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THE ECONOMICS OF FARM GRAIN STORAGE AND DRYING IN KANSAS

by

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CHAPTER I

INTRODUCTION

Due to the seasonal nature of grain production, a safe place must be provided for the greater part of grain produced until it is needed for consumption. Grain stocks are used continuously throughout the year as food, feed, seed and for industrial purposes. Some grain has always been stored on farms. A substantial portion of the feed grain crop never leaves the farm or community in which it is grown. Farm storage, if available, is also used to hold excess stocks produced in bumper crop years that commercial facilities can't handle or to store a large portion of the crop when commercial elevators can't move grain as fast as modern combines can harvest it.

Many farmers are finding that the best way to maintain marketing alternatives including control of the timing of their sales is by storing crops themselves. To do this successfully represents a significant refinement to the marketing skills of the modern farmer. Farmers with storage have more marketing flexibility because they are able to choose from more market alternatives.

Grain storage systems represent long-term specialized investments by farmers and the decision to purchase farm drying and storage equipment should be based on careful assessment of many factors, one of which is the cost of performing the storage function on the farm. The size of this investment, once made, reduces the feasibility of other drying and storing alternatives for the life of the equipment. It is therefore important that the costs of owning and operating the farm storage equipment and the returns it will generate be carefully evaluated before the investment is made. Farmers must also consider the greater risk, inconvenience, and extra transportation, labor and handling involved in farm storage when determining investment feasibility.

Objectives

The general objective of this study is to determine the costs to Kansas farmers of several alternative storage and drying systems. Procedural steps in this determination include the following intermediate objectives:

1. To review methods and techniques used and economic results from previous literature on farm storage and drying costs and returns,
2. To determine representative designs and accompanying investment in storage and drying systems for farm use,
3. To determine operating and annualized ownership costs for grain storage and drying systems under various operating conditions, and
4. To relate cost of systems operation to potential income gains to farmers from operation of on-farm storage and drying systems.

Review of Literature

Literature reporting research on the economic aspects of farm grain storage and drying systems has been published by various agricultural experiment stations in a continuing effort to identify and promote minimum cost marketing systems to the benefit of producers and consumers alike. Studies identify a variety of storage facilities adapted to specific locations and atmospheric environments, types of grain handled, and changes in harvesting, storage, and marketing technology. Studies also identify (and may have been conducted in response to) changes in availability of commercial storage space and changes in input cost relationships, e.g. the dynamic fossil fuel energy situation and current rate of general inflation of farm input costs.

Most studies begin by defining environmental characteristics of the study area, identifying the grains to be stored and reviewing their unique storage characteristics. A study done in the Northern Great Plains Region of the U.S. in 1956[1] defined the environment as a cool, dry climate which is fortunate with

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[1]Montana State College, Agricultural Experiment Station, Economic Aspects of Grain Storage in the Northern Great Plains (Great Plains Council, Bulletin 523, August 1956), p. 8-9.

regard to storage problems. The common insects and molds which cause grain to go out of condition are not hard to control in a cool, dry environment as in a warm, moist environment. The danger of deterioration in storage decreases progressively from Kansas to Montana. Kansas is on the southern boundary of the Northern Great Plains and has mean annual temperature of 55.1°F and 26.57 average annual inches of rainfall. The study gave the following recommendations for safe grain storage in the Northern Great Plains.[2]

1. Good bins, well ventilated and capable of excluding rain, snow, rodents and birds.

2. Control of rodents and insects by careful cleaning of bins and premises and by spraying bins before use.

3. Storage of grains never more than 14 percent moisture, preferably not more than 12 percent. Grain with a moisture content above 13 percent normally have moisture removed by aeration or drying for safe storage.

4. Frequent inspection of grain in bins to guard against heating and insect infestation. Insect infestation can be controlled by fumigation.

Further investigation of safe moisture levels reveal variations depending on type of grain and length of the storage period. Moisture content levels for the grains listed below were compiled by midwestern agricultural engineers in 1976.[3]

Grain	At Harvest percent	For Safe Storage (1 yr.) percent
Wheat	9 to 17	Up to 13.5
Grain Sorghum	10 to 25	Up to 13.0
Corn	14 to 30	Up to 13.0

For any grain stored as seed stock and for long-term storage up to 5 years, the moisture levels for safe storage should be two percent lower than indicated above. The data show that the harvesting moisture contents for wheat range above and below

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[2]Ibid.

[3]Midwest Plan Service, Planning Grain and Feed Handling (Iowa State University, Ames, Iowa, February 1976). p. 66.

the safe storage level. Harvest moisture contents are frequently at or below safe storage level in hard red winter wheat producing areas. For this reason artificial air drying is seldom used for wheat in Kansas. It is a more common practice to allow the wheat crop to field dry to safe moisture levels.

The moisture levels for harvesting grain sorghum and corn in Kansas are much greater than safe storage levels. Also, weather interferes with optimum time of harvest at least once in three years in all areas of Kansas where grain sorghum and corn are produced.[4] The two crops are physiologically mature at moisture contents of around 28 percent and harvesting for optimum results may begin at about 25 percent for corn and 22 percent for sorghum.[5] Without drying facilities an important portion of these crops is lost in the field while waiting for grain to become dry enough to store or sell on the dry grain market. These losses occur from birds, wind shatter, fallen stalks, vines and general grain quality deterioration.

A study done in Mississippi in 1975 on the cost of farm rice storage and drying[6] describes an analysis of storage and drying costs at various storage drying capacities and throughput sizes of farm facilities. Capital investment requirements were developed for facilities with 15,000, 30,000, 40,000, 60,000, 80,000, and 150,000 bushel storage capacities. Capital requirements were estimated for storage bins and equipment including dryers, conveyors, and electrical panels. The total investment costs ranged from $25,000 for the smallest facility to over $150,000 for the largest facility. From the investment costs a capital

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[4]Elwin S. Holmes, On-Farm Grain Drying (Cooperative Extension Service, Manhattan, Kansas, September, 1972), p. 1. (hereafter cited as Holmes, On-Farm Grain Drying)

[5]Ibid.

[6]Shelley Holder, Jr., Sjako Subandrijo Olsman, and David W. Parvin, Jr., Costs of On-Farm Rice Drying-Storage Facilities in Mississippi, 1975 (Mississippi Agricultural and Forestry Experiment Station, Bulletin 837, January 1976).

investment curve was derived to approximate the investment for facilities of other sizes.

Cost of owning and operating each of the facilities was estimated for three levels of utilization--100 percent, 75 percent, and 50 percent.[7] At the 100 percent level of utilization, total annual costs for storing rice for a 5 month period ranged from $0.32 per bushel for 15,000 bushel facility to about $0.19 per bushel for the 150,000 bushel facility. Corresponding annual costs per bushel of grain stored at the 50 percent level of utilization (annual grain volume at 50 percent of available storage capacity at one point in time) were $0.58 and $0.32 per bushel. The results indicated that, generally, facility size and costs per bushel were inversely related. But, a larger facility utilized at less than capacity is more costly than using a smaller facility at capacity.

The study[8] divided the ownership (fixed) costs into categories of depreciation, interest, insurance, and property tax. Depreciation and interest on investment were the largest items of fixed costs, together accounting for about 77 percent of all fixed costs. The operating (variable) cost categories were labor, electricity, dryer fuel, repairs, insurance on rice and interest on operating capital. Labor, electricity, and dryer fuel are the major variable cost items. These items combined account for about two-thirds of total variable costs.

The design or format of the study permitted development of both short-run and long-run cost curves although the short-run cost curves were not the typical text-book representation of U-shaped curves. The short-run average cost curves developed in this study decrease but show no signs of turning up in the typical U-shape. Their shape reflects the absolute capacity reached at 100 percent utilization of the facility when all available storage capacity is filled at harvest. The long-run average cost curve was represented by a smooth curve drawn at the low-point of each of the short-run average cost curves. It falls

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[7]Ibid.

[8]Ibid.

rapidly as size of storage facilities increase to 60,000 bushels then remains nearly constant over the remaining storage levels. This is a situation which may be typical in many businesses although in most cases the curve begins to reflect increased unit costs at extremely high output levels.

An Illinois study in 1977[9] used similar techniques except that various types of dryer units were analyzed at various storage levels. The researchers divided the study into systems designed for cash grain farms and livestock farms. Drying systems analyzed included the batch-in-bin, batch-in-bin stir dryer, low temperature dryer, automatic bath, continuous flow, oxygen free storage, acid treated bin storage, ear corn storage and commercial elevator storage.[10] The latter four with the exception of commercial elevators were used for livestock farms only while the others were used for livestock farms and cash grain farms.

Fixed and variable costs were computed for each storage and drying system at 5,000, 10,000, 20,000, 40,000, 60,000, 80,000, and 100,000 bushel capacities. In addition to the basic fixed and variable costs, a field loss cost was included. Field harvesting losses occur as a result of differences in the number of days required to complete harvest. The field losses increased for lower moisture contents at the beginning of harvest and with greater length of harvest.

The results of cash grain farm systems which were analyzed[11] showed that the commercial elevator was the lowest cost alternative to farmers storing and drying annual volumes of 5,000 and 10,000 bushels. The batch-in-bin dryer was

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[9]R. B. Schwart and L.D. Hill, "Costs of Conditioning and Storing Corn on Illinois Farms," (Agricultural Experiment Stations, University of Illinois at Urbana-Champaign, manuscript, May 1977). (hereafter cited as Schwart, "Costs of Storing on Illinois Farms").

[10]Brief definitions are listed in Appendix Table 23.

[11]Schwart, "Costs of Storing on Illinois Farms," p.19-20.

the lowest cost drying system from 10,000 bushels to 20,000 bushels. The corresponding total costs ranged from $0.3511 per bushel to $0.2600 per bushel. Above the 20,000 bushel volume the in-bin dryer with a stirring device provides a lower cost alternative. Its costs ranged from $0.2204 per bushel to $0.1821 per bushel at the 20,000 through 100,000 bushel volumes, respectively. The costs of the automatic batch and continuous flow dryers were highest at all volumes but compare closely with others at the 80,000 and 100,000 bushel volumes. The total costs ranged from $0.6681 per bushel to $0.2082 per bushel, and $0.7616 per bushel to $0.2048 per bushel for the automatic batch and continuous flow systems at the 5,000 to 100,000 bushels, respectively. The low-temperature dryer costs were considerably above that of all systems when annual volume was above 10,000 bushels.

Another study done in Ohio in 1975[12] used a study design similar to the Illinois study cited above, comparing cost and operation of storage and drying systems. The study reported costs for continuous flow, automatic batch, batch-in-bin, low temperature, and crib drying systems at 20,000, 40,000 and 60,000 bushel sizes for removing 10 points of moisture and storing grain for 7 months.

The results of this study indicate that the batch-in-bin dryer system was the least cost artificial drying unit.[13] These systems are able to dry relatively large volumes of corn at moderate investment levels. The total cost ranged from $0.5275 per bushel to $0.4532 per bushel for the 20,000 and 60,000 bushel systems respectively. The continuous flow storage and drying system was the highest cost system due to the large capital investment requirements. Its total costs are $0.6046, $0.5547 and $0.5094 per bushel for the 20,000, 40,000 and 60,000

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[12]Roger W. Smith and Dean E. Baldwin, Economics of Farm Drying and Storage Systems in Ohio (Cooperative Extention Service, Ohio State University, May 1975), (hereafter cited as Smith, Economics of Farm Storage in Ohio).

