	724	1,810	2,714	3,619	7,238	0.62	0.76	1.19	1.55	2.00	3.95	0.07	0.17	0.68	1.33	2.29	9.05
	12.5	4,524	452	905	2,262	3,393	4,524	9,048	0.69	0.90	1.61	2.23	3.03	6.50	0.10	0.26	1.15	2.39	4.34	18.6
	15.0	5,429	543	1,086	2,714	4,072	5,429	10,857	0.79	1.10	2.08	3.20	4.10	9.61	0.14	0.38	1.79	4.12	7.04	33.0
452.39 ft^2	17.5	6,333	633	1,267	3,167	4,750	6,333	12,666	0.88	1.34	2.73	4.10	5.75	14.2	0.18	0.54	2.74	6.16	11.5	56.9
	20.0	7,238	724	1,448	3,619	5,429	7,238	14,477	1.01	1.61	3.50	5.30	7.40	18.5	0.23	0.74	4.01	9.11	16.9	84.8
	25.0	9,048	905	1,810	4,524	6,786	9,048	18,096	1.31	2.21	5.56	8.75	12.5	35.0	0.38	1.27	7.96	18.8	35.8	200
	30.0	10,857	1,086	2,171	5,429	8,143	10,857	21,714	1.69	3.07	7.70	13.6	18.7	--	0.58	2.11	13.2	35.0	64.2	--
	40.0	14,477	1,448	2,895	7,238	10,857	14,477	28,954	2.66	5.00	14.3	24.8	36.5	--	1.22	4.58	32.8	85.2	167	--
	50.0	18,096	1,810	3,619	9,048	13,572	18,096	36,192	3.91	8.00	24.5	41.8	69.5	--	2.24	9.16	70.2	180	398	--
27	2.5	1,145	115	229	573	859	1,145	2,290	0.51	0.52	0.54	0.56	0.58	0.67	0.02	0.04	0.10	0.15	0.21	0.49
	5.0	2,290	229	458	1,145	1,718	2,290	4,580	0.53	0.56	0.66	0.75	0.85	1.27	0.04	0.08	0.24	0.41	0.62	1.84
	7.5	3,435	344	687	1,718	2,577	3,435	6,871	0.57	0.65	0.87	1.07	1.29	2.19	0.06	0.14	0.47	0.87	1.40	4.76
	10.0	4,580	458	916	2,290	3,435	4,580	9,161	0.62	0.76	1.19	1.55	2.00	3.95	0.09	0.22	0.86	1.68	2.90	11.5
	12.5	5,726	573	1,145	2,863	4,294	5,726	11,451	0.69	0.90	1.61	2.23	3.03	6.50	0.13	0.33	1.46	3.03	5.49	23.6
	15.0	6,871	687	1,374	3,435	5,153	6,871	13,741	0.79	1.10	2.08	3.20	4.10	9.61	0.17	0.48	2.26	5.22	8.91	41.8
572.56 ft^2	17.5	8,016	802	1,603	4,008	6,012	8,016	16,032	0.88	1.34	2.73	4.10	5.75	14.2	0.22	0.68	3.46	7.80	14.6	72.0
	20.0	9,161	916	1,832	4,580	6,871	9,161	18,322	1.01	1.61	3.50	5.30	7.40	18.5	0.29	0.93	5.07	11.5	21.5	107
	25.0	11,451	1,145	2,290	5,726	8,588	11,451	22,902	1.31	2.21	5.56	8.75	12.5	35.0	0.47	1.60	10.1	23.8	45.3	254
	30.0	13,741	1,374	2,748	6,871	10,306	13,741	27,482	1.69	3.07	7.70	13.6	18.7	--	0.73	2.67	16.7	44.4	81.3	--
	40.0	18,322	1,832	3,664	9,161	13,741	18,322	36,644	2.66	5.00	14.3	24.8	36.5	--	1.54	5.80	41.5	108	212	--
	50.0	22,902	2,290	4,580	11,451	17,177	22,902	45,804	3.91	8.00	24.5	41.8	69.5	--	2.83	11.6	88.8	227	504	--

