Grain Dryer Selection & Energy Efficiency

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Natural Air Drying

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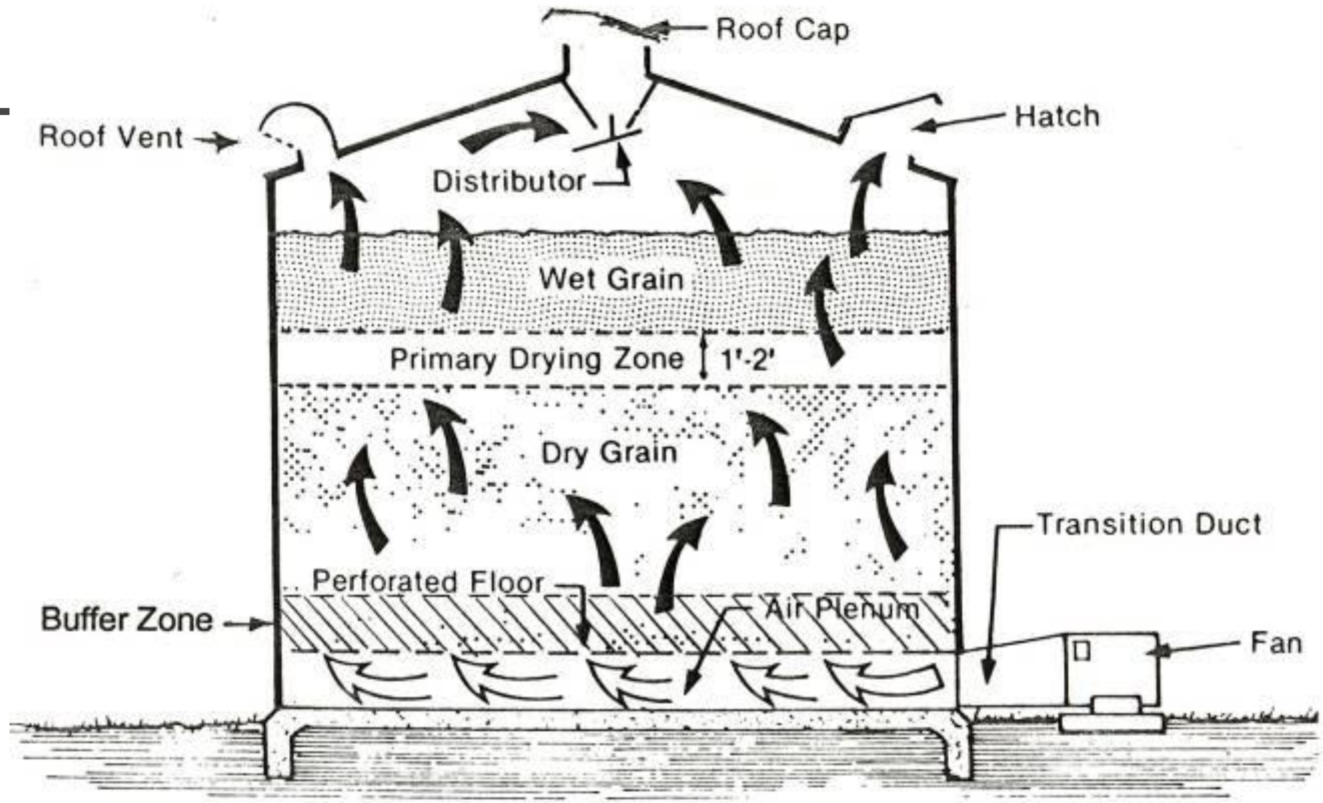

Natural air drying, if properly designed and managed, is the most energy efficient drying. It is not efficient on very wet grain or at November-March temperatures.

Natural Air Drying Cost

@ $0.08 kWh = $0.054/bu = $0.013/bu-pt.