[13]Ibid, p. 9-10.

bushel levels respectively.

The Ohio study reported costs separately for storage, drying and total storing and drying which allowed a unique comparison of costs. For example, the study showed that, "average fixed cost of drying decreases as production volumes increase, because the existing drying equipment was used more intensely."[14] The study included the same categories for fixed and variable costs as mentioned above, but had come changes and additions. Repair and maintenance was included as a fixed cost estimated to be a fixed percentage of the systems purchase price. Additional variable cost categories were loss in handling, quality loss in storage and an excess drying cost for corn to 13.5 percent moisture rather than the 15.5 percent level. These costs were $0.005, $0.02, and $0.0694 per bushel, respectively.

Another study done in Indiana in 1952[15] identified costs for one system of average size. A survey of farmers found that a typical small grain farmer in that area had 2,400 bushels of storage capacity. The fixed and variable costs were then computed at 100 and at 60 percent of capacity. The variable costs computed for systems storing wheat were $0.112 per bushel. This included costs of $0.029, $0.005, $0.005, $0.0031, and $0.0042 per bushel for shrinkage (2.1 percent), turning, insurance, extra labor and quality deterioration, respectively.

A study in North Dakota done in 1951[16] was very similar to the Indiana study above. A survey showed that farmers utilized their storage an average of 57 percent. The costs were then computed at 57 percent and 100 percent utilization

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[14]Ibid, p. 5.

[15]U.S. Department of Agriculture, Farm Credit Administration, Where and How Much Cash Grain Storage for Indiana Farmers, by Thomas E. Hall; J. W. Hicks; Walter K. Davis; and Norman Coats, Bulletin 68 (Washington, D.C., April 1952).

[16]U.S. Department of Agriculture, Farm Credit Administration, Where and How Much Cash Grain Storage for North Dakota Farmers, by Thomas E. Hall; J. W. Hicks; Walter K. Davis; and Norman Coats. Bulletin 61 (Washington,D.C., December 1963).

rates and were $0.145 per bushel and $0.114 per bushel, respectively. The variable cost for storing small grains such as wheat included shrink (1.5 percent) at $0.027 per bushel; insurance on grain at $0.01 per bushel; and risk and inconvenience at $0.005 per bushel. It is interesting to note that variable costs were based on a market value of $2.03 per bushel for wheat. The 1977 prices are very similar to 1951 prices.

Regardless of study design, the costs developed in each study were divided into fixed and variable categories. Fixed costs typically included depreciation, interest, insurance, taxes and maintenance. A wide variety of insurance and property tax rates were used to compute costs among the studies reviewed since the studies were done in many different states and time periods. Cost estimates for depreciation, interest and maintenance were somewhat more uniform. The range of values used are summarized below. Each figure represents the percentage which was multiplied by the initial investment to determine the respective annual cost. (Interest was computed on one half the initial investment or average investment).

Depreciation			
Buildings	3.33 percent	to	8.33 percent
Equipment	6.70 percent	to	12.50 percent
Interest	8.00 percent	to	10.00 percent
Repairs			
Buildings	.40 percent	to	2.50 percent
Equipment	2.40 percent	to	3.00 percent

The depreciation percentages represent estimated uselife periods ranging from 12 to 33 years for buildings and 8 to 15 years for equipment and were reported in studies cited above.

The estimates used for variable costs varied over an even larger range than fixed costs. However it was useful to look at cost estimates used in determing shrink and drying. When considering crops safely stored without drying, e.g. wheat a cost of .5 percent of the value of grain was used to estimate the annual cost of shrinkage in commercial flat type storage in a 1963 Kansas study.[17] Grain sorghum shrink in storage was estimated at one and two percent of the grain value in a 1963 study.[18] Drying costs were estimated for removing approximately 10 percentage points of moisture, and include electricity, fuel and labor. The total drying cost was estimated to be $0.04, $0.05, and $0.07 per bushel respectively for the 1977 Illinois study, the 1975 Ohio study and a 1974 Iowa study.[19]

The various styles of study designs were useful in identifying many unique characteristics of storage and drying. Studies which analyzed the cost of systems of various size levels were able to determine the effects of utilization and economies of size on total costs of farm storage. The studies that analyzed various farm drying systems at various storage level, are useful in comparing dryer cost performances at various storage levels. A farmer producing 10,000 bushels of corn and grain sorghum had a different least-cost drying system than the 100,000-bushel-per-year producer. The method of determining costs for an average size system was applicable when analyzing the costs and benefits of farm storage for decision processes concerning farm bins.

Many benefits may be generated by farm grain storage. It must be recognized that each farm is unique and hence the patterns of benefits are also unique. These gross benefits may be included in the following categories.[20]

1. Appreciation of inventory value due to seasonal price variation.

2. Participation in the government programs.

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[17] U.S. Department of Agriculture, Farmer Cooperative Service, Economics of Flat Grain Storage Facilities in Kansas, by Robert W. Summit and L. Orlo Sorenson, Marketing Research Report No. 685. (Washington, D.C., December 1964), p. 11-12.

[18] R.E. Angus and H. M. Stults, Grain Storage in Arizona, Technical Bulletin 159 (Arizona Agricultural Experiment Station, University of Arizona, Tucson, December 1963) p. 16 (hereafter cited as Angus, Grain Storage in Arizona).

[19] See Schwart. "Costs of Storing on Illinois Farms"; Smith. Economics of Farm Storage in Ohio; C. Phillip Baumel, Robert N. Wisner, and John J. Miller, "On the Farm Versus Elevator Storage Costs," American Society of Farm Managers and Rural Appraisers, (October 1974), p. 15.

[20] Angus, Grain Storage in Arizona, p. 8-14.

3. Federal and state income tax savings.

4. Reduction of out-of-pocket harvest cost.

5. Multipurpose use.

An analysis done on grain sorghum prices[21] indicated that measurable seasonal price patterns exist. The analysis stated, "if the period examined is representative of future price behavior, farmers may expect moderate returns as a result from storing grain from seasonal price variations over a series of years. However, the magnitude of the returns will vary from year to year with losses occuring occassionally."[22]

Government programs concerning price supports and loan conditions change over the years, but farmers with storage facilities may benefit at times by taking a loan on grain at harvest time. The benefit occurs when the loan rate received is greater than the market price.

Storage may be used to save federal and state income taxes by equalizing annual incomes if reporting on a cash tax basis. This benefit is not associated with the operation of storage but managers use it especially when grain is a major source of income. Provisions for rapid tax depreciation of storage facilities can also provide a tax advantage.

Harvest-time costs may be reduced by farm storing the grain and delivering it for market during slack times. Benefits depend on the difference between the hauling cost at harvest and extra handling and delivery cost.

Multipurpose use of farm storage facilities is not a benefit in the same category as above, but it increases the utilization, thus lowering the average cost. This utilization may be increased by planting crops with different maturity dates, storing other grains when not storing major crops or use for storing miscellaneous farm items, e.g. fertilizer.

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[21]Ibid.

[22]Ibid, p. 13.

Total net benefits from the combined categories just discussed may be quantified by deducting the storage costs. Benefits are available to farmers from inventory appreciation, government programs and income tax equalization whether they use farm storage or commercial storage. However, larger net benefits accrue to the least cost storage system.

A study done on storing grain in Central Texas in 1958[23] focused on identifying returns to storage from seasonal price movements. Ten years of average monthly grain sorghum prices were used to estimate returns from grain sorghum harvested at 13 percent moisture content or less and grain sorghum harvested over 15 percent moisture which required drying. Average seasonal margins were computed between August and later prices to compare with storage costs of the two grain storage situations.

The results for grain harvested at 13 percent moisture showed that profit from storage could have been made every year from sale at yearly highs. Profits could have been made 7 out of 10 years from sale in January, March or May. When considering the case where grain sorghum must be dried for safe storage, at no time did returns from average seasonal margins exceed the cost of storage. However, farmers could have profited in 6 of the 10 years had they selected the right month in which to sell. March was determined to be the most favorable month for sale of grain under the conditions specified.

A variety of benefits arise from farm grain storage, and each farmer must evaluate those applicable to his situation. A survey done in Ohio in 1971 listed reasons why farmers constructed storage on the farm, as indicated in Table 1.1. A ranking of reasons by farmers provides some insight into relative priorities assigned by Ohio farmers.

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[23]Clarence A. Moore, Storing Grain Sorghum in Central Texas, Bulletin 891 (Texas Agricultural Experiment Station, College Station Texas, March 1958), p. 2-6.

TABLE 1.1

ORDER OF IMPORTANCE OF REASONS FOR CONSTRUCTING FARM STORAGE AND DRYING SYSTEMS AS GIVEN BY FARMERS WITH A MINIMUM OF 10,000 BUSHELS OF FARM STORAGE AND A DRYER.

Reason	Percentage of Total Points[a]
1. Convenience	20.28
2. Profitable investment	16.53
3. More market flexibility	15.57
4. Cheaper than commercial storage	15.46
5. Storage for feed	12.76
6. Commercial storage not available	7.11
7. Low interest government loan for storage	5.75
8. Government storage payments	5.46
9. Others	1.02
	100.00%

SOURCE: "Storage on the Farm or at Your Elevator?" Grain and Feed Journal, 13 March 1974, p. 8-9.

[a]Points were based on 8 points for the reason listed most important, 7 points for the reason listed second, and so on.

CHAPTER II

SCOPE AND METHODS OF STUDY

Study Design

Farm grain storage cost studies have a variety of designs, however based on specific study objectives three major types of studies emerged in the literature review. They were studies designed to determine; (1) the cost of farm storage at various facility size levels and grain volumes, (2) the cost of farm storage with various types of drying systems, and (3) the simple average cost of farm storage based on normative operations and practices.

These analyses of farm grain storage consolidates the first two categories and are aimed at three types of cash grain enterprises: (1) wheat-producing farms, (2) wheat farms planning to diversify, and (3) diversified grain farms. For purposes of this study, diversified grain farms are defined as those which produce combinations of wheat, grain sorghum and corn. These crops are of primary importance to many Kansas farmers, in 1975 351 million bushels of wheat, 144.1 million bushels of grain sorghum and 137.8 million bushels of corn was produced in Kansas. Production of crops which were less prominent in Kansas such as, soybeans, oats and barley was only 22.1, 6, and 1.9 million bushels, respectively.[1]

The exact production mix of the primary Kansas crops varies by county and by farm depending upon factors such as crop rotations, soil, annual rainfall, and irrigation resources. In 1975 the top wheat producing counties were concentrated in South Central Kansas, the main grain sorghum producing counties

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[1]Kansas Department of Agriculture, Farm Facts 1975-1976, Kansas State Board of Agriculture (1975), p. 16F-17F.

were in Northeast, Central and Southwest Kansas, while the major corn producing counties were in Southwestern Kansas.[2]

Description of Farm Grain Storage Systems

Farm grain storage systems analyzed in this study are divided into two major categories, those systems designed for storage only, and those designed for storage and drying. The first are referred to as "storage systems." The second category includes various "storage and drying systems" and are identified by type of drying system employed.