APPENDIX A

PREPARED BY:
Kenneth J. Hellevang
Extension Agricultural Engineer

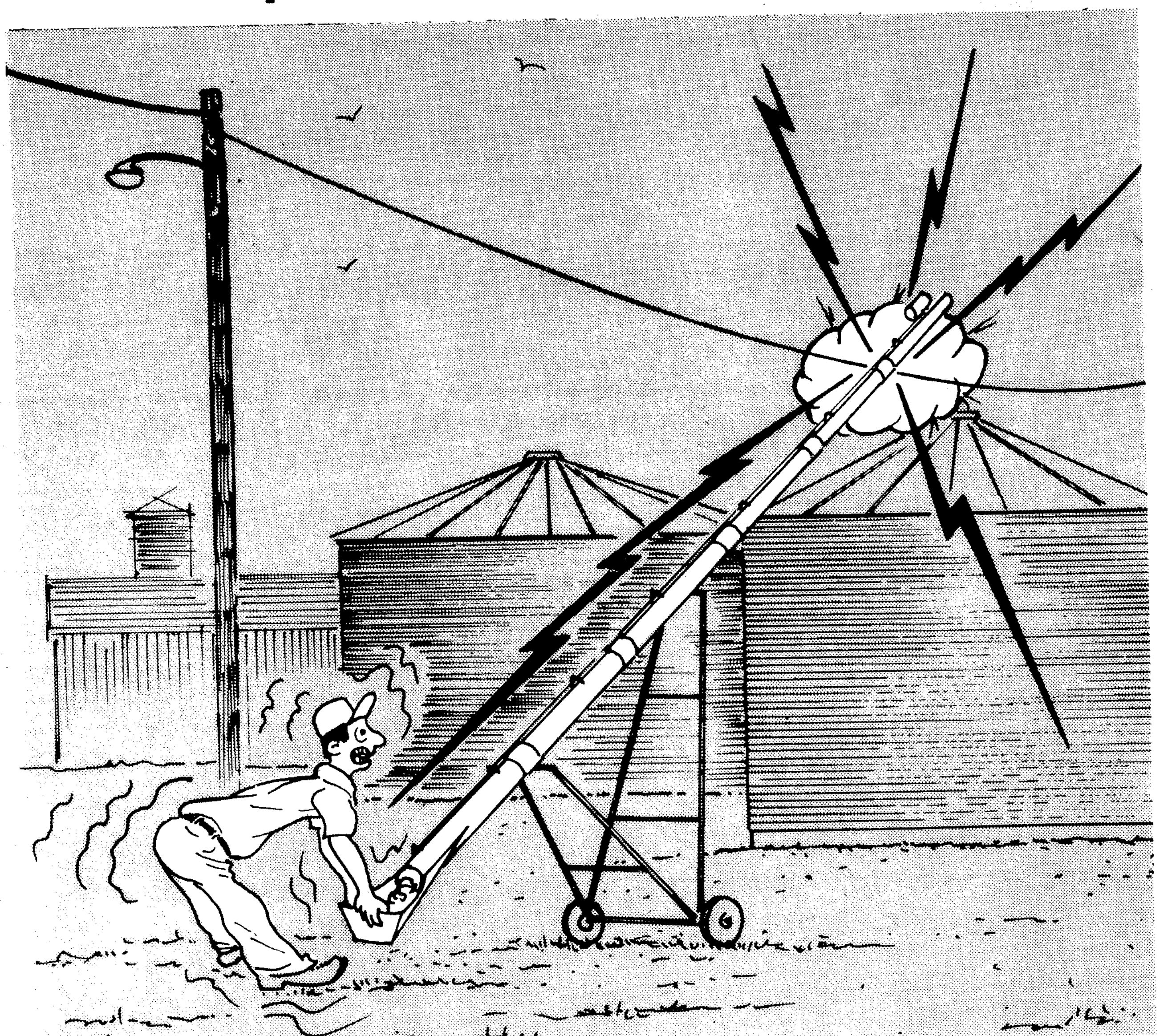
BARLEY

SP = Shedd × 1.5 + 0.5

BIN DIA.	GRAIN DEPTH	GRAIN VOLUME	AIR VOLUME (cfm) AT						STATIC PRESSURE (inches of water) AT						FAN MOTOR (hp) (50% Eff.) AT					
			1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2	1/10	1/5	½	¾	1	2
FT.	FT.	BU.	(cfm per bushel)						cfm/bu.						cfm/bu.					
30	2.5	1,414	141	283	707	1,060	1,414	2,828	0.51	0.52	0.54	0.56	0.58	0.67	0.02	0.05	0.12	0.19	0.26	0.60
706.86 ft²	5.0	2,827	283	565	1,414	2,121	2,827	5,654	0.53	0.56	0.66	0.75	0.85	1.27	0.05	0.10	0.30	0.50	0.76	2.27
	7.5	4,241	424	848	2,121	3,181	4,241	8,482	0.57	0.65	0.87	1.07	1.29	2.19	0.08	0.17	0.58	1.08	1.73	5.88
	10.0	5,655	566	1,131	2,827	4,241	5,655	11,310	0.62	0.76	1.19	1.55	2.00	3.95	0.11	0.27	1.06	2.08	3.58	14.1
	12.5	7,069	707	1,414	3,534	5,301	7,069	14,137	0.69	0.90	1.61	2.23	3.03	6.50	0.15	0.40	1.80	3.74	6.78	29.1
	15.0	8,482	848	1,696	4,241	6,362	8,482	16,965	0.79	1.10	2.08	3.20	4.10	9.61	0.21	0.59	2.79	6.44	11.0	51.6
	17.5	9,896	990	1,979	4,948	7,422	9,896	19,792	0.88	1.34	2.73	4.10	5.75	14.2	0.28	0.84	4.27	9.63	18.0	88.9
	20.0	11,310	1,131	2,262	5,655	8,482	11,310	22,620	1.01	1.61	3.50	5.30	7.40	18.5	0.36	1.15	6.26	14.2	26.5	132
	25.0	14,137	1,414	2,827	7,069	10,603	14,137	28,274	1.31	2.21	5.56	8.75	12.5	35.0	0.59	1.98	12.4	29.4	55.9	313
	30.0	16,965	1,697	3,393	8,482	12,724	16,965	33,930	1.69	3.07	7.70	13.6	18.7	--	0.91	3.30	20.7	54.8	100	--
	40.0	22,620	2,262	4,524	11,310	16,965	22,620	45,240	2.66	5.00	14.3	24.8	36.5	--	1.90	7.16	51.2	133	261	--
	50.0	28,274	2,827	5,655	14,137	21,206	28,274	56,548	3.91	8.00	24.5	41.8	69.5	--	3.50	14.3	110	281	622	--
36	2.5	2,036	204	407	1,018	1,527	2,036	4,072	0.51	0.52	0.54	0.56	0.58	0.67	0.03	0.07	0.17	0.27	0.37	0.86
1017.88 ft²	5.0	4,072	407	814	2,036	3,054	4,072	8,143	0.53	0.56	0.66	0.75	0.85	1.27	0.07	0.14	0.43	0.72	1.10	3.27