17%-13% moisture Wheat

High Temperature ~ $0.029/bu-pt. @ (2,500 Btu/lb water)

$0.023/bu-pt. @(2,000 Btu/lb water)

@ $1.30 propane

21 ft bin, 18 ft depth, 4,988 bu.

0.75 cfm/bu,

Drying time = 31 days = 744 hrs.

Fan 5 hp Centrifugal 4.5 Kw

Electrical usage = 3,348 Kwh

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Effect of Supplemental Heat When NA/LT Drying Wheat

17% initial M.C., 0.75 cfm/bu, 10,000 bu Bin, $0.06 electric heat, $6.00/bu.

Adding heat increases drying and shrink cost. Only warm the air 5°F when necessary to reduce grain moisture.

	Temp (F)	RH (%)	EMC (%)	Drying Time (Days)	Shrink Cost	Heat Cost	Overdry Cost
Ave Sep	58	65	14.4	--			
+3 Fan	61	58	13.5	31			
10 + 3	71	41	10.8	27	$1,818	$940	$2,758
Ave Oct Cold Sep	47	65	15.0	--			
+3 Fan	50	58	13.9	39			
10 + 3	60	40	11.0	37	$1,686	$1,278	$2,964
Humid Sep	58	75	16.1	--			
+3 Fan	61	67	14.6	40			
10 + 3	71	47	11.6	28	$1,290	$968	$2,258
5 + 3	66	56	12.9	32	$414	$484	$898

Additional Fans are Expensive

Fan Hp	Cfm/bu	Drying Cost	Days	SP
1 x 7.5	0.86	$0.065	27	6.5
2 x 7.5	1.20	$0.094	19	9.8
3 x 7.5	1.45	$0.117	16	12.4
4 x 7.5	1.57	$0.143	15	13.7
5 x 7.5	1.62	$0.174	14	14.3

HSC Fan, Drying wheat 17% to 13% mc, electricity $0.06 Kwh

Increasing airflow rate increases drying cost. Optimal airflow rate for wheat is about 0.75 cfm/bu and for corn is about 1.0 – 1.2 cfm/bu.

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Fan Type Affects Airflow

1 x 7.5 hp LSC = 0.92 cfm/bu
1 x 7.5 hp ILC = 0.97 cfm/bu
1 x 7.5 hp HSC = 0.86 cfm/bu
1 x 7.5 hp Axial = 0.70 cfm/bu

2 x 7.5 hp LSC = 1.40 cfm/bu
2 x 7.5 hp ILC = 1.35 cfm/bu
2 x 7.5 hp HSC = 1.21 cfm/bu
2 x 7.5 hp Axial = 0.80 cfm/bu (in parallel)
2 x 7.5 hp Axial = 1.15 cfm/bu (in series)

21 ft diameter bin with wheat 17.5 ft deep

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Fan Type Comparison

Corn: 21 ft. diameter, 20 ft. deep, 10 hp fan

Fan	cfm	Airflow Rate (cfm/bu)	Static Pressure (in. wg)
AF 24″ (Axial Flow)	5,907	1.07	4.42
ILC (In-line Centrifugal)	5,458	0.98	3.95
LSC (Low-speed Centrifugal, 1750 rpm)	7,826	1.41	6.67
HSC (High-speed Centrifugal, 3500 rpm)	5,501	0.99	3.99

Typically the low speed centrifugal fan moves the most airflow through corn, so is the most efficient.

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Fan Power Required

	Corn Depth (ft)				
Airflow Rate	16	18	20	22	24
(cfm/bu)	--- hp per 1,000 bu ---				
1.0	0.6	0.8	1.1	1.3	1.7
1.25	1.1	1.4	1.8	2.3	2.9
1.5	1.7	2.2	2.9	3.6	4.5

Limit corn depth to about 20 ft and airflow rate to less than 1.2 cfm/bu for efficient drying.