Costs are separately computed for storage buildings, storage equipment and dryers. This allowed separate analysis for storage and drying functions and provides information for storage with plans to add dryers in the future and complete storage and drying systems.

The storage and storage and drying systems used in this analysis will be described below. Each system is designed for various storage capacities. They include 5,000, 10,000, 20,000, 30,000, 40,000, 50,000, 60,000, 90,000 and 120,000 bushels. The 5,000, 40,000 and 50,000 bushel capacities are omitted for analysis of storage and drying systems.

The size categories included storage volumes needed by farms that produce the largest portion of the major crops in Kansas. Table 2.1 shows the number of farms which harvested the major crops and total production, listed by acreage group. More than two-thirds of the production came from farms harvesting at least 250 acres of wheat, and from farms harvesting 100 acres or more of grain sorghum and corn.

The storage needs of farms in the size ranges mentioned above are estimated by multiplying the acreage in production by typical yields per acre[3]

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[2] Ibid., p. 20F-21F.

[3] Ibid., p. 16F.

The range of production for wheat and corn using hypothetical yields for the various acreage categories are shown below (Table 2.2).

TABLE 2.1

NUMBERS OF KANSAS FARMS AND PRODUCTION
OF THREE MAJOR CROPS FOR VARIOUS ACREAGE GROUPS IN 1974.

	Wheat		Sorghum for Grain		Corn for Grain	
Acres Harvested	No. of Farms	Production (1,000 Bu.)	No. of Farms	Production (1,000 Bu.)	No. of Farms	Production (1,000 of Bu.)
1 to 14	2,886	725	2,977	1,014	1,878	587
15 to 24	3,572	1,833	3,625	2,510	1,556	1,128
25 to 49	7,107	6,717	7,558	9,618	2,497	3,725
50 to 99	10,041	19,424	8,828	23,189	2,456	8,983
100 to 249	15,679	66,623	8,303	50,886	2,670	29,147
250 to 499	9,108	83,248	1,900	27,216	1,113	33,026
500 acres +	5,324	120,142	544	13,369	610	49,371
TOTAL	54,017	298,173	33,735	131,754	12,780	125,970

SOURCE: U. S. Department of Commerce, Bureau of the Census, 1974 Census of Agriculture, Vol. 1 part 16, Kansas State and County Data (Washington, D.C.: Government Printing Office, May 1977), p. I-22, I-23.

The hypothetical production categories generated in Table 2.2 show a range of individual farm production based on acres and yields for corn and wheat.

TABLE 2.2

INDIVIDUAL FARM PRODUCTION BASED ON VARIOUS ACRES
AND YIELDS FOR WHEAT AND CORN

Yield per Acre - Wheat

Acres Harvested	20 bu.	30 bu.	40 bu.
250	5,000	7,500	10,000
500	10,000	15,000	20,000
750	15,000	22,500	30,000
1,000	20,000	30,000	40,000
1,500	30,000	45,000	60,000

TABLE 2.2 CONTINUED

Yield per Acre - Corn

Acres Harvested	70 bu.	80 bu.	100 bu.	120 bu.
100	7,000	8,000	10,000	12,000
250	17,500	20,000	25,000	30,000
500	35,000	40,000	50,000	60,000
750	52,500	60,000	75,000	90,000
1,000	70,000	80,000	90,000	120,000

The wheat data represent lower production than corn at any given acreage because yields are lower. Farms which produce diverse combinations of wheat, grain sorghum, and corn may have storage needs anywhere between the 5,000 and 120,000 bushel limits shown for 250 acres to 1,000 acres harvested cropland. In 1974, 2,744 Kansas farms harvested 1,000 acres or more of cropland. Farms harvesting more than 1,000 acres could need more than 120,000 bushels of storage space. The breakdown of farm size by acres of total harvested cropland in Kansas is shown below (Table 2.3).

TABLE 2.3

FARMS IN KANSAS BY ACRES OF HARVESTED CROPLAND IN 1974

Acres Harvested	Number of Farms
1 to 49	12,897
50 to 99	10,835
100 to 199	14,291
200 to 499	21,199
500 to 999	8,607
1,000 and over	2,744
TOTAL	70,573

SOURCE: U. S. Department of Commerce, Bureau of the Census, 1974 Census of Agriculture, Vol. 1 Part 16, Kansas State and County Data (Washington, D.C.: Government Printing Office, May 1977) p. 1-1.

Storage Systems

Farm storage designs and layouts are almost as numerous as the number of farm storage facilities. Regardless of design each storage system must be capable of receiving, storing and unloading grain. Since no drying facilities are included, the moisture content must be near safe storage levels.

These cost data are determined for round steel storage bins equipped with aeration systems for quality maintenance. Loading and unloading are accomplished with bin sweep and unloading augers, and a portable auger. Storage bins and necessary equipment costs are assembled for combinations of bins which gave the storage capacities mentioned above. Each size category include combinations of bins that had the lowest investment cost possible.

Storage and Drying Systems

Farms which produce more than one crop need additional facilities. Bin sizes must be smaller to store volumes of different grains and some grain may require artificial drying (e.g., grain sorghum and corn) so dryers must be designed to handle drying for various sizes of grain storage facilities. In this study drying systems are designed to dry 100 percent capacity of each storage system and remove 10 points of moisture. Three drying systems are used in this study. They are the batch-in-bin, in-bin continuous flow and continuous flow artificial air drying systems. Drying systems selected represent types predominantly used by Kansas farmers.

Batch-in-Bin Dryers

The batch-in-bin drying system requires a minimum of two bins and a bin unloader in the drying bin. The batch bin has the capacity to handle an average days harvest at a grain depth of 2 to 4 feet. A batch is dried, cooled and then removed from the drying bin for storage elsewhere. This system requires a conveyor from the dryer bin to the storage bin. Air flow through the wet grain generally runs 10 to 25 cubic feet per minute (CFM) per bushel at air temperatures around 120°F.[4] The fastest drying rate of batch-in-bin systems

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[4]Holmes, On-Farm Grain Drying, p. 6.

in this study is 220 bushels per hour. This dryer has two principle advantages; (1) grain may be stored in the same bin in which it was dried and (2) many bushels can be dried with a relatively small investment in drying equipment. However, two disadvantages are; (1) a relatively slow drying rate and (2) the need for more management than with other available systems to prevent overdrying of the bottom layer. To increase drying capacity the diameter of the drying tank must be increased to increase the drying surface. For use in this study, these dryers will be called "in-bin dryers" for simplicity.

In-Bin Continuous Flow

The in-bin continuous flow dryers are one of the most recent developments in farm dryers. The drying bin has a fan heater unit, plenum chamber[5] and perforated floor similar to other bin dryers. This dryer has augers that move around the floor under the grain bringing the dry bottom grain to a center discharge auger for removal to a dry bin or for recirculation. This type of equipment is added to an in-bin drying system, because there is a tendency to dry the bottom layers of grain before the upper part of the grain mass is completely dried. Systems used in this study are also equipped with stirring devices to move the grain, mixing the layers and producing even moisture content from top to bottom in the in-bin system.[6] Study at Iowa State University shows that stirrers do a reasonable job of bringing grain up from the bottom of the bin towards the top and because the stirrers loosen the grain, the grain level in the bin will rise and air will flow more readily. The stirrers were also found to give a 22 percent increase in pounds of water removed over conventional bin dryers in a trial case.[7] These dryers offer faster drying (rate of 340 bushels per hour of largest system in this study) and flexibility in grain drying depth,

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[5]Refers to the air space between the perforated drying floor and the concrete floor where the heated air is forced to flow through the grain.

[6]Butler Manufacturing Company, Grain Drying, Bulletin p. 4.

[7]Holmes, On-Farm Grain Drying, p. 13.

but require larger investment, mechanical reliability may be a problem and automatically moving hot grain may cause more cracking. Clean grain, uniform floor coverage and a cooling bin to receive the dried grain are essential for satisfactory results with this system. This system will hereafter be referred to as "in-bin continuous flow dryers."

Continuous Flow

The typical continuous flow dryer receives wet grain at the top. Grain then moves through the heated air which usually varies from 180 to 240°F. Air flows in wet grain in these units generally vary from 50 to 150 CFM. The grain continues to move as it dries until it enters the cooling area where the temperature is reduced for safe storage. The fastest drying rate of continuous flow systems analyzed in this study was 566 bushels per hour. The continuous flow grain dryer is semi-automatic, flexible, and enables the farmer to select a precise moisture content but requires a large capital investment and causes high kernel stress from fast drying and cooling.[8] Due to the large initial investment, many manufacturers do not recommend its use until 30,000 bushels of grain are to be dried.[9]

Column batch dryers are used in this study at the 10,000 and 20,000 bushel levels. These dryers are used in conjunction with augers with automatic starters for filling the batch dryers and for moving dry grain back to storage. Grain drying occurs in this system by holding the grain between perforated steel columns and passing heated air through it at rates of 30 to 100 CFM per bushel. Column batch dryers offer the same advantages as continuous flow dryers, but

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[8] Agricultural Engineering, "Energy Efficiencies of Various Drying Techniques", American Society for Agricultural Engineers (May 1975): p. 18.

[9] Behlen Manufacturing Company, Guidelines in Planning Grain Conditioning and Storage Systems, (Columbus, Nebraska) p. 13.

are not as well suited for large systems. Neither type of dryer offers any appreciable storage capacity but may be particularly suited to farmers who want to dry grain in several scattered locations. These systems will be hereafter referred to collectively as "continuous-flow dryers."

Data Collection

The components and respective purchase prices for the storage and storage and drying systems analyzed in this study were obtained from personal interviews with numerous dealers at retail outlets across Kansas. Dealers designed each system to be operable at each given size unit, but also the layout of each system allowed planned expansion in the future. There was some additional cost in planning for expansion, but planning was stressed by numerous dealers and farmers and adds flexibility and practicality to these systems.

The dealers itemized the bins, equipment, and drying components and their respective purchase prices.[10] The total purchase price is the initial capital investment necessary for each system and represented a complete turnkey job. Interviews with farmers and dealers revealed that farmers were frequently able to bargain for discounts of ten to thirty percent, depending on the season. In this study the purchase price represented January 1, 1977 retail prices at a 20 percent discount from manufacturers suggested retail price. These prices also included labor and installation costs.

Method of Analysis

A commonly used method of economic analysis, fixed and variable cost analysis or simple budget analysis is used to calculate the annual cost associated with an investment in farm grain storage.

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[10]See Tables 1 and 4-12.

Total ownership and operating costs are composed of two broad categories--fixed and variable. Fixed costs include depreciation, insurance, interest, taxes and repairs and maintenance. The variable costs included are grain insurance, insect control, aeration, handling, drying, and shrinkage and invisible loss.

The fixed costs do not change as the amount of grain in storage changes and are incurred even if no grain is in storage. Total variable costs vary directly with the amount of grain in storage. Since each storage and storage and drying system performs a unique task, the fixed and variable costs must be computed separately for each system.

