1974

EC74-860 Corn Conditioning and Storage Systems...Characteristics and Costs

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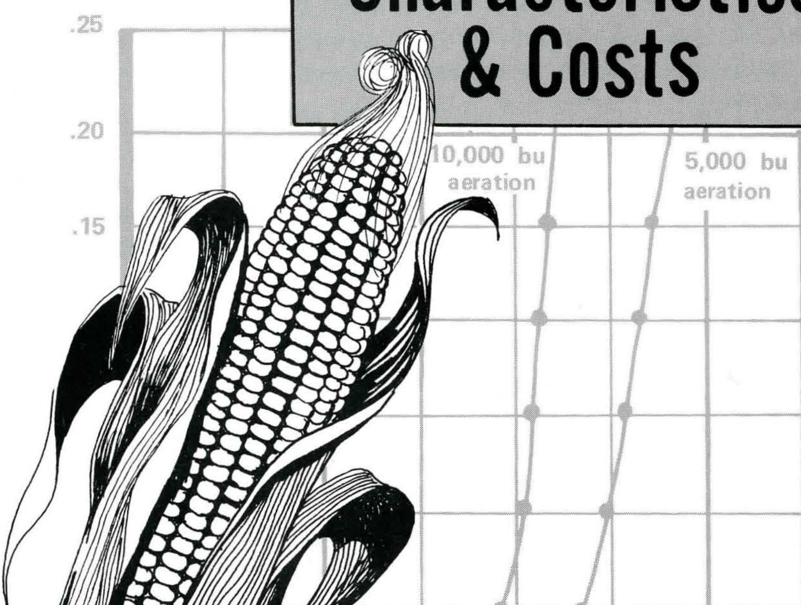
EC 74-860

CORN

Conditioning and Storage Systems....

Characteristics & Costs



Extension Service
University of Nebraska-Lincoln College of Agriculture Cooperating with the
U.S. Department of Agriculture and the College of Home Economics
J. L. Adams, Director

Contents

Issued February 1974, 3,000

CORN CONDITIONING AND STORAGE SYSTEMS – CHARACTERISTICS AND COSTS

P. W. Lytle and D. L. Coffman[1/]

Nebraska's production of corn for grain has increased about 115 percent from 250 million bushels in 1965 to 538 million bushels in 1972. This 1972 production ranks Nebraska third in the United States and accounts for about 10 percent of the total output of corn for grain.

Rapid adoption of corn combines has shortened the time needed for harvesting but requires conditioning of the high-moisture corn. Many farmers are increasing their on-farm conditioning and storage capacity because of on-farm feeding requirements, inadequate drying and/or storage capacity of country elevators, and lack of transportation.

Several on-farm grain conditioning and storage systems are available. A 1971 survey showed that 61 percent of Nebraska farmers were using either batch-in-bin or in-storage layer systems (Table 1). Continuous flow systems were being used by about 20 percent of the farmers.

Table 1. On-farm drying systems, Nebraska, 1971.

System type	*Producers that artificially dry shelled corn (%)*
Batch	13
Batch-in-bin	28
Continuous flow	21
In-storage layer	33
Other	5

Source: Nebraska Department of Agriculture, State-Federal Division of Agricultural Statistics, Lincoln, Nebraska.

[1/]Assistant Professor and Undergraduate student, respectively, Department of Agricultural Economics.

This circular presents cost data on the following on-farm grain conditioning and storage systems:

1. Continuous flow drying and storage.
2. Batch-in-bin drying and storage.
3. Continuous aeration drying and storage.
4. Bunker silo.
5. Acid treatment.

Costs for each system have been developed using specific assumptions for each system. Since these assumptions change, intersystem cost comparisons may not reflect a true picture for any specific situation. Costs for comparable systems using the same assumptions are given in the cost summary. Increases in costs will cause many of the budgeted values to change over time. However, the basic cost relationships and system descriptions remain valid.

Continuous Flow Drying and Storage System

High-moisture corn from a wet-grain holding bin is constantly added to the continuous flow dryer. The grain moves down through drying columns where relatively high temperatures and air flow rates are used for drying. The grain then proceeds down through a cooling section of the dryer and is moved into dry storage bins.

Cost data are in Table 2. Actual weather data and representative harvesting conditions in the Hall County, Hamilton County area of Nebraska were used for the 1969, 1970, and 1971 harvest seasons.

It was assumed the drying system was new in 1969, had a 1,669 bushel wet-storage holding bin and four 12,573 bushel dry-storage bins, and a dryer rated at 320 bushels per hour on a 10 point basis (drying from 25 to 15 percent moisture). About 44,000 bushels of high-moisture shelled corn was dried and stored until July during each of the three years.

Fixed costs include depreciation, property taxes, insurance on equipment, and interest on facility investment. Variable costs include trucking, repairs, electricity, fuel, taxes, interest and insurance on corn inventory, and labor.[2/]

[2/] Fixed costs are incurred whether or not you operate the system. Variable costs are incurred as a result of operating the system.

Implications from figures in Table 2 are that per bushel costs of drying and storage can be reduced by:

1. Delaying harvest until corn moisture in the field is 24 percent or less.
2. Increasing drying air temperatures from 160°F to 190°F.
3. Drying corn to 15.5 percent instead of 13 percent moisture.

Each of these actions has disadvantages which must be considered.

Delaying harvest can increase field losses. Increasing the drying air temperatures can reduce grain quality. Increasing the final moisture level can require aeration of stored corn because of the increased risk of spoilage.

Spreading the system's fixed costs over a larger quantity of corn dried would also reduce per bushel costs. This would result in an increased length of drying season since daily capacity is fixed. Costs shown in Table 2 are based on 18, 17, and 15-day drying seasons for 1969, 1970, and 1971, respectively. Increasing the drying season to 35 days will significantly reduce the average costs of drying.[3/]

Table 2. Per bushel drying and storage costs for the continuous flow system.

Drying air temperature and final moisture	*Original moisture 28% or less*			*Original moisture 24% or less*		
	1969 18-day drying season	*1970 17-day drying season*	*1971 15-day drying season*	*1969 18-day drying season*	*1970 17-day drying season*	*1971 16-day drying season*
			. . . cents per bushel . . .			
160°F, 13%	28.27	25.20	24.53	26.84	25.18	22.74
190°F, 13%	26.80	24.60	24.69	25.71	24.56	21.99
160°F, 15.5%	25.40	23.14	22.35	24.21	23.13	20.60
190°F, 15.5%	24.69	23.00	22.92	23.75	22.99	20.36

Source: Robert D. Zuehlsdorf, "Simulation and Economic Analysis of a Continuous Flow Corn Drying System" (Unpublished Master of Science Thesis, University of Nebraska-Lincoln, 1972).

[3/] Gary B. Baker, "Grain Drying in Country Elevators—Costs and Economies of Size" (Unpublished Master of Science Thesis, University of Nebraska-Lincoln, 1972).

Batch-In-Bin Drying and Storage System

As corn is brought from the field it is conveyed into a drying bin equipped with a fan and heating unit. As the bottom layer of grain is dried it is removed from the bin with a floor unloader and augered to storage bins. Storage bins are usually equipped with aeration fans to keep grain in good quality. The drying bin can be used for storage when the other bins are full.

Costs in Table 3 are budgeted for a system composed of three 10,000 bushel bins.[4/]

Table 3. Budgeted costs of storing and drying corn for a 30,000 bushel batch-in-bin system.

	1 Month	*3 Months*	*6 Months*	*9 Months*
		. . . cents per bushel . . .		
Drying, fixed costs	1.759	1.759	1.759	1.759
Storage, fixed costs	2.615	2.615	2.615	2.615
Drying, operating costs	2.317	2.317	2.317	2.317
Interest on inventory at 7%	.642	1.925	3.850	5.775
Insurance on inventory	.032	.096	.193	.289
Handling costs	1.000	1.000	1.000	1.000
Repairs and maintenance	.267	.267	.267	.267
Total Costs	8.632	9.979	11.281	14.022

Assumptions:

1) *Batch-in-bin drying system with fans, heaters, perforated floor and a circulator.*
2) *Corn harvested at 25% moisture, dried to 15.5%.*

Fixed costs in this analysis include depreciation, interest on investment, taxes, and insurance. Variable costs include dryer operating costs, interest and insurance on inventory, handling costs, and repairs and maintenance.