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Natural Air and Low Temperature Corn Drying

21% Initial Corn Moisture Content, Average ND Climatic Conditions

				Drying Time (Days)	
Month & added heat	**Temp. (F)**	**RH**	**EMC**	**1.0 cfm/bu**	**1.25 cfm/bu**
Oct. +3 F (fan)	50	58%	13.5%	42	34
Oct. 15 – Nov +3 F (fan)	37	66%	15.8%	65	52
Nov. +3 F (fan)	30	64%	16.0%	70	56
Nov. +3 F (fan)+2 F	32	58%	14.6%	65	52
Nov. +10 F	37	48%	12.5%	51	41
Note: After 30 days of November drying, using an airflow rate of 1.25 cfm/bu. and fan heat, 44% of the corn has not dried				**Days to dry remaining 44% of corn**	
Dec. +3 F (fan)	16	65%	17.6%	50	40
Dec. +8	21	51%	14.3%	35	28

NA/LT corn drying works well until outdoor temperatures approach freezing, then becomes inefficient.

Natural Air & Low Temperature Corn Drying

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Spring Drying

				Drying Time (Days)	
Month & added heat	Ave. Temp (^{o}F)	RH	Corn EMC	**1.0** cfm/bu	**1.25** cfm/bu
Apr	**42**	**65%**	**15.3%**	**51**	**41**
+5^{o}F	**47**	**54%**	**13.3%**	**46**	**37**
May	**56**	**60%**	**13.5%**	**43**	**34**

Natural air drying is very efficient in the spring. Start fans when outdoor temperatures average about 40°F.

Heat of Vaporization

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HEAT OF VAPORIZATION (BTU/LB) OF SOME GRAINS AT DIFFERENT MOISTURE CONTENTS (% DRY BASIS) AND TEMPERATURES

Product and MC % db	Temp °F 32	50	70	100	150
Wheat					
5	1,289	1,277	1,265	1,243	1,208
10 (9.1% wb)	1,230	1,218	1,207	1,186	1,153
15 (13% wb)	1,174	1,163	1,152	1,133	1,101
20 (17% wb)	1,101	1,091	1,081	1,062	1,032
Corn					
5	1,474	1,460	1,446	1,422	1,382
10	1,384	1,371	1,359	1,335	1,298
15	1,304	1,292	1,280	1,258	1,223
20	1,202	1,191	1,180	1,160	1,127
Sorghum					
5	1,299	1,287	1,275	1,253	1,218
10	1,226	1,214	1,203	1,182	1,149
15	1,165	1,154	1,144	1,124	1,093
20	1,107	1,097	1,087	1,068	1,038
Water	1,075	1,065	1,055	1,037	1,008

SOURCE: Haynes (1961).

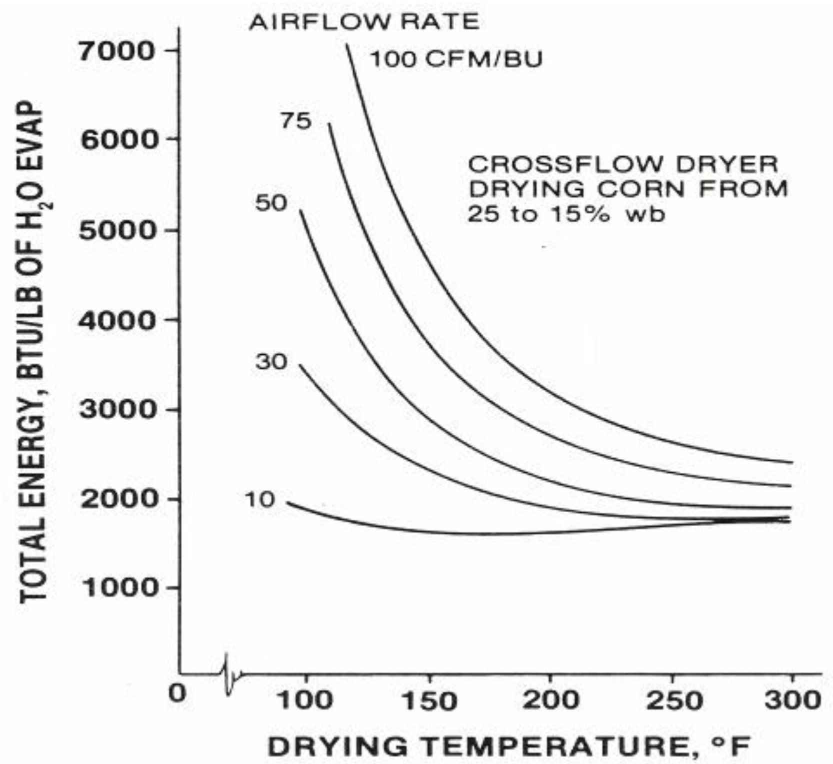
Drying Cereal Grains – Brooker, Bakker-Arkema, Hall