Fixed costs

Fixed costs are computed at a fixed percentage of the purchase price. Because of the high capital investment requirements for farm grain storage, the fixed costs of depreciation and interest have a significant impact on total costs.

Depreciation refers to the actual annual loss in cash value due to wear and obsolesence. In this study the economic life periods are estimated to be: 20 years for all buildings (bins) and 10 years for the storage equipment and dryers. These periods were selected based on agricultural engineers recommendations and information from the literature review. The annual depreciation is calculated by the straight-line method with ten percent salvage value for the bins and zero salvage for storage equipment and dryers. This represents 4.5 percent and 10 percent of the respective investments in buildings and in storage and drying equipment.

Insurance represents an explicit cost for protection against unpredictable events. The coverage includes protection against natural disasters such as fire, lightning, wind, hail and man-made losses such as vandalism. A state-wide insurance company which insures a large portion of farm buildings in Kansas supplied the rate information. The annual charge is at a rate of $1.20 for every $100 value. Annual insurance cost is then computed by multiplying one-half the initial investment (average investment) by the annual rate and dividing by one hundred. Annual insurance cost is .6 percent of the investment in storage buildings and equipment and dryers.

Interest is a cash cost paid for borrowed capital when external financing is used or an "opportunity cost"[11] in the case of internal financing. The annual interest costs are computed by multiplying the average investment by 8.5 percent. This represents 4.25 percent annually of initial cost for the life of the investment.

Property tax is a fixed cost which must be paid for ownership rights. The assessed value in Kansas is thirty percent of market price and the average rural mill levy used is $0.667 per dollar of assessed value. The annual property tax is then computed by multiplying the assessed value by .0667. This represents 2 percent of the total investment.

Repairs and maintenance are estimated at a fixed rate per unit of production, but rates vary among systems since added automation and moving parts for some systems require more maintenance than for less automated systems. Secondary data on these costs are not readily available, but based on dealer recommendations and discussions with agricultural engineers, the annual costs are assumed to be 1 percent of initial investment for storage systems and 1.5 and 2.5 percent of initial investment for the in-bin, and in-bin continuous flow and continuous flow systems, respectively. The annual repairs and maintenance cost is then computed by multiplying the total investment by the above percentages.

The total annual fixed costs by system type are the following percentages

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[11]The opportunity cost refers to the return those internal capital resources can earn when put to its best alternative use.

of initial investment.

	Buildings	Equipment and Dryers
Storage Systems	12.35 percent	17.85 percent
Storage and Drying Systems		
In-Bin	12.85 percent	18.35 percent
In-Bin Continuous Flow	13.85 percent	19.35 percent
Continuous Flow	13.85 percent	19.35 percent

Variable Costs

The variable costs are computed on a per bushel cost basis and the total variable cost therefore depends on the level of production. These calculations are based on a 6-month storage period. Changes in length of storage period will only affect the grain insurance and aeration costs. The following prices are used in calculating variable costs: Liquid Propane Gas (L.P.), $0.27 per gallon; electricity, $0.0375 per kilawatt hour; and labor $3.50 per hour.

Expenditures on grain insurance secures protection against loss of grain from wind, fire, theft, etc. The rate is obtained from a leading Kansas insurer of farm property and is $0.53 per $100 of market value of the grain. The value of the grain is estimated to be two dollars per bushel for all grains. On this basis the grain insurance cost is $0.011 per bushel. This cost may change if the price of grain changes. For example, when the price is increased to $3.00 the per bushel cost changes to $0.016. For purposes of this study the annual cost of insurance is estimated to be $0.011 per bushel.[12]

The costs of insect control is not readily available, since interviews suggested that few farmers had regular insect control programs for stored grain. Discussion with agricultural entomologists lead to applying costs of a recommended procedure for insect control. A prodecure using malathion as a protectant when grain goes into storage has proven effective for wheat, grain sorghum and corn.

[12]Some annual rates are greater than $0.011 per bushel. However, refunds are common practice if storage is less than a year and may cause this cost to be overstated.

A one pint dosage afforded nearly complete protection from insect damage for 12 months.[13] One quart of premium grade malathion costs $4.38 and will treat approximately 2,000 bushels for a per bushel cost of $0.0022. If insect control treatment is not used, the cost estimated in this study may represent a conservative figure for quality deterioration. Many other methods of treatment such as fumigation or contracted pest control methods are used. This study estimated costs for treating grain with molathion as a preventive measure.

Aeration--the moving of air through stored grain--has become a generally accepted practice for maintaining market quality of stored grain without turning it. With aeration the market quality of grain can be maintained and at the same time handling cost is minimized. The most commonly used airflow rates range from 1/20 to 1/10 cubic feet of air per minute (CFM) per bushel. These rates are generally adequate for reducing insect and mold activity and for holding moisture migration and accumulation to acceptable limits.[14] Interviews with agricultural engineers suggest that heavy aeration (1/4 CFM) can be obtained in 16- to 20-foot bin depths by using 1/4 horsepower (HP) per 1,000 bushels. Appendix 18-19 shows the range of HP per 1,000 bushels to be .6 and .2 for dealer designed systems used in this study. The larger HP per 1,000 bushels, the more

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[13] U. S. Department of Agriculture, Agricultural Research Service, Evaluation of Malathion, Synergized Pyrethrum and Diatomaceaus Earth as Wheat Protectants in Small Bins, by Delmon W. LaHue, Marketing Research Report No. 726 (Washington, D.C., August 1965), p. 1: U. S. Department of Agriculture, Agricultural Research Service, Evaluation of Malathion, Synergized Pyrethrum and Diatomaceaus Earth on Shelled Corn as Protectants Against Insects in Small Bins, by Delmon W. LaHue, Marketing Research Report No. 768 (Washington, D.C., October 1968), p. 1: U. S. Department of Agriculture, Agricultural Research Service, Evaluation of Several Formulations of Malathion as a Protectant of Grain Sorghum Against Insects in Small Bins, by Delmon W. LaHue, Marketing Research Report No. 828 (Washington, D.C., June 1969), p. 1.

[14] United States Department of Agriculture, Aeration of Grain, by Leo E. Holman, Agricultural Marketing Service, Transportation and Facilities Research Division, Marketing Research Report No. 178 (1966) p. 1.

rapid the cooling occurs. The aeration fans in this study are estimated to operate 33 hours per month for a six month storage period. The electricity cost for operating aeration fans for each system is then computed using the following engineering formula as a base:

1 HP for 1 hour = 1 KWH[15]
where KWH = kilowatt hour

The cost of electricity is computed as follows:

(Installed HP) X (Hrs. of Operation) X ($0.0375 KWH) = Cost of Electricity

Handling costs represent the cost of the load-in and load-out operations of moving grain through the system and includes expenditures on labor and electricity. The bushel-per-hour (BPH) capacity of the slowest auger is the limiting factor in these operations. Total bushels handled divided by BPH gives the time required in hours. Then electrical costs are again computed by the above formula. Labor cost is computed by multiplying the wage rate times hours of labor required for each separate operation. The same calculations are made for load-out operations. Appendix Table 20-21 summarizes the calculations for each system.

Drying costs were derived from engineering data based on British Thermal Unit (BTU) consumption. To simplify calculations it is assumed that ten points of moisture are removed from 100 percent of the systems capacity in corn or grain sorghum. Appendix Table 22 summarizes the steps involved in computing the drying cost. The first step is to determine the pounds of water removed when ten points of moisture are evaporated. This computation is based on grain of 56 pounds per bushel. Next the total BTU's is computed by multiplying the pounds of water to be removed by the BTU's required by each dryer type to evap-

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[15]Holmes, On-Farm Grain Drying, p. 12.

orate one pound of water.[16] Then the BTU's necessary to maintain desired drying temperature [17] are divided into total BTU's to get hours to dry. Fuel, electricity and labor cost are computed as follows:

$$\frac{\text{Total BTU's}}{\text{91,000 BTU's per gal.}} \times (\$0.27\text{ gal.}) = \text{Fuel Cost}$$

(Total Hours) X (HP) X ($0.0375/KWH) = Electricity Cost

(# of days) X (3 hours per day) X ($3.50/hr.) = Labor Cost

The dryers are estimated to operate 18 hours per day and require management by one man 1/6 of the drying time.

This analysis does not include costs that may be incurred due to over-drying or quality loss in drying. The exclusion of these costs assumes good management and proper drying temperatures.

Quality loss of stored grain is a subjective estimate. The goal in storing grain is to maintain conditions in the grain that will preserve marketing and processing qualities at as high a level as possible. Deterioration of grain quality begins when storage begins, however the rate of quality loss is controlable under proper conditions so that loss in market value does not occur. The rate of quality deterioration is slowest when grain is dry and cool.

Weight loss occurs in storage and drying under all management condition. Two components of weight loss are considered in this study. They are shrink and

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[16]Behlen Manufacturing Company, The New BTU Heat Unit Rating Method, (Columbus, Nebraska), p. 14: Interview with Jerry Joseph, Middle State Manufacturing Company, Nebraska, July 14, 1977: Agricultural Engineering, "Energy Efficiencies of Various Drying Techniques," American Society for Agricultural Engineers (May 1975): p. 18.

[17]Behlen Manufacturing Company, The New BTU Heat Unit Rating Method, (Columbus, Nebraska), p. 1 Chart #9.

invisible loss. (1) Shrink is the actual physical loss of weight during the storage period due to water loss. It is estimated to be 2 percent when considering grain artificially dried and placed in farm storage at 15 percent moisture. The 2 percent shrink results from additional moisture removed by the aeration system to lower moisture content to 13 percent. Grain arriving from the field at moisture levels of 13 percent or less (e.g., wheat) will lose very little weight through moisture loss in storage.[18] Loss due to shrink under this condition is estimated at .25 percent.[19] (2) Weight loss includes both moisture loss and a dry matter loss. The dry matter loss consists of such things as cracked kernels, dust, and the respiration that occurs in the grain. This is often referred to as invisible shrink or handling shrink. Usually, .5 percent is allowed for dry matter shrink.[20] Assuming the grain is valued at $2.00 per bushel, costs of shrink and invisible loss are $0.04 and $0.01 per bushel, and $0.005 and $0.01 per bushel for grain which is dried to safe moisture levels and stored, and grain which enters storage at safe moisture content, respectively.

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[18] U. S. Department of Agriculture, Agricultural Marketing Service, Marketing Research Division, Shrinkage Losses and Grade Changes in Wheat Stored at Kansas Bin Sites, by James W. Taylor and Ruth E. Clifton, Report No. 325 (Washington, D.C., August 1959), p. 3.

[19] Ibid.

[20] A. L. Frederick, Economic Considerations in Marketing High Moisture Grain (Cooperative Extension Service, Kansas State University, Manhattan, Kansas, December 1971), p. 2.

CHAPTER III

COSTS OF FARM STORAGE AND DRYING

Storage Systems

Capital Requirements

Farm grain storage systems require large initial capital investments. This investment must be repaid over several years. To determine the feasibility of an investment, it is necessary to know the purchase price of alternative investments. The initial investment of each alternative storage system analyzed in this study is shown in Table 3.1.