	7.5	6,107	611	1,221	3,054	4,580	6,107	12,215	0.57	0.65	0.87	1.07	1.29	2.19	0.11	0.25	0.84	1.55	2.49	8.47
	10.0	8,143	814	1,629	4,072	6,107	8,143	16,286	0.62	0.76	1.19	1.55	2.00	3.95	0.16	0.39	1.53	3.00	5.15	20.4
	12.5	10,179	1,018	2,036	5,089	7,634	10,179	20,358	0.69	0.90	1.61	2.23	3.03	6.50	0.22	0.58	2.59	5.39	9.76	41.9
	15.0	12,215	1,222	2,443	6,107	9,161	12,215	24,429	0.79	1.10	2.08	3.20	4.10	9.61	0.31	0.85	4.02	9.28	15.8	74.3
	17.5	14,250	1,425	2,850	7,125	10,688	14,250	28,500	0.88	1.34	2.73	4.10	5.75	14.2	0.40	1.21	6.16	13.9	25.9	128
	20.0	16,286	1,629	3,257	8,143	12,215	16,286	32,572	1.01	1.61	3.50	5.30	7.40	18.5	0.52	1.66	9.02	20.5	38.1	191
	25.0	20,358	2,036	4,072	10,179	15,269	20,358	40,715	1.31	2.21	5.56	8.75	12.5	35.0	0.84	2.85	17.9	42.3	80.5	451
	30.0	24,429	2,443	4,886	12,215	18,322	24,429	48,858	1.69	3.07	7.70	13.6	18.7	--	1.31	4.75	29.8	78.9	145	--
	40.0	32,572	3,257	6,514	16,286	24,429	32,572	65,144	2.66	5.00	14.3	24.8	36.5	--	2.74	10.3	73.7	192	376	--
	50.0	40,715	4,072	8,143	20,358	30,536	40,715	81,430	3.91	8.00	24.5	41.8	69.5	--	5.04	20.6	158	404	895	--
42	2.5	2,771	277	554	1,385	2,078	2,771	5,542	0.51	0.52	0.54	0.56	0.58	0.67	0.04	0.09	0.24	0.37	0.51	1.18
1385.44 ft²	5.0	5,542	554	1,108	2,771	4,156	5,542	11,084	0.53	0.56	0.66	0.75	0.85	1.27	0.09	0.20	0.58	0.99	1.49	4.45
	7.5	8,313	831	1,663	4,156	6,235	8,313	16,625	0.57	0.65	0.87	1.07	1.29	2.19	0.15	0.34	1.14	2.11	3.39	11.5
	10.0	11,084	1,108	2,217	5,542	8,313	11,084	22,167	0.62	0.76	1.19	1.55	2.00	3.95	0.22	0.53	2.09	4.08	7.02	27.2
	12.5	13,854	1,385	2,771	6,927	10,391	13,854	27,709	0.69	0.90	1.61	2.23	3.03	6.50	0.30	0.79	3.53	7.33	13.3	57.0
	15.0	16,625	1,663	3,325	8,313	12,469	16,625	33,250	0.79	1.10	2.08	3.20	4.10	9.61	0.42	1.16	5.47	12.6	21.6	101
	17.5	19,396	1,940	3,879	9,698	14,547	19,396	38,792	0.88	1.34	2.73	4.10	5.75	14.2	0.54	1.64	8.38	18.9	35.3	174