Water Heat of Vaporization = 1,070 Btu/lb @ 40°F

Minimum energy to evaporate water from corn is about 1,200 Btu per pound. Realistic dryer minimum is probably about 1,500 Btu.

Energy requirements of a conventional cross-flow dryer as a function of drying air temperature and airflow rate.

(University of Nebraska)



Energy required to remove a pound of water is reduced at higher plenum temperatures and lower airflow rates.

Use the maximum temperature that will not damage the grain.

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Pounds of Water Removed

The following equation shows the adjustment in quantity due to a change in moisture content

$$\text{Adjusted Quantity} = \frac{100 - \text{Base Moisture (\%)}}{100 - \text{Actual Moisture (\%)}} \times \text{Measured Quantity}$$

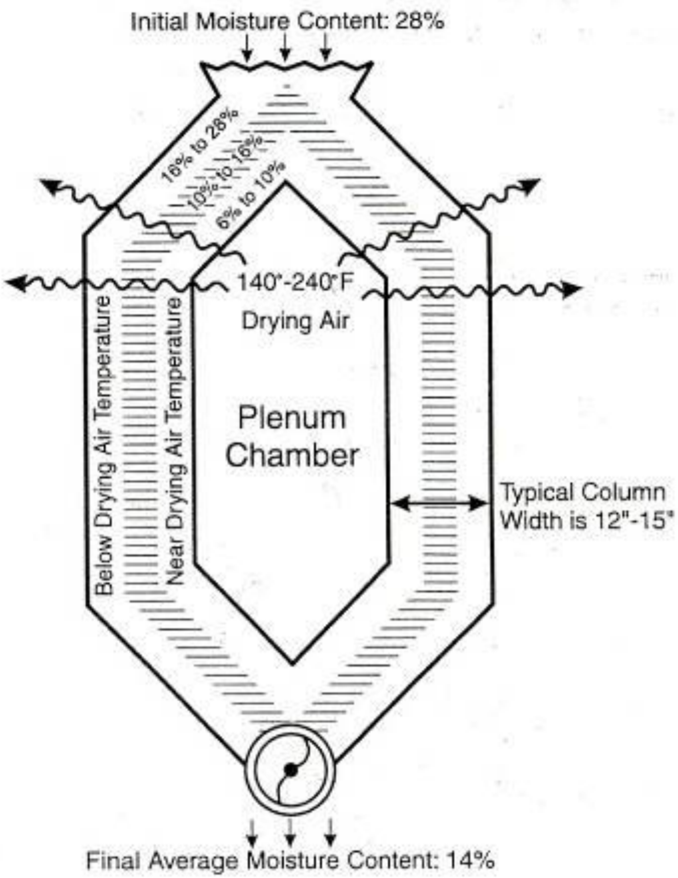
$$= \frac{100-15.5}{100-25} \times 56 \text{ pounds}$$

$$= 63.09 \text{ pounds at } 25\% \text{ moisture}$$

63.09 – 56 = 7.09 pounds water removed per bushel

About 0.75 pounds of water must be removed per bushel per point of moisture dried.