Buildings

Estimated capital requirements for buildings (steel bins) range from $0.61 to $0.45 per bushel at the lowest and highest volumes, respectively. This corresponds to $3,166 and $58,724 of total investment in buildings (Appendix Table 1). Storage bins and their assembly account for the largest portion of building investment varying from around 75 percent for the smallest size to 81 percent for the largest.

The remainder of building investment estimates include a concrete floor, flush floor aeration, ladders and control pipe and rod to operate the center unloading hopper. These items do not require large investments (24 and 19 percent, respectively, for the smallest and largest size facilities) but are necessary building components

Equipment

Investments for equipment vary from $0.45 to $0.09 per bushel for the lowest and highest volumes. This corresponds to $2,346 and $11,230 total investment, respectively (Appendix Table 1).

TABLE 3.1

SUMMARY OF CAPITAL INVESTMENT PER BUSHEL OF AVAILABLE SPACE FOR STORAGE SYSTEMS OF SELECTEO SIZES

	5,000 bu.	10,000 bu.	20,000 bu.	30,000 bu.	40,000 bu.	50,000 bu.	60,000 bu.	90,000 bu.	120,000 bu.
					-Oollars per bushel-				
Capital Investment									
Buildings	.61	.55	.55	.51	.50	.47	.45	.45	.45
Equipment	.45	.30	.22	.16	.12	.11	.10	.09	.09
Total	1.05	.05	.77	.67	.62	.50	.55	.55	.55

These amounts are 42 and 16 percent of total investment in buildings and equipment, respectively. The proportion of equipment investment to total investment decreases as storage volumes increase. This occurs due to greater utilization of equipment, e.g., portable augers used for loading and unloading grain accounts for 68 percent of the equipment investment at lowest volume and 21 percent of investment at the highest volume.

Equipment investment costs also include aeration fans, bin unloading augers and bin sweep augers. The aeration fans are needed to maintain proper grain quality by controlling moisture and temperature conditions in the grain. The additional augers allow the grain to be unloaded with minimum of manual labor.

Total Investment

The estimated total building and equipment costs exceed $5,500 for the smallest facility size and $70,000 for the largest (Appendix Table 1). This corresponds with average or per bushel investment costs of $1.05 and $0.55, respectively. The economic relationship between storage capacity and average investment in buildings and equipment is displayed in graphic form in Figure 3.1.

The average investment requirement in farm storage decreases sharply from 5,000 to 10,000 bushels of storage capacity and then decreases at a diminishing rate through 30,000 bushels of capacity. At approximately 30,000 bushels of storage most economies have been reached since the increase in volume is greater than the decrease in cost. At storage sizes of 60,000 and greater the average investment curve is relatively flat due to the addition of bins of equal size, rather than larger bins at a reduced unit cost.

This curve shows that economies of size from investments in farm storage systems are significant until 60,000 bushel volumes. But, from 60,000 bushels through 120,000 bushels there is almost no investment cost advantage.

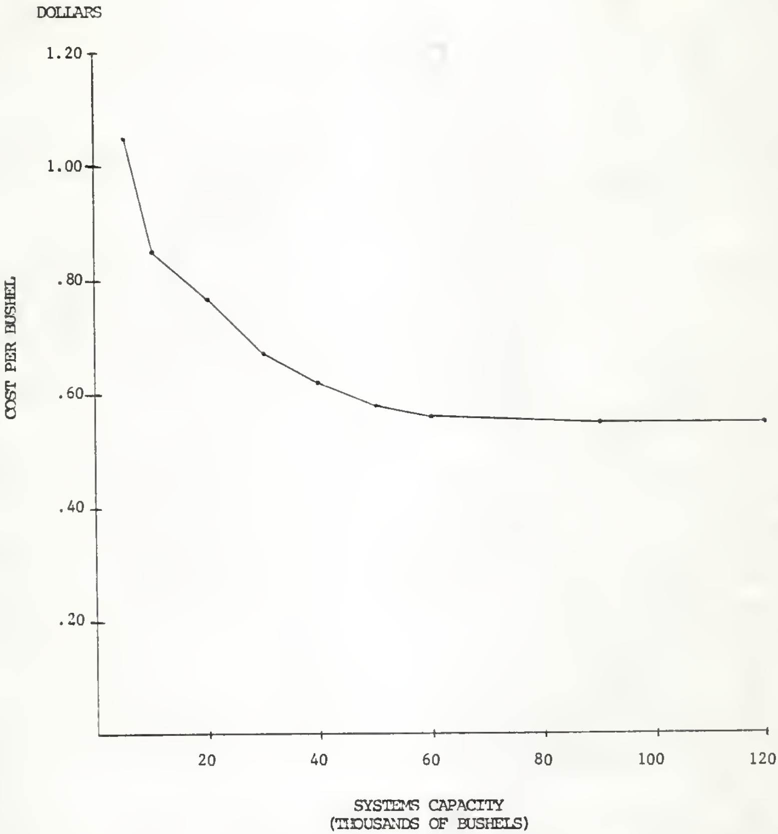

FIGURE 3.1: CAPITAL INVESTMENT CURVE DERIVED FOR STORAGE SYSTEMS

Ownership and Operating Costs

The method of computing fixed and variable costs is explained in detail in Chapter II above. Per unit fixed costs are determined for each system by dividing total fixed costs by estimated storage use (Appendix Tables 2 & 3). The variable costs are determined on a per bushel basis (Appendix Table 3).

Fixed Cost

Because of high capital investment requirements for farm storage systems, fixed costs have a large impact on annual costs per bushel. At 100 percent utilization the average fixed costs are 81 and 67 percent of average total cost for the lowest and highest volume systems, respectively.

Fixed costs of depreciation and interest on investment have significant effect on total fixed cost, representing nearly 75 percent of total fixed cost at all sizes.

Total annual fixed costs range from $809 to $9,273 for the smallest and largest systems, respectively. This corresponds to $0.155 to $0.072 per bushel ranges in average annual fixed cost at 100 percent utilization and $0.31 and $0.144 per bushel ranges in average fixed costs at 50 percent utilization.

Variable Cost

Grain insurance and weight loss are the most expensive variable cost items. These two items cost $0.011 and $0.015 per bushel for each system. The sum of these costs represent approximately 70 percent of the total variable costs for all facility sizes.

The range in total variable costs for all systems is from $0.038 to $0.034 per bushel. This range is quite small and variation is due to slight differences in per bushel aeration and handling costs for different systems (Appendix Table 2).

Variable cost was computed on a dollar per bushel basis. Variations in the throughput rates have no effect on the average or unit variable costs calculated in this study. Total variable cost increases as throughput increases, but variable cost per bushel remains constant.

Total Costs

Average annual total costs at 100 percent utilization range from $0.19 to $0.11 per bushel for the smallest and largest sizes, respectively (Table 3.2). The corresponding range in costs at 50 percent utilization is $0.347 to $0.179 and at 125 percent utilization, $0.161 and $0.092 per bushel.

The economic effect of utilization rate and volume on unit costs become more evident when presented graphically (Figure 3.2). Average total costs are plotted for each storage volume at 50, 75, 100 and 125 percent utilization rates. The series of short-run average cost curves shows that conditions which reduce utilization of existing facilities such as severe weather (e.g., hail) or reduced acreage allotment may have a significant impact on average total cost of farm storage. For example, a farmer is considering an investment in a 30,000 bushel capacity storage system which he estimates he will utilize at a 75 percent rate on the average. The curves show that investing in a 20,000 bushel system and utilizing it at from 100 to 125 percent capacity offers cost advantages to the first alternative.

Under similar utilization rates, the size change has a significant effect on storage cost. Average cost advantage of successively larger storage systems are relatively large until the 40,000 bushel storage level. There is only slightly more than one cent per bushel cost advantage above 40,000 bushels capacity up through 120,000 bushels. This is true for each utilization rate.

Storage and Drying Systems

These systems include storage and drying systems capable of safely storing

TABLE 3.2

SUMMARY OF AVERAGE TOTAL COSTS OF STORAGE SYSTEMS OF SELECTED SIZE

	5,000 bu.	10,000 bu.	20,000 bu.	30,000 bu.	40,000 bu.	50,000 bu.	60,000 bu.	90,000 bu.	120,000 bu.
Average Total Cost									
50% utilization	.35	.28	.25	.22	.20	.19	.19	.18	.18
75% utilization	.25	.20	.18	.16	.16	.14	.14	.13	.13
100% utilization	.19	.16	.14	.13	.13	.13	.11	.11	.11
125% utilization	.16	.13	.12	.11	.11	.10	.10	.09	.09

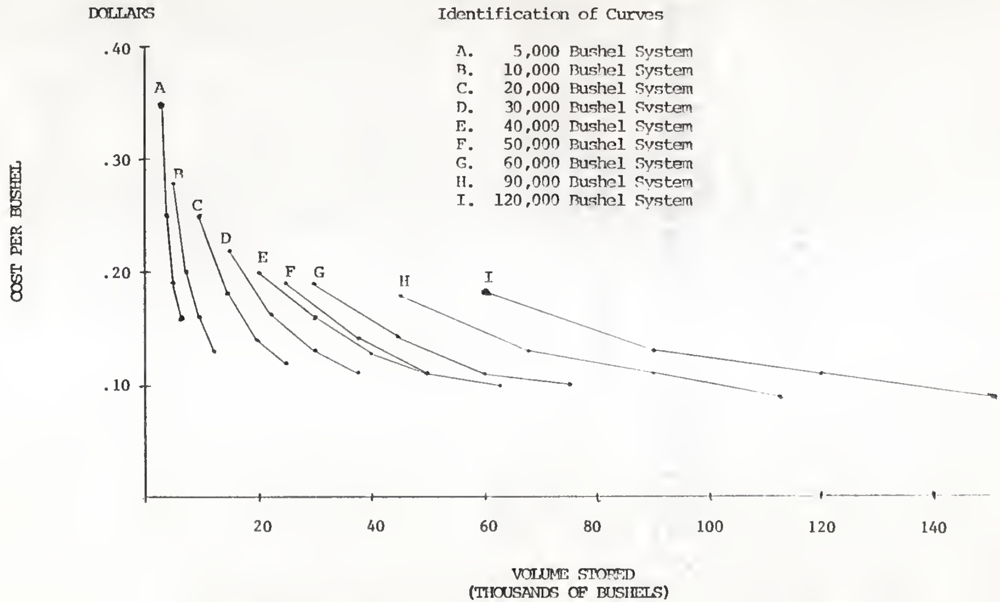

FIGURE 3.2: SHORT-RUN AVERAGE TOTAL COST CURVES FOR SELECTED STORAGE SYSTEMS

grains that require drying, in addition to grains which do not. The costs are determined separately for storage buildings, storage equipment and dryers.

The storage costs presented in this section do not represent least cost systems, but rather storage systems which have been designed to easily adapt to designated dryer facilities. The additional investment for buildings and equipment, may be viewed as the cost of planning for future needs.

Capital Requirements

The addition of drying facilities to storage systems is a major financial investment requiring thorough investigation of capital needs. The capital investment requirements for storage and drying systems analyzed in this study are summarized in Table 3.3 and Appendix Tables 4 through 12.