	20.0	22,167	2,217	4,434	11,084	16,625	22,167	44,334	1.01	1.61	3.50	5.30	7.40	18.5	0.71	2.26	12.3	27.9	51.9	260
	25.0	27,709	2,771	5,542	13,855	20,782	27,709	55,418	1.31	2.21	5.56	8.75	12.5	35.0	1.15	3.88	24.4	57.5	110	--
	30.0	33,250	3,325	6,650	16,625	24,938	33,250	66,500	1.69	3.07	7.70	13.6	18.7	--	1.78	6.46	40.5	107	196	--
	40.0	44,334	4,433	8,867	22,167	33,251	44,334	88,668	2.66	5.00	14.3	24.8	36.5	--	3.73	14.0	100	261	512	--
	50.0	55,418	5,542	11,084	27,709	41,564	55,418	110,836	3.91	8.00	24.5	41.8	69.5	--	6.86	28.1	215	550	--	--
50	2.5	3,927	393	784	1,964	2,945	3,927	7,854	0.51	0.52	0.54	0.56	0.58	0.67	0.06	0.13	0.34	0.52	0.72	1.67
1963.50 ft²	5.0	7,854	785	1,571	3,927	5,891	7,854	15,708	0.53	0.56	0.66	0.75	0.85	1.27	0.13	0.78	0.82	1.40	2.11	6.31
	7.5	11,781	1,178	2,356	5,891	8,836	11,781	23,562	0.57	0.65	0.87	1.07	1.29	2.19	0.21	0.48	1.62	2.99	4.81	16.3
	10.0	15,708	1,571	3,142	7,854	11,781	15,708	31,416	0.62	0.76	1.19	1.55	2.00	3.95	0.31	0.76	2.96	5.79	9.94	39.3
	12.5	19,635	1,964	3,927	9,818	14,726	19,635	39,270	0.69	0.90	1.61	2.23	3.03	6.50	0.43	1.12	5.00	10.4	18.8	80.8
	15.0	23,562	2,356	4,712	11,781	17,672	23,562	47,124	0.79	1.10	2.08	3.20	4.10	9.61	0.59	1.64	7.75	17.9	30.6	143
	17.5	27,489	2,749	5,498	13,745	20,617	27,489	54,978	0.88	1.34	2.73	4.10	5.75	14.2	0.77	2.33	11.9	26.7	50.0	247
	20.0	31,416	3,142	6,283	15,708	23,562	31,416	62,832	1.01	1.61	3.50	5.30	7.40	18.5	1.00	3.20	17.4	39.5	73.6	368
	25.0	39,270	3,927	7,854	19,635	29,453	39,270	78,540	1.31	2.21	5.56	8.75	12.5	35.0	1.63	5.49	34.5	81.6	155	870
	30.0	47,124	4,712	9,425	23,562	35,343	47,124	94,248	1.69	3.07	7.70	13.6	18.7	--	2.52	9.16	57.4	152	279	--
	40.0	62,832	6,283	12,566	31,416	47,124	62,832	125,664	2.66	5.00	14.3	24.8	36.5	--	5.29	19.9	142	370	726	--
	50.0	78,540	7,854	15,708	39,270	58,905	78,540	157,080	3.91	8.00	24.5	41.8	69.5	--	9.72	39.8	304	779	--	--