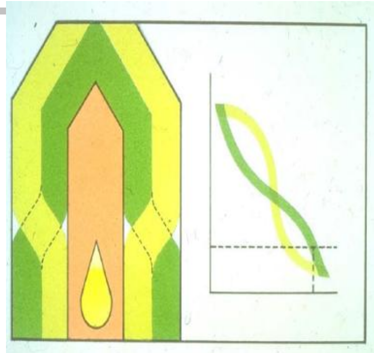
Cross-Flow Dryer

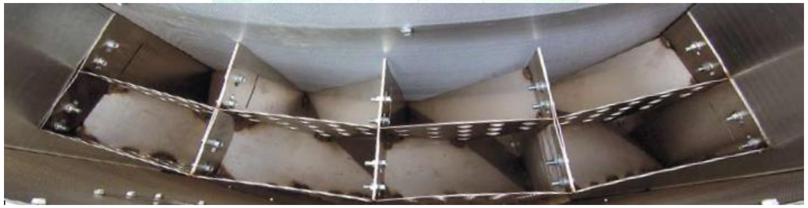


A traditional cross-flow dryer requires about 2,500 Btu to remove a pound of water from corn.

Dryer Improvements

Staged Temperature





Grain Turner or Inverter

Using a higher plenum temperature on the wettest grain reduces energy consumption. A grain turner or inverter reduces over-drying, moisture variation and excessive kernel temperatures.

Differential Grain Speed Dryer

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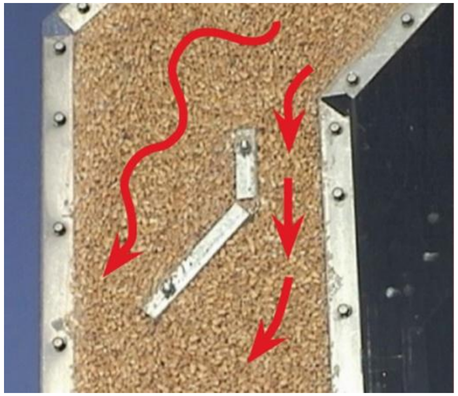

Increasing the grain flow rate near the plenum reduces excessive grain temperatures and creates a more uniform grain moisture content coming from the dryer.