Comparing the itemized costs of Table 3 by length of time corn is stored shows that interest and insurance on inventory are the only items that increase. This increase amounts to 5.390 cents per bushel over eight months (14.022 for nine months of storage minus 8.632 for one month of storage).

4/ Total investment costs, including bin construction and cost of drying equipment, is 47 cents per bushel of storage capacity.

Natural Air Drying and Storage System

High moisture shelled corn is placed in storage bins equipped with aeration fans only. The fans run continuously for 60 to 90 days, reducing grain moisture to about 16 or 17 percent. From this time on fans are operated about one night per week until the corn is removed from storage.

Original (field) grain moisture levels of 26, 24, 22, 20, and 18 percent are compared for this system. We assumed that motors larger than 20 horsepower are not practical for natural air. As a result, grain at 28 percent moisture or above cannot be handled with this system. For grain quality maintenance the maximum permissible grain depth in the storage bin is seven feet for 26 percent moisture and 13 feet for 24 percent moisture corn.

Storage bins for this system are 28 feet in diameter and have 21.5 feet sidewalls, with a 10,000 bushel maximum capacity. Alternative systems of 10,000, 30,000, and 50,000 bushel capacities are considered requiring one, three, and five storage bins, respectively.

Each bin with fan and motor is assumed to have a retail price of $4,260. The resulting system characteristics using these assumptions are shown in Table 4.

Table 4. Characteristics for the natural air systems.

Original grain moisture (%)	*Minimum airflow rate (cfm/bu)*	*Fan motor size (hp)*
26	5.0	20
24	2.5	20
22	1.0	10
20	0.3	3
18	0.1	3/4

Source: Unpublished research developed by T. L. Thompson, Agricultural Engineering, University of Nebraska-Lincoln.

Both fixed and variable costs using two different market strategies are calculated for the three sizes of systems. Fixed costs include depreciation, taxes, interest on investment, repairs, and insurance on facilities. Variable costs include interest and insurance on inventory, storage losses, and electricity.

The two alternative marketing strategies are: 1. Sell the corn in a single sale in July of the crop year and, 2. Sell or feed the corn throughout the marketing year in an even stream from harvest until July of the crop year.

Per bushel costs using these assumptions are shown in Tables 5 and 6. Costs are lower for the option of using the corn continuously since variable costs such as interest on inventory and electricity will be lower due to removing part of the grain earlier.

Using natural air will provide a high moisture, palatable feed grain for the first 60-90 days of fan operation. After the grain is dry it can be sold as a high quality dried product whenever price warrants, adding flexibility to the system and affording the opportunity to earn a return for storage.

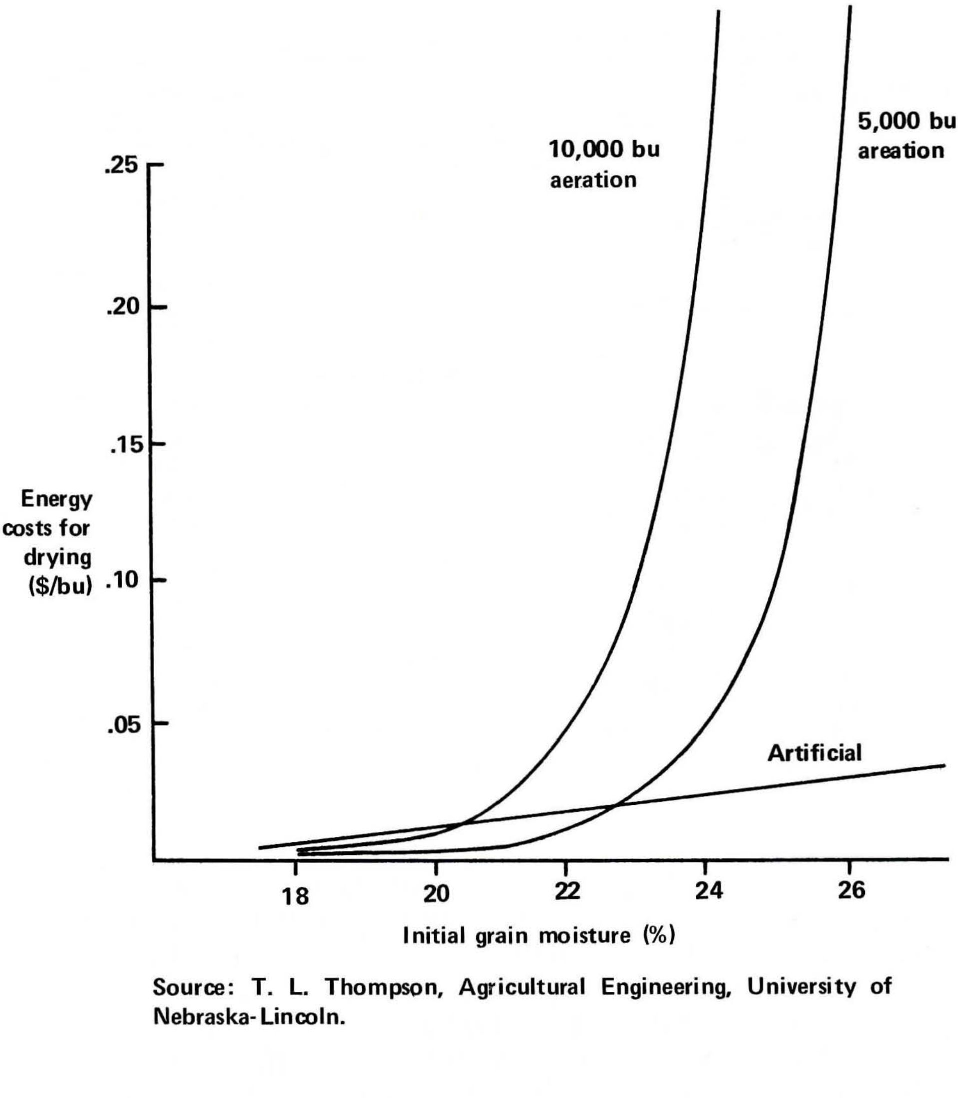
Table 5. Natural air costs for using corn continuously throughout the crop year.

Original grain moisture (%)	*Total annual costs ($)*		*Per bushel annual costs ($)*
		1 - 10,000 bu bin	
26	1394.41		0.4277
24	1419.70		0.2347
22	1086.39		0.1086
20	862.92		0.0863
18	802.75		0.0828
		3 - 10,000 bu bins	
26	4094.18		0.0280
24	4169.48		0.3446
22	3216.34		0.1072
20	2575.34		0.0858
18	2403.86		0.0801
		5 - 10,000 bu bins	
26	6570.79		0.6712
24	6744.84		0.3716
22	5287.09		0.1057
20	4215.94		0.0852
18	4503.63		0.0800

Tables 5 and 6 show that the cost of using natural air for grain at 26 and 24 percent moisture is comparatively high. The limits on grain depth per bin, at these moisture levels, reduces capacity to

3,260 bushels per bin for 26 percent moisture corn and to 6,050 bushels per bin for 24 percent moisture corn. This cost disadvantage is also shown in Figure 1.

Figure 1. Energy costs for continuous aeration and artificial drying



Source: T. L. Thompson, Agricultural Engineering, University of Nebraska-Lincoln.

Figure 1 was generated from assumptions of electrical costs of $.0175 per killowat hour and fuel costs (for artificial drying) equal to $.12 per gallon to determine energy requirements for different initial grain moistures. The assumed systems use a 30 foot diameter bin with an 18 foot grain depth for 10,000 bushels and a 9 foot grain depth for 5,000 bushels.

Table 6. Natural air costs for single sale in July.

Original grain moisture (%)	*Total annual costs ($)*	*Per bushel annual costs ($)*
	1 - 10,000 bu bin	
26	1460.98	0.4482
24	1547.70	0.2558
22	1305.01	0.1305
20	1089.67	0.1090
18	1035.83	0.1036
	3 - 10,000 bu bins	
26	4382.92	0.6722
24	4643.10	0.3837
22	3915.03	0.1305
20	3269.01	0.1090
18	3107.49	0.1036
	5 - 10,000 bu bins	
26	7304.88	0.7470
24	7738.49	0.4264
22	6525.05	0.1305
20	5448.35	0.1090
18	5179.15	0.1036

At lower initial grain moistures and lower grain depths the aeration system has energy cost advantages over artificial drying. Artificial drying costs less above 20 percent initial grain moisture for the 10,000 bushel-18 foot depth aeration system, and 22 to 23 percent initial moisture for the 5,000 bushel-nine foot depth.

Capacity of many existing on-farm grain conditioning systems could be increased and energy costs reduced by using artificial drying to remove moisture from corn above 20 to 22 percent and then changing to natural air drying for the remaining moisture reduction.

Bunker Silo

A horizontal, open top silo can be built above or below the ground surface. High moisture grain is dumped into the silo, packed, and covered with plastic. Grinding the grain improves packing. As an ensiled product the corn can only be fed to livestock. It is, however, a very palatable, high quality feed.

Three bunker sizes are considered: 280-ton (10,000 bushels), 840-ton (30,000 bushels), and 1,400-ton (50,000 bushels). Fixed costs are: depreciation, repairs and maintenance, interest, taxes, and insurance on investment. Variable costs are: interest and insurance on inventory, storage losses, and a plastic cover. It is assumed that the farmer already has the necessary loading, unloading, and grinding (if used) equipment. Corn is fed out evenly over a nine-month period.

The resulting total and per bushel annual costs are shown in Table 7 for initial grain moisture levels of 28, 26, 24, and 22 percent. Corn below 24 percent would require reconstitution to ensile. Per bushel costs can be reduced significantly by increasing silo size ($.0613 for 280 tons to $.0505 for 840 tons to $.0453 for 1,400 tons, all at 28 percent moisture).

As an alternative to feeding grain on the farm where produced, producers could use bunkers for storage and contract with local feeders for delivery throughout the year. This would allow the producer to earn a storage return and save the feeder from storage facility ownership costs and tying up capital in inventories purchased at harvest time.

Table 7. Costs of owning and operating bunker silos.

Original grain moisture (%)	*Total annual costs ($)*	*Per bushel annual costs ($)*
	280-ton silo	
28	613.03	0.0613
26	622.57	0.0623
24	631.27	0.0631
22	640.18	0.0640
	840-ton silo	
28	1,516.19	0.0505
26	1,544.81	0.0515
24	1,590.88	0.0530
22	1,597.62	0.0533
	1,400-ton silo	
28	2,262.89	0.0453
26	2,312.61	0.0463
24	2,356.05	0.0471
22	2,400.61	0.0480

Acid Treatment

Propionic acid and mixtures of propionic and acetic acids are marketed as preservatives for high-moisture corn. The acid is sprayed on and, in essence, pickles the grain. As a result there is little or no biological activity on or in the grain. Therefore, if effective, the grain does not heat and incurs little or no dry matter loss. The grain *must*, however, be fed to livestock. Special applicators are available and can be rented or purchased.

Both propionic and acetic acids have low orders of toxicity to humans and animals. Propionic acid is a normal component in the digestive tract of ruminants. Vinegar is a dilute solution of acetic acid. However, plastic linings for storage bins may be necessary to avoid sidewall deterioration.

One manufacturer of the propionic-acetic acid mixture recommends that grain be given the total treatments (application rates) shown in Table 8. These rates should be adequate to preserve the grain throughout the crop year, although actual storage time may be shorter than this.

A manufacturer of the 100 percent propionic acid treatment has recommended application rates for various storage period lengths

(Table 9). Reducing application rates will cut treatment costs but will also reduce the feeder's flexibility of the time within which grain must be used. Storage cost will be incurred in addition to the acid costs shown in Tables 8 and 9.

Feeding trial data comparing acid treated grain to dry grain reveal improved average daily gain and feed efficiency using the preserved grain (Table 10). Similar trials comparing treated grain to ensiled corn show essentially equal average daily rates of gain and feed efficiency (Table 11).

Table 8. Application rates and treatment costs for 80 percent propionic and 20 percent acetic acid grain preservative, 1973.

Initial grain moisture (%)	*Application rate (% bu wt)*	*Acid costs (cents/bu)*
15	0.60	8.7
20	0.90	13.1
25	1.20	17.5
30	1.50	21.8
35	1.75	25.5

Assumption: Retail price of treatment = 26 cents/lb.

Table 9. Application rates and treatment costs for 100 percent propionic acid grain preservative, 1973.

Initial grain moisture (%)	*Application rate (oz/bu)*	*Acid costs (cents/bu)*
	Up to 6 months storage	
21 or less	3	5.4
22 through 25	4	7.3
26 through 30	6	10.9
	Up to 9 months storage	
21 or less	4	7.3
22 through 25	6	10.9
26 through 30	8	14.5
	Up to 12 months storage	
21 or less	6	10.9
22 through 25	8	14.5
26 through 30	9	16.3

Assumption: Retail price of treatment - 29 cents/lb.

Table 10. Beef cattle performance on acid treated high moisture grain compared to dry grain.

	Average daily gain			*Feed Efficiency*		
	Dry (lb)	*Treated (lb)*	*% Improve-ment*	*Dry (lb)*	*Dry (lb)*	*% Improve-ment*
Iowa State						
Bunker	2.00	2.02	+ 1.0	713	690	+ 3.3
Self-Fed	2.28	2.77	+21.5	637	554	+15.0
Illinois	3.21	2.94	- 9.2	529	513	+ 3.1
Nebraska	1.90	1.85	- 2.6	1,010	1,000	+ 1.0
Penn State	2.42	2.59	+ 7.0	818	780	+ 4.9
Purdue 1	2.58	2.63	+ 1.9	680	620	+ 9.7
2	2.44	2.50	+ 2.5	638	607	+ 5.1
Guelph	2.92	3.06	+ 4.8	549	500	+ 9.8
Average			+ 3.3			+ 6.5

Source: *Low Temperature Drying and Chemical Preservatives, U. of Illinois Grain Conditioning Conference Proceedings, Champaign, Illinois, January 17-18, 1973.*

Table 11. Beef cattle performance on acid treated high moisture grain compared to ensiled corn.

	Average daily gain			*Feed Efficiency*		
	Ensiled (lb)	*Treated (lb)*	*% Improve-ment*	*Ensiled (lb)*	*Treated (lb)*	*% Improve-ment*
Iowa State	2.36	2.02	-14.4	590	690	-14.5
Illinois	2.91	2.93	- 0.7	510	513	- 0.6
Nebraska						
Silo[a/]	1.98	1.85	- 6.6	920	1,000	- 8.0
Bunker	1.61	1.85	+14.9	1,030	1,000	+ 3.0
Kansas	2.89	3.07	+ 6.2	760	694	+ 9.5
Purdue	2.51	2.50	- 0.4	613	607	+ 1.0
Guelph	3.09	3.06	- 1.0	543	500	+ 8.6
Average			- .03			- 0.1

[a/]Silo is a vertical oxygen limiting type.

Source: *Low Temperature Drying and Chemical Preservatives, U. of Illinois Grain Conditioning Conference Proceedings, Champaign, Illinois, January 17-18, 1973.*

Cost Summary of Comparable Size Drying Systems

Comparing average costs of different drying systems can provide useful information. Great care, however, must be taken in interpreting cost comparisons. Management requirements of the system, weather differences, rated versus actual equipment capacities, management capabilities, length of drying season, actual moisture reduction, initial purchase price, electricity and gas rates, and many other conditions affect the true cost of any actual system.

Comparable representative on-farm drying systems have been developed using the following assumptions. Each system has a 200 bushel per hour or 2,400 bushel per day drying capacity removing 10 points of moisture (25 percent to 15 percent). Length of drying season is 15 days giving a yearly volume of 36,000 bushels. Electric motors are always used.

Only the costs of drying are calculated. Loading and unloading equipment, and wet holding and dry storage bin costs are not included.

Types of systems analyzed are: crossflow[5/] including continuous flow, portable batch, and batch-in-bin; concurrent flow;[6/] and counterflow[7/] (via use of a floor unloader in the drying bin).

Fixed costs used in the analysis are depreciation, interest and insurance on investment, and taxes. Variable costs considered are fuel, electricity, and maintenance and repairs.

Physical characteristics of the systems are shown in Table 12. After these data were determined, purchase cost estimates were provided by drying equipment manufacturers.

5/ In cross flow the grain moves downward and the air moves crosswise.

6/ In concurrent flow both the air and the grain moves downward.

7/ In counter flow the grain moves down and the air moves upward.

Table 12. Characteristics of similar size dryers.

	Crossflow			*Con-current flow*	*Counter[c] flow*
	Con-tinuous flow	*Port-able batch[a]*	*Batch in-bin[b]*		
Airflow					
cfm/bu	50.0	50.0	10.0	--	--
ft/min	--	--	--	50.0	40.0
Fan horsepower[d]					
Theoretical requirement	7.6	10.6	8.6	8.1	10.8
Actually used	15.0	25.0	15.0	15.0	2-10's
Air temperature (^{o}F)	190	190	120	250	140
Fan use (hr/dry)	12.0	16.6	19.0	12.0	12.0

a/ *Portable batch system is assumed to need one hour per batch for loading, unloading, and cool-down. The system's drying capacity is rated at 290 bushels per hour to remove 10 points of moisture (25% to 15%).*

b/ *The batch-in-bin system is stacked four feet deep.*

c/ *The counter flow system is stacked three feet deep and uses a bottom unloader.*

d/ *The motor size actually used in the cost budgeting is about two times the horsepower requirement, assuming approximately 50% motor efficiency.*

Fixed and variable costs for each system type are calculated both as total annual and average annual (per bushel) costs (Table 13).

Table 13. Fixed and variable annual costs of drying corn with similar size systems.

	Crossflow			*Con-current flow*	*Counter flow*
	Con-tinuous flow	*Portable batch ($)*	*Batch-in-bin ($)*		
Fixed Costs					
Depreciation	810.00	900.00	455.00	850.00	768.60
Insurance	36.45	40.50	20.48	38.25	34.59
Taxes	92.14	102.38	51.76	96.69	87.43
Interest	303.75	337.50	170.63	318.75	288.23
Total fixed costs	1242.34	1380.38	697.87	1303.69	1178.85
Per bushel fixed costs	.0345	.0383	.0194	.0362	.0328
Variable Costs					
Fuel	978.66	1852.59	782.93	878.59	748.99
Electricity	37.80	87.15	59.85	37.80	50.40
Maintenance and repairs	56.70	63.00	31.85	59.50	53.80
Total variable costs	1073.16	2002.74	874.63	975.89	853.19
Per bushel variable costs	.0298	.0556	.0243	.0271	.0237
Total costs	2315.50	3383.12	1572.50	2279.58	2050.04
Per bushel fixed plus variable costs	.0643	.0939	.0437	.0633	.0565

Comparisons of these values show that the batch-in-bin system has the lowest per bushel cost (4.37 cents) and the portable batch the highest (9.39 cents). The higher initial purchase costs and fuel consumption of the portable batch and concurrent flow system pushed their average costs up. Using PTO drives on these systems would reduce costs.

Choosing the best grain drying and storage system for any operation should be based on the costs of owning and operating that system. Factors constraining the system type chosen are existing facilities of the farm, desired marketing flexibility (related to quality requirements and intended utilization), and managerial capabilities of maintaining grain quality and in marketing.

Help in determining costs of specific grain conditioning systems can be obtained from the Agricultural Extension Service as well as equipment manufacturers.