SAFETY TIPS!

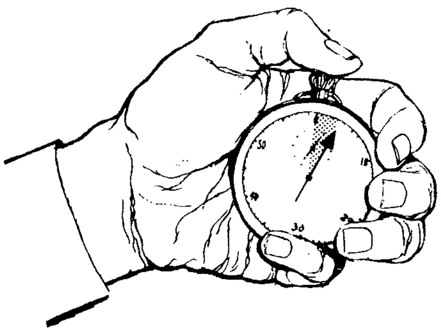
Look Up For Overhead Power Lines.

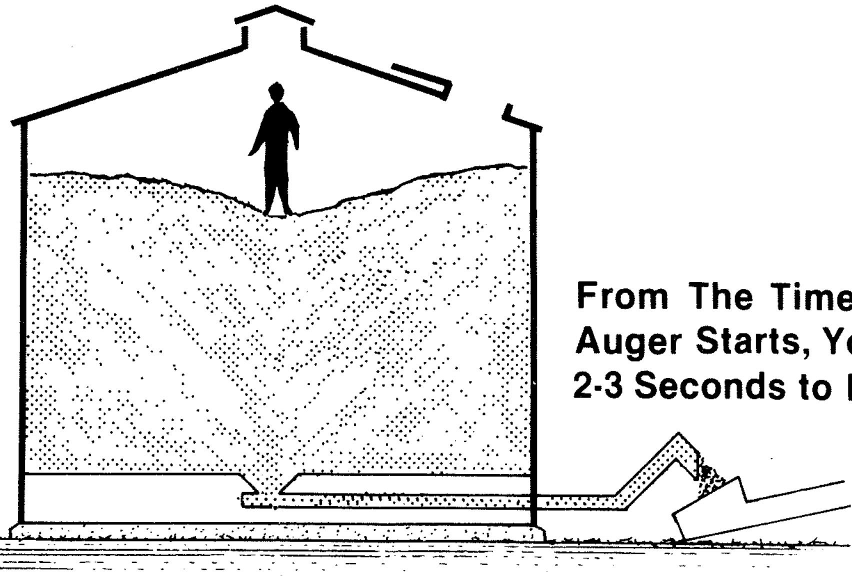


Do Not Locate Bins Near Power Lines!

FLOWING GRAIN CAN KILL YOU!