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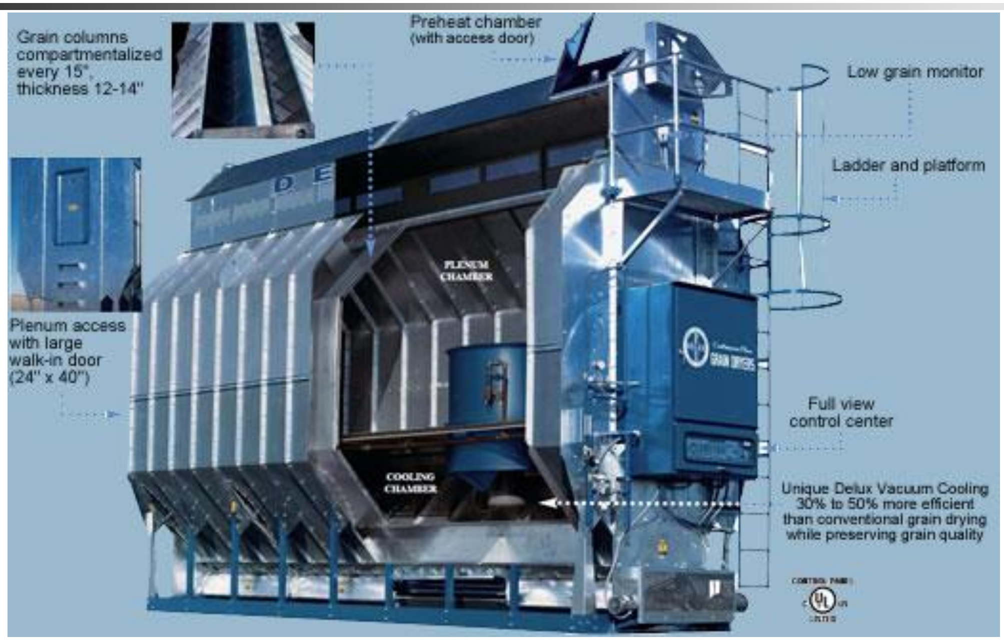
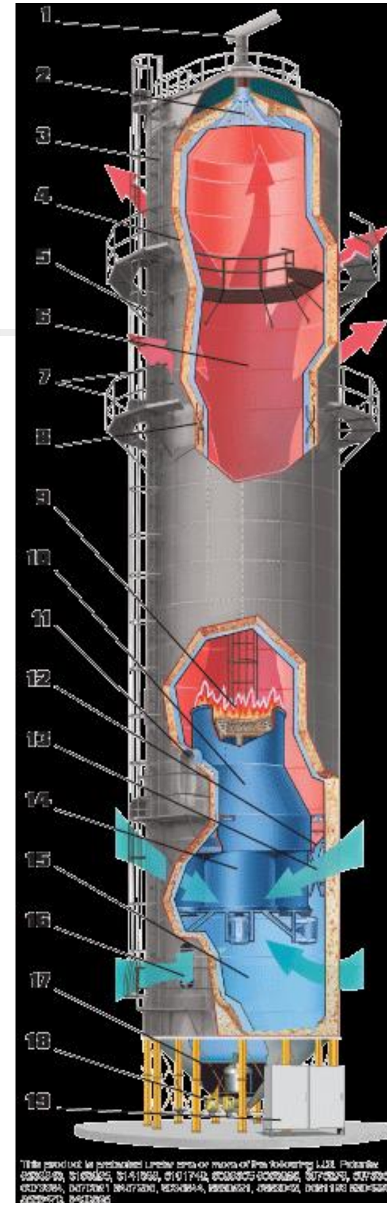
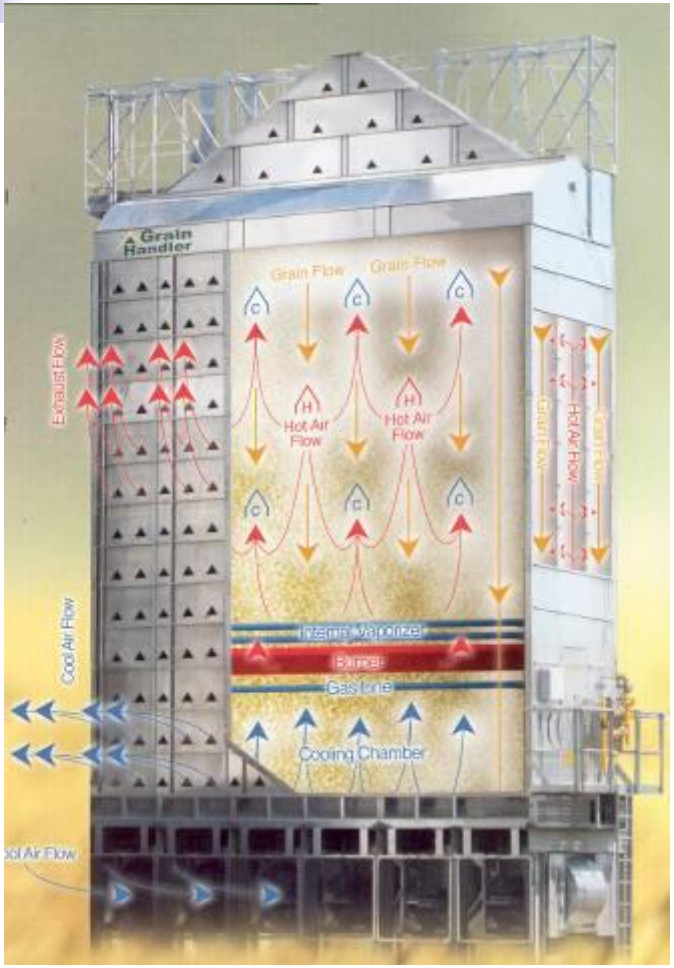
Vacuum Cooling





Vacuum cooling increases drying energy efficiency by 25% to 30%. This is more beneficial in cold northern climates.

Mixed Flow Dryer



A mixed flow dryer uses a lower airflow rate per bushel than a cross-flow dryer which increases energy efficiency. The moving grain design minimizes exposure to the hot plenum air which reduces the potential for grain damage.

Drying Cost Increases at Colder Temperatures

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High Temperature Drying

@ $1.10/gal propane ≈ 2.4¢/bu-pt.

21% to 15.5%   2,500 Btu/lb of water

Outside Temp.	% Increase	Cost ¢/bu
40	---	13.2
20	114	15.0
0	129	17.0
-20	142	18.7

With Air Recirculating 2,000 Btu/lbw ≈ 1.9¢/bu-pt. @ 40 F ≈ 10.5¢/bu

Dry when it is warmer if possible, since it takes more energy to dry at colder temperatures.

Drying Energy Cost Estimation

High Temperature Drying~210°F

Assumes 2,500 Btu/lb water

Propane cost / bu-point moisture =

0.022 x price/gal

\$ 0.033/bu-pt = 0.022 x \$1.50/gal

(@ 1,800 Btu/lbw)

\$ 0.024/bu-pt = 0.0158 x \$1.50/gal

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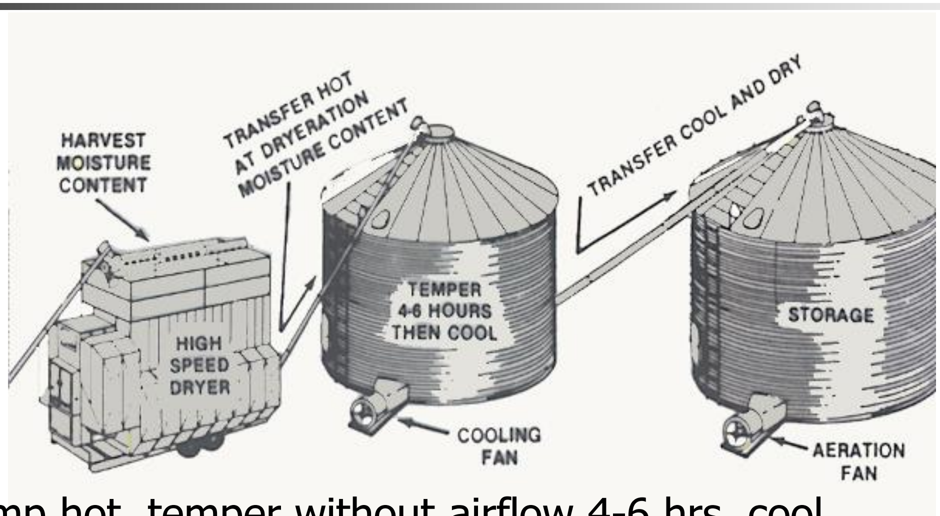
Drying energy cost has been estimated based on 2,500 Btu/lb of water removed. With a more efficient dryer, the multiplier might be about 0.016 times propane price.

Dryeration



- Dump hot, temper without airflow 4-6 hrs, cool
- Extensive condensation - must move corn to another bin
- Moisture reduction: 0.25%/10 F cooled, ≈2.5%
- Increases dryer capacity 50%-75%,
- Reduces energy by about 25%

Dryeration reduces energy consumption by about 25%, but it is imperative to move the corn to another bin for storage to prevent storage problems.

In-Storage Cooling

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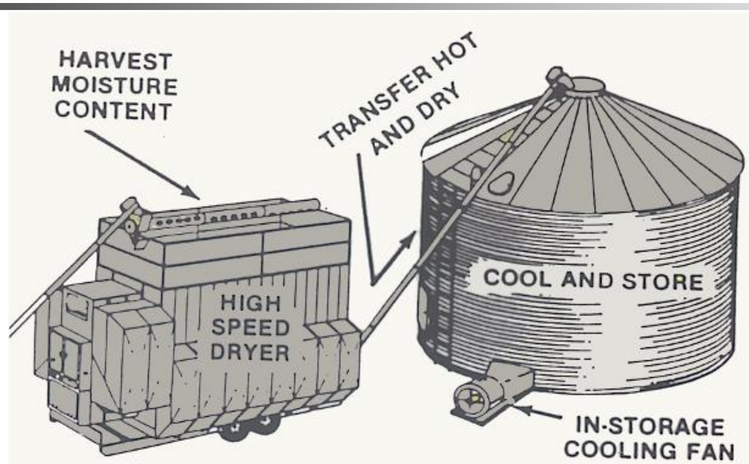
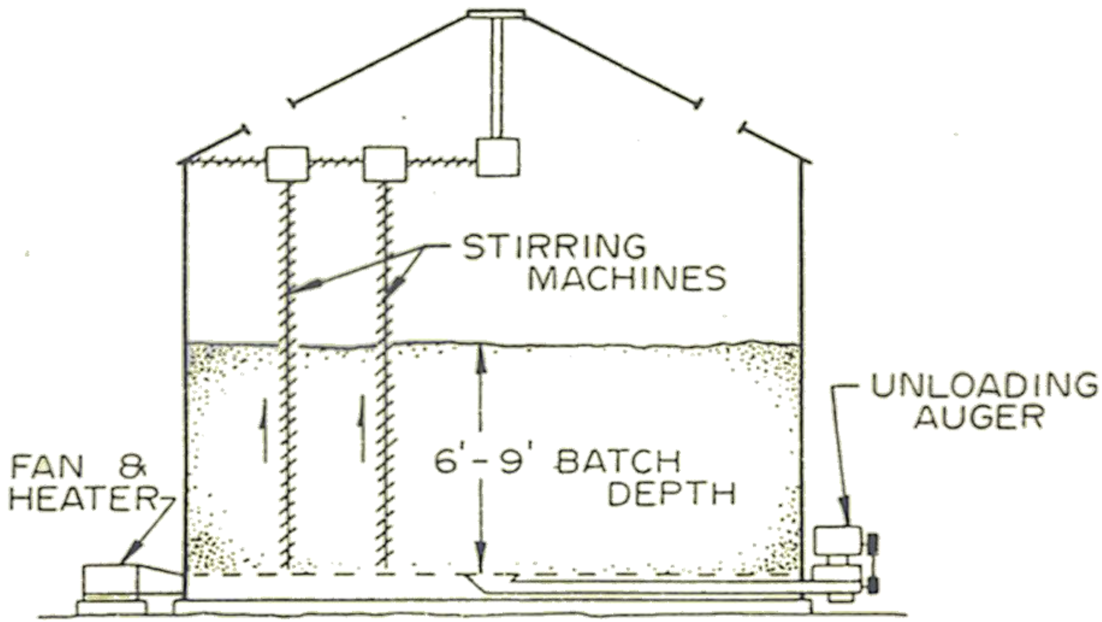


- Immediately cool, Airflow rate ≈ 12 cfm/bu-hr of fill rate
- About 1-1.5 percentage point moisture reduction
- Reduce condensation by partial cooling in the dryer – typically to about 90 F

In-storage cooling requires rapid cooling and cooler initial grain temperature to limit condensation. Slow cooling saves more energy, but storage problems typically occur near the bin wall.

Stirring Batch Bin Dryer



Maximum drying rate obtained with shallow depth. Use maximum temperature that will not damage the grain. Stirring limits overdrying.

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Continuous Flow Bin Dryer

Again use maximum air temperature and limit grain depth to maximize dryer capacity and efficiency. Cooling is done in a separate bin.

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For More Information

http://www.ag.ndsu.nodak.edu/abeng

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