Buildings

Investments for buildings range from $0.86 to $0.53 per bushel of available storage capacity in the in-bin system; from $0.69 to $0.49 per bushel for the in-bin continuous flow system; and $0.76 to $0.51 per bushel for the continuous system. This corresponds to total investment in buildings ranging from $8,259 to $64,114; $7,133 to $61,396; and $7,869 to $62,398 for the respective systems.

The investment for buildings is composed primarily of bins, and bin assembly cost, they represent 83 and 81 percent, 71 and 78 percent, and 75 and 74 percent of investment in buildings for in-bin, in-bin continuous flow and continuous flow systems, respectively for the 10,000 and 120,000 bushel sizes (Appendix Tables 4-6). The cost of concrete floors, ladders attached to bins, aeration ducts, aeration installation, etc. were a minimum 17 percent of investment in buildings and a maximum 26 percent.

The estimated capital requirements for buildings is different for each storage and drying system despite similar sizes. This variation is due in part to facility design since taller bins of smaller diameter require slightly smaller

TABLE 3.3

SUMMARY OF CAPITAL INVESTMENT COSTS OF
SELECTED FARM STORAGE AND DRYING SYSTEMS.

System	10,000 Bu.		20,000 Bu.		30,000 Bu.		60,000 Bu.		90,000 Bu.		120,000 Bu.	
	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.
In-bin												
Storage:												
Buildings	8,259	.86	15,188	.74	20,452	.71	34,206	.56	50,788	.55	64,114	.53
Equipment	2,058	.21	2,746	.13	2,979	.10	5,097	.08	6,473	.07	7,849	.07
Sub-total	10,317	1.07	17,934	.87	23,431	.81	39,303	.64	57,261	.63	71,963	.60
Drying equipment	2,363	.25	2,363	.12	3,001	.10	5,570	.09	5,715	.06	5,715	.05
Total	12,680	1.32	20,297	.99	26,431	.91	44,873	.73	62,976	.69	77,678	.65
Bin continuous flow												
Storage:												
Buildings	7,133	.69	12,714	.62	17,345	.61	32,029	.52	46,713	.50	61,396	.49
Equipment	2,345	.23	4,074	.20	4,481	.16	8,152	.13	11,082	.12	14,011	.11
Sub-total	9,478	.92	16,788	.82	21,826	.77	40,181	.65	57,795	.62	75,407	.60
Drying equipment	6,477	.63	6,477	.32	8,778	.31	8,778	.14	8,778	.09	8,778	.07
Total	15,955	1.55	23,265	1.14	30,604	1.08	48,959	.79	66,573	.71	84,185	.67
Continuous flow												
Storage:												
Buildings	7,869	.76	12,560	.61	18,840	.62	31,199	.51	46,798	.51	62,398	.51
Equipment	1,298	.13	1,858	.09	2,524	.08	27,416	.44	30,881	.34	34,346	.28
Sub-total	9,167	.89	14,418	.70	21,364	.70	58,615	.95	77,679	.85	96,744	.79
Drying equipment	7,694	.74	10,561	.52	15,747	.52	18,877	.31	18,877	.21	18,877	.16
Total	16,861	1.63	24,979	1.22	37,111	1.22	77,492	1.26	96,556	1.06	115,621	.95

investment per bushel, but two other factors are more relevant. The first is the indivisibility of storage units and manner in which bins of different sizes have been combined. For example, 30,000 bushels of storage may be obtained by combining three 10,000 bushel bins or two 15,000 bushel bins. The latter alternative is lower cost since the larger bins have a lower investment cost per bushel. The second and more important factor is the relative portion of storage space that is in higher priced drying tanks. Drying tanks used for bin drying and as storage bins require special design that causes a higher investment cost per bushel than ordinary storage bins.

Equipment

Estimated capital requirements for equipment range from $0.21 to $0.07 per bushel for the in-bin system; $0.23 to $0.11 per bushel for the in-bin continuous flow; and $0.13 to $0.28 per bushel for the continuous flow system. The increase in equipment investment per bushel for the continuous flow system is due to the addition on an elevator leg at the 60,000 bushel size.

The bin equipment components include aeration fans, unloading augers, bin unloading and sweep augers, and portable augers to load and unload trucks for most systems (Appendix Tables 7-9). The continuous flow storage and drying system has a different design. An elevator leg was added as equipment for the 60,000, 90,000 and 120,000 bushel continuous flow systems. This caused investment in equipment to jump from $0.08 to $0.44 per bushel for the 30,000 and 60,000 bushel systems, respectively (Appendix Table 9).

The investment for equipment represents 20 and 12 percent, and 25 and 18 percent of total building and storage equipment investment (excluding dryers) for in-bin and in-bin continuous flow systems, respectively, at the 10,000 and 120,000 bushel volumes. The proportion of equipment investment to total storage investment decreases as volume increases. This also occurs in the continuous flow systems. The equipment investment per bushel declines from 15 to 11 percent of total investment in building and equipment for sizes 10,000 through 30,000 bushels. For facility sizes 60,000 through 120,000 bushels equipped with elevator legs, cost of equipment decreases from 46 to 35 percent of total investment in buildings and equipment as size of facility increases.

The investment for storage is the sum of investment costs for buildings and investment costs for equipment (Table 3.3). This subtotal was made only to compare investment costs for storage (Table 3.1) with investment costs for storage systems designed to fit dryers, the difference being the investment cost of maintaining options for future development.

Estimated investment in storage buildings and equipment where provision is made for later addition of a dryer are $1.07, $0.98 and $0.89 per bushel of available capacity for the respective systems at a total capacity level of 10,000 bushels. Without provisions for addition of a dryer, investment in bins and equipment at 10,000 bushels of capacity is $0.85 per bushel of available space. At 10,000 bushels investment savings obtained by not maintaining the dryer option range from $0.22 to $0.04 depending on choice of system type. At large capacities investment difference per bushel of available space range from $0.20 to $0.10 per bushel.

Dryers

The estimated investment for drying equipment range from $2,363 to $5,715 for the in-bin dryer; $6,477 to $8,778 for the in-bin continuous flow dryer and $7,694 to $18,877 for the continuous flow dryer. This corresponds to $0.25 to $0.05; $0.63 to $0.07; and $0.74 to $0.16 per bushel, respectively. (Appendix Tables 10-12).

The economic impact of investment costs of the three dryers is most evident when viewed graphically (Figure 3.3). The in-bin drying system requires the least

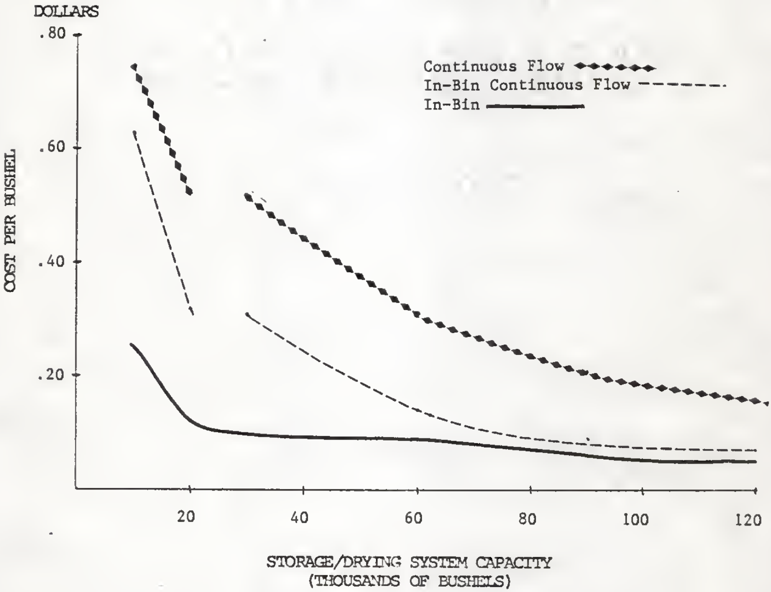

FIGURE 3.3: INVESTMENT PER BUSHEL FOR DRYING EQUIPMENT OF THE IN-BIN CONTINUOUS FLOW, AND CONTINUOUS FLOW DRYERS FOR SELECTED VOLUMES.

investment cost at all sizes. The investment for the in-bin continuous flow system is much greater than investment for in-bin systems at sizes up to 60,000 bushels. Above 60,000 bushels the two systems have only slightly different investment per bushel capacity provided. The continuous flow system has the highest investment cost per bushel of the drying systems studied.

The broken curves in the graph result from major changes in drying systems. For example the continuous flow curve represents automatic batch dryers at the 10,000 and 20,000 bushel sizes and column continuous flow dryers at the 30,000 through 120,000 bushel sizes. Therefore, the interval between 20,000 and 30,000 bushels has no economic implication. The break in the in-bin continuous flow curve occurs between 20,000 and 30,000 bushel capacities because the design specified a major addition to drying equipment at 30,000 bushels. Addition of storage capacity above 20,000 bushels but less than 30,000 with the initial drying equipment would cause equipment investment per bushel to decline beyond 20,000 bushels in the same manner as the 10,000 to 20,000 bushel interval.

Total Investment

Total building, equipment and dryer investment cost is $12,680 for the small in-bin storage and drying system and $115,621 for the large continuous flow storage and drying system (Table 3.3). The corresponding average investments are $1.32 and $0.95 per bushel, respectively. The relationship between the storage capacity and per bushel investment cost is more evident when seen graphically (Figure 3.4).

Average investment for in-bin storage and drying systems range from $1.32 to $0.67 per bushel. Storage and drying systems equipped with in-bin continuous flow dryers require investments up to $1.50 per bushel at small storage size but decrease to $0.67 per bushel at large volumes. This occurs since the additional investment for drying equipment necessary for in-bin continuous flow systems (e.g., bottom unloading and stirring devices) is spread over the drying

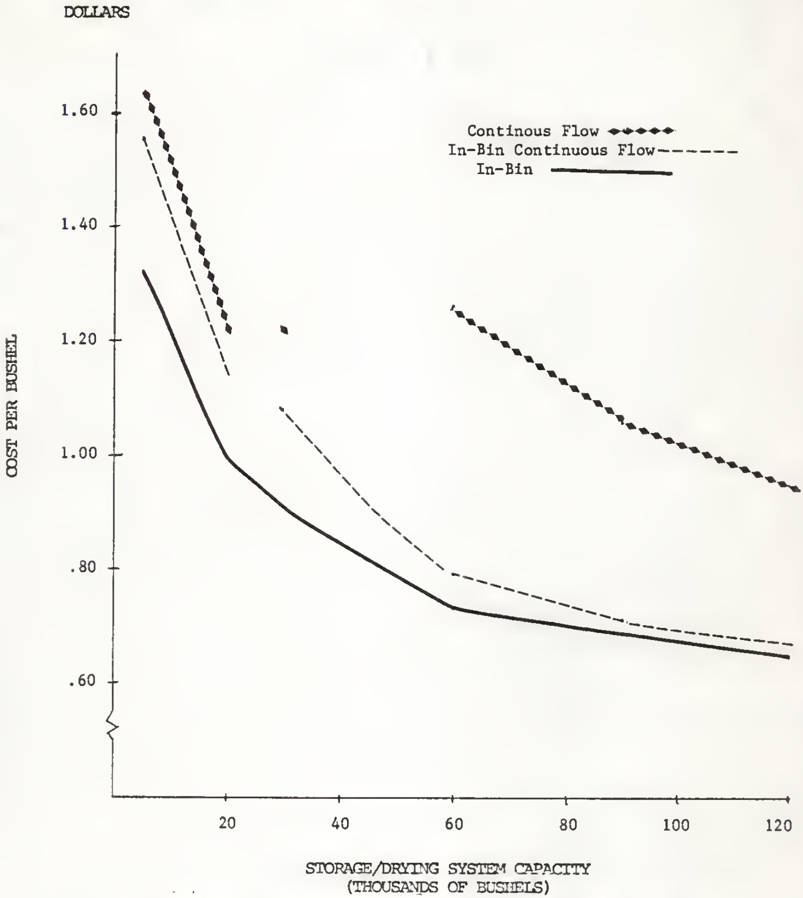

FIGURE 3.4: TOTAL INVESTMENT PER BUSHEL FOR THREE SELECTED STORAGE AND DRYING SYSTEMS AT VARIOUS VOLUMES

of additional bushels of grain. The continuous flow system requires the largest capital investment of all storage and drying systems. It ranges from $1.63 to $0.95 per bushel.

The broken curves in the graph are due to changes in the design of the storage and drying systems which break the continuity of economic information. The break in the in-bin continuous flow curve results from a change in drying equipment discussed, above. The three segments of the continuous flow curve are due to two factors. First, the 10,000 and 20,000 bushel sizes have the automatic batch dryers previously described. Secondly, the column continuous flow dryers of the 30,000 through 120,000 bushel systems are differentiated by the addition of an elevator leg at the 60,000 bushel volume.

Ownership and Operating Costs

The level of combined ownership and operating costs of farm grain storage and drying systems is important to all farmers utilizing these systems or contemplating purchasing new systems.

Costs are separated into fixed and variable costs. The fixed costs and variable costs included are the same as those determined for storage systems, except that the per bushel cost of drying is added to variable costs.

The annual fixed costs are derived for building, equipment and dryer investment by applying interest, depreciation and other cost rates discussed in Chapter II. Average annual fixed cost per bushel of space[1] were then obtained by dividing total fixed cost figures by their respective storage unit sizes[2] (Appendix Tables 13 to 15).

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[1]Storage space was assumed to be 100 percent of bushel capacity. This assumes that the full capacity may be stored and dried and leaves no extra work space.

[2]Average fixed cost of storage and drying systems were compiled at 100 percent utilization only.

Fixed Costs

The annual fixed costs for the storage and drying systems analyzed in this study range from $0.192 to $0.089, $0.262 to $0.101, and $0.273 to $0.157 per bushel for the in-bin, in-bin continuous flow and continuous flow dryers, respectively. This corresponds to $1,852 to $11,128, $2,696 to $12,914, and $2,829 to $19,016 total annual fixed costs, respectively (Table 3.4).

The economic relations shown in fixed costs are identical to those previously discussed in analyzing the capital investment for each storage and drying system. For example, the addition of the elevator leg to the 60,000 bushel continuous flow system caused the fixed cost for equipment to increase from $0.016 to $0.086 per bushel at 30,000 and 60,000 bushel volumes respectively. The corresponding relationships occur since fixed cost is a set percentage of investment cost.

Variable Costs

The total variable costs ranged from $0.115 to $0.106, $0.106 to $0.102, and $0.115 to $0.108 per bushel for the in-bin, in-bin continuous flow and continuous flow storage and drying systems, respectively, (Table 3.5).

Weight loss, and drying cost were the largest variable cost items. Weight loss is the cost incurred when grain which has been dried to 15.5 percent moisture content shrinks to 13.5 percent from the use of aeration during storage to obtain safe moisture content. This includes the moisture shrink of 2 percent and a dry matter shrink or handling shrink of .5 percent, thus the cost was estimated at $0.05 per bushel for all systems.[3]

Drying costs ranged from $0.044 to $0.038, $0.034 to $0.031, and $0.040 to

[3]Assumes storage capacity filled with grains which need drying, e.g., corn and grain sorghum. If filled with grains such as wheat the weight loss percentage used in the storage systems is applicable.

TABLE 3.4

SUMMARY OF ANNUAL FIXED COST OF STORAGE AND DRYING SYSTEMS ($/BU.).

System	10,000 Bu.		20,000 Bu.		30,000 Bu.		60,000 Bu.		90,000 Bu.		120,000 Bu.	
	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.	$	$/bu.
In-bin												
Storage:												
Buildings	1,061	.11	1,952	.095	2,628	.091	4,396	.073	6,527	.072	8,239	.068
Equipment	357	.037	504	.025	547	.019	935	.016	1,188	.013	1,440	.012
Sub-total	1,418	.147	2,456	.120	3,175	.110	5,331	.089	7,715	.085	9,679	.080
Drying equipment	434	.045	434	.021	551	.019	1,022	.017	1,449	.012	1,449	.009
Total	1,852	.192	2,890	.141	3,726	.129	6,353	.106	9,164	.097	11,128	.089
Bin continuous flow												
Storage:												
Buildings	988	.096	1,761	.086	2,402	.084	4,436	.072	6,470	.069	8,504	.067
Equipment	454	.044	789	.039	867	.03	1,577	.026	2,144	.023	2,711	.021
Sub-total	1,442	.140	2,550	.125	3,269	.114	6,013	.098	8,614	.092	11,215	.088
Drying equipment	1,254	.122	1,254	.061	1,699	.06	1,699	.028	1,699	.018	1,699	.013
Total	2,696	.262	3,804	.186	4,968	.174	7,712	.127	10,313	.110	12,914	.101
Continuous flow												
Storage:												
Buildings	1,090	.105	1,740	.085	2,610	.086	4,321	.069	6,482	.071	8,643	.071
Equipment	250	.024	360	.018	488	.016	5,305	.086	5,762	.063	6,720	.056
Sub-total	1,340	.129	2,100	.103	3,098	.102	9,626	.155	12,244	.134	15,363	.127
Drying equipment	1,489	.144	2,044	.099	3,047	.101	3,653	.059	3,653	.04	3,653	.03
Total	2,829	.273	4,144	.202	6,145	.203	13,279	.214	15,897	.174	19,016	.157

TABLE 3.5

SUMMARY OF AVERAGE VARIABLE COSTS OF STORAGE AND DRYING SYSTEM.

	10,000	20,000	30,000	60,000	90,000	120,000
In-bin			- Dollars per Bushel -			
Insurance	.011	.011	.011	.011	.011	.011
Insect control	.002	.002	.002	.002	.002	.002
Aeration	.002	.003	.002	.002	.002	.002
Handling	.006	.006	.006	.003	.003	.003
Drying	.044	.042	.044	.038	.038	.038
Weight loss	.05	.05	.05	.05	.05	.05
Total	.115	.114	.115	.106	.106	.106
In-bin continuous flow						
Insurance	.011	.011	.011	.011	.011	.011
Insect control	.002	.002	.002	.002	.002	.002
Aeration	.002	.002	.002	.002	.003	.003
Handling	.007	.007	.007	.005	.005	.005
Drying	.034	.034	.031	.031	.031	.031
Weight loss	.05	.05	.05	.05	.05	.05
Total	.106	.106	.103	.101	.102	.102
Continuous flow						
Insurance	.011	.011	.011	.011	.011	.011
Insect control	.002	.002	.002	.002	.002	.002
Aeration	.005	.002	.002	.002	.002	.002
Handling	.007	.007	.007	.003	.003	.003
Drying	.040	.040	.041	.040	.040	.040
Weight loss	.05	.05	.05	.05	.05	.05
Total	.115	.112	.113	.108	.108	.108

$0.040 per bushel for the in-bin, in-bin continuous flow and continuous flow storage and drying systems, respectively. Total variable costs of drying includes electricity, labor, handling and fuel costs (Appendix Table 22). The drying costs varied among systems due to physical differences in the dryers. Bin dryers are the most fuel efficient of the units studies due to the nature of their drying operation. Very little heat is lost when it is forced through the grain, as compared with continuous flow dryers.

Aeration is a useful technique for conditioning grain in storage even if the grain were artificially dried. Moving air through grain keeps it cool and dry in order to maintain quality. Aeration costs are determined relative to horsepower per thousand bushels (Appendix Table 18). The highest cost computed was $0.005, but most were around $0.002 per bushel. The variation was due to fans of different horsepower per thousand bushel specified by dealers.

Handling costs were $0.006, $0.007, and $0.007 per bushel for the in-bin, in-bin continuous flow and continuous flow storage and drying systems, respectively for the 10,000 through 30,000 bushel volumes. The corresponding costs decreased to $0.003, $0.005, and $0.003 per bushel, respectively for the 60,000 through 120,000 bushel systems. The handling cost reduction was due to the use of higher capacity augers in larger systems which reduced the per bushel handling time and allowed more efficient use of labor. The elevator leg used in the large continuous flow system further increased speed of handling grain.

Total Costs

The average total cost of the various storage and drying systems is the sum of average fixed and average variable costs. The total cost ranges from $0.31 to $0.195, $0.368 to $0.203, and $0.388 to $0.265 per bushel for the in-bin, in-bin continuous flow, and continuous flow storage and drying system, respectively (Table 3.6). The cost relationships of the various storage and drying systems are presented graphically in Figure 3.5.

A close examination of Figure 3.5 shows that the shape of the average total cost curves are the same as the shapes of the average fixed cost curves. This relationship occurs because the average variable cost curves are almost straight lines.

The in-bin storage and drying system has the lowest average total cost per bushel for all sizes of facilities. It's average fixed costs are low due to relatively lower investment in facilities and equipment. The variable costs for the system were in the 10 and 11 cents per bushel range, as were all the systems, so no significant economic advantage of lower operating costs was present for any of the three system types.

The in-bin continuous flow storage and drying system follows the in-bin system in low cost. It has a higher average total cost at all levels, but narrows to nearly the same total costs as the in-bin storage and drying system over the 30,000 to 60,000 bushel volume levels. The economic advantage of the in-bin storage and drying system becomes very small from 30,000 to 120,000 bushels. For storage and drying systems in this interval, farmers may find the benefits of the faster drying rates and continuous flow movement to be greater than the additional costs of an in-bin continuous flow system. For example, an in-bin continuous flow system operated at 125 percent throughput has total cost of $0.204 per bushel compared to the in-bin cost of $0.212 per bushel at 100 percent throughput, at the 60,000 bushel level.

The continuous flow dryers have the highest average total cost of storage and drying at all volumes. But again, the economic benefits obtained from their fast drying rates, accurate drying levels and high capacity handling of grain must be weighed against their additional costs before eliminating this drying alternative.

TABLE 3.6

SUMMARY OF AVERAGE ANNUAL FIXED COST, VARIABLE COST,[a] AND TOTAL COST FOR THREE STORAGE AND DRYING SYSTEMS.

	In-Bin			In-Bin Continuous Flow			Continuous Flow		
	Storage	Dry	Total	Storage	Dry	Total	Storage	Dry	Total
				- Dollars per Bushel -					
10,000 Bushels									
Annual fixed cost	.15	.045	.195	.140	.122	.262	.129	.144	.273
Variable cost	.071	.044	.115	.072	.034	.106	.075	.040	.115
Total cost/bu.	.221	.089	.31	.212	.156	.368	.204	.184	.388
20,000 Bushels									
Annual fixed cost	.12	.021	.141	.125	.061	.186	.103	.099	.202
Variable cost	.072	.042	.114	.072	.034	.106	.072	.040	.112
Total cost/bu.	.192	.063	.255	.197	.095	.292	.175	.139	.314
30,000 Bushels									
Annual fixed cost	.11	.019	.129	.114	.06	.174	.102	.101	.203
Variable cost	.071	.044	.115	.072	.031	.103	.072	.041	.113
Total cost/bu.	.181	.063	.244	.186	.091	.277	.174	.142	.316
60,000 Bushels									
Annual fixed cost	.089	.017	.106	.091	.028	.119	.155	.059	.214
Variable cost	.068	.038	.106	.070	.031	.101	.068	.040	.108
Total cost/bu.	.157	.055	.212	.161	.059	.220	.223	.099	.322
90,000 Bushels									
Annual fixed cost	.085	.012	.097	.092	.018	.110	.134	.040	.174
Variable cost	.068	.038	.106	.071	.031	.102	.068	.040	.108
Total cost/bu.	.153	.050	.203	.163	.049	.212	.202	.080	.282
120,000 Bushels									
Annual fixed cost	.080	.009	.089	.088	.013	.101	.127	.030	.157
Variable cost	.068	.038	.106	.070	.031	.102	.068	.040	.108
Total cost/bu.	.148	.047	.195	.158	.044	.203	.195	.070	.265

[a] Assuming 6-month storage at 100 percent utilization of available storage space.

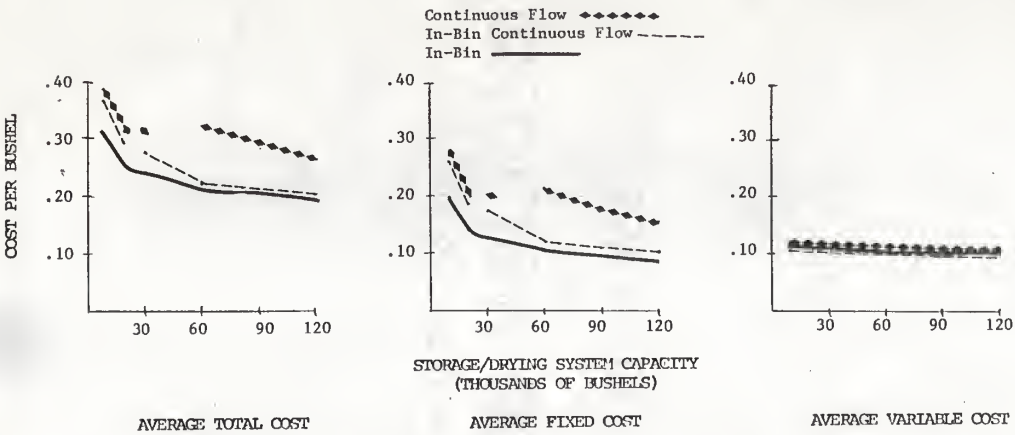

FIGURE 3.5: AVERAGE TOTAL, FIXED, AND VARIABLE COSTS FOR SELECTED STORAGE AND DRYING SYSTEMS

No specific rules can be given to determine when to use the various storage and drying systems analyzed in this study. However, the economic relationships among the costs of the various systems can be used to suggest guidelines. The dryer selected to fit a farm storage system is analagous to a "funnel" that controls the rate at which grains can move through the system. The study showed that the in-bin storage and drying systems have the slowest drying rate and moderate investment levels. The faster drying rates obtainable with the in-bin continuous flow system required a larger investment and the fastest drying rate, obtainable with the continuous flow system required even more investment. In general, the more drying capacity the more it will cost.

The energy efficiency of farm grain dryers is another consideration with significant economic impact in future years. The results of this study showed the total drying variable costs to be between three and four cents per bushel, with fuel cost representing the major portion. However, there has been limited work done in the area of field testing of various dryer types. Future studies of this type would be helpful to more accurately determine cost differences by various dryers.

The future of fossil fuel reserves also needs to be considered when selecting a drying system. As natural gas and L.P. gas become scarce, the cost of these fuels will skyrocket or their use may be restricted. If this occurs the industry must shift to new technology. Current development in solar drying may be easily adapted to bin dryers, this may cause continuous flow dryers to become obsolete. Changes of this sort have many far reaching effects which merit consideration.

Summary

There are significant economies of size in investments for farm grain storage systems until the 60,000 bushel size facility. From 60,000 to 120,000 bushels there is almost no investment cost advantage. These economies of size develop due to lower average cost of larger bins and greater utilization of equipment.

Lower investment per bushel for larger bin sizes are reflected in per-bushel average costs for grain storage. Variable costs per bushel of grain are reduced only slightly as facility size and corresponding annual volume of grain stored increases. Hence average cost per bushel of storing an amount of grain equal to storage capacity reduces significantly through 40,000 bushels annually, but not thereafter.

The rate of utilization of farm storage systems may offset the economies of size. Large capacity systems at low utilization rates record nearly the same average cost as full utilization of smaller facilities. This is due to the rate at which fixed costs are spread over bushels of stored grain.

Many farming operations may have the need for farm storage and drying equipment. The results of this study show that the in-bin storage and drying systems have the lowest average total costs at all facility sizes. Cost advantages of these in-bin dryers may be offset in the market place due to the discount system since it is difficult to maintain correct moisture levels with this system and underdrying or overdrying may result.

The in-bin continuous flow storage and drying system has higher average total costs than in-bin systems at all facility sizes, but narrows to nearly the same costs over the 30,000 to 60,000 bushel size. Beyond this point the cost differences are insignificant. However, farmers may find the benefits of faster drying rates and continuous flow movement to be greater than the additional costs.

Continuous flow storage and drying systems had the highest cost for all sizes in this study. These higher costs may be offset by benefits obtained from faster, more accurate drying and larger handling capacities.

The cost relationships reported in this chapter are those reflected by the various systems designed for this analysis. This same analysis may be used to evaluate other alternatives before selecting a farm storage and drying system. This may be necessary before cost data are applied to a specific situation due to differences in acquisition price depending on the season, location, brand selected and individual dealer.

CHAPTER IV

POTENTIAL BENEFITS OF FARM STORAGE AND DRYING

On-Farm Costs Versus Commercial Charges

During the study, data were collected to provide the basis for comparisons of farm storage costs with commercial elevator storage charges. Elevator managers gave data on rates charged to farmers for storage and drying. The rate schedules varied somewhat but the typical rate charged is $0.02 per bushel per month of storage. The drying charge is on a sliding scale of moisture removed but is usually $0.20 per bushel to remove 10 percentage points of moisture.

The costs to the farmer for storing cash grain on the farm and for storing at the local elevator are then compared for grains which do not require drying (only the storage function) and for grains which require drying and storing.

Storage

The costs of storing grains which are at safe storage moisture levels on the farm and the rates farmers must pay for commercial storage of similar grain are shown in graphic form (Figure 4.1).

The elevator storage charges are shown by horizontal lines for storage periods of 3, 6, 9, and 12 months. These charges represent only the storage cost to the farmer and include no additional handling charges that might be incurred if the farmer wanted to take the grain out of storage for marketing.

Farm storage cost curves represent the annual total cost per bushel at various storage levels. For this comparison these costs do not change relative

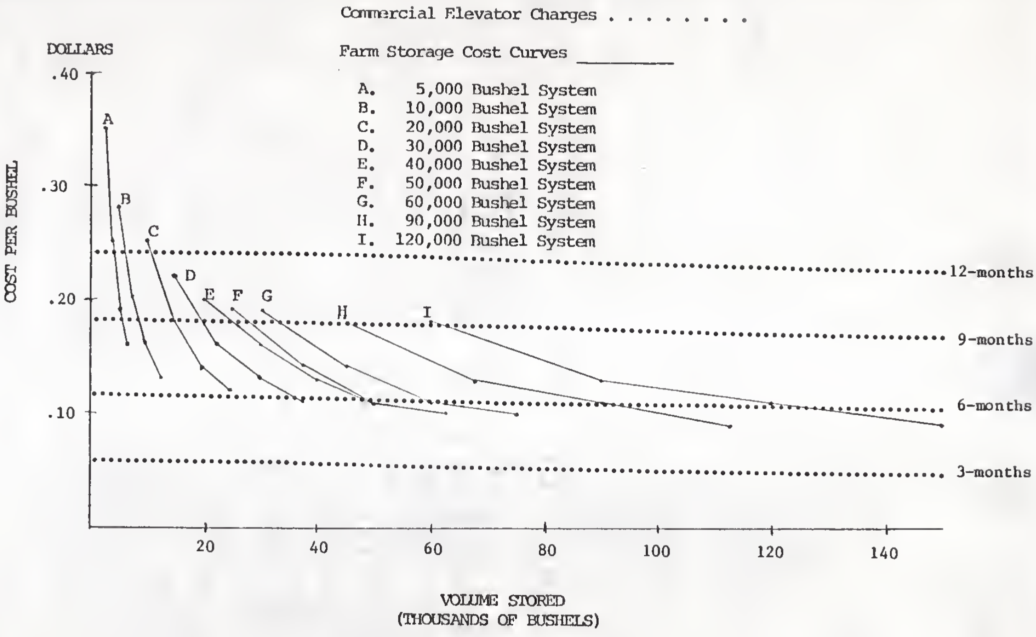

FIGURE 4.1: COMPARISON OF FARM STORAGE COSTS PER BUSHEL WITH COMMERCIAL ELEVATOR CHARGES FOR STORING GRAIN 3, 6, 9 AND 12 MONTH PERIODS

to length of storage period. Fixed costs are not affected by length of storage period within the marketing year. Variable costs are influenced by length of storage period, however, additional costs for longer storage after suitable storage conditions have been attained occur only for aeration and insurance. Aeration and insurance costs are $0.0022 and $0.011 per bushel, respectively for the six-month period. This totals to $0.0132 per bushel for 6 months or $0.0022 per bushel per month. This amount is relatively small but because cost estimates in this study are based on a 6-month storage period, farm storage costs are slightly overstated for storage periods of less than 6 months and slightly understated for storage periods greater than 6 months.

The graph shows that elevator storage is the least cost alternative for a 3-month storage period. However, farmers may disregard fixed costs for storage decisions in any one year, fixed costs for the facilities will be there whether grain is stored or not. Under these circumstances farm storage variable cost for the three-month period is $0.038 per bushel, which is lower than commercial charge for storage period of 3 months or more. The farm may operate in the short-run by meeting variable costs only, but in the long-run all costs become variable and must be covered for economic survival.

Farmers who have storage systems of 50,000 bushels or larger have total cost per bushel advantages over the commercial alternative. When