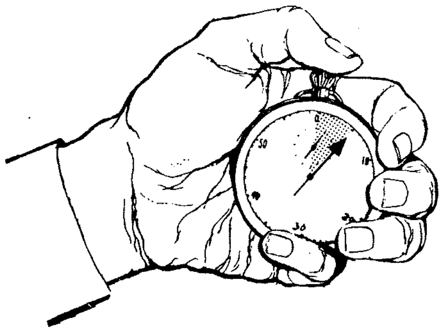
2-3
SECONDS

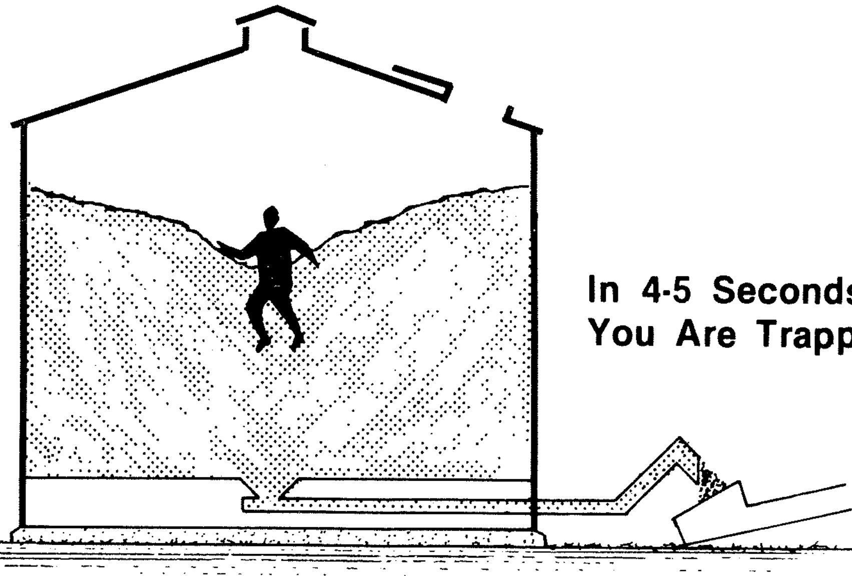




From The Time The Auger Starts, You Have 2-3 Seconds to React.

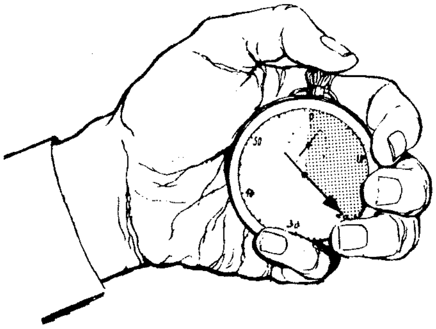
4-5
SECONDS

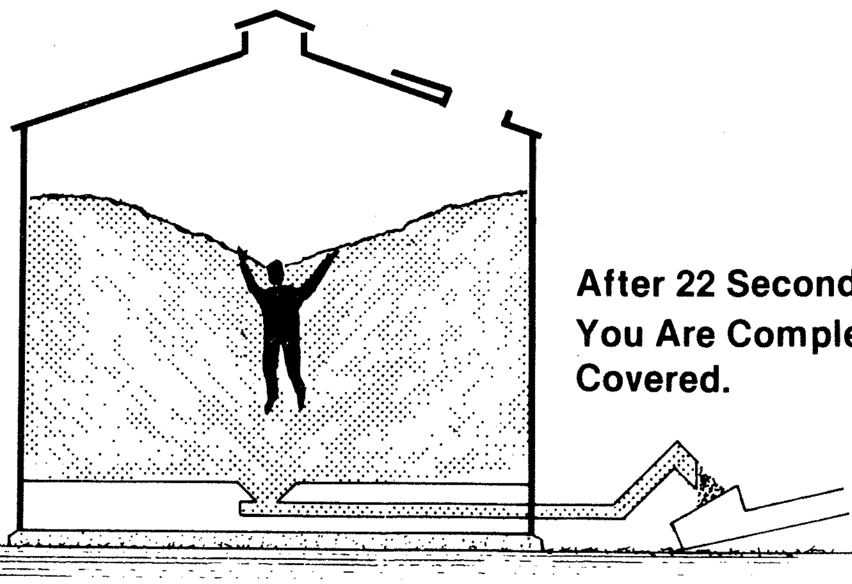




In 4-5 Seconds, You Are Trapped.

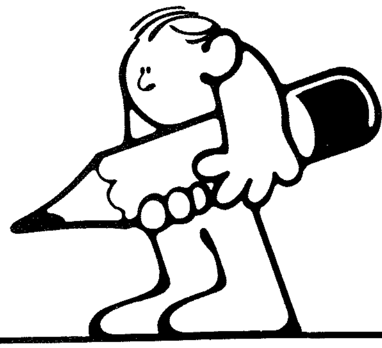
22
SECONDS





After 22 Seconds, You Are Completely Covered.

Write it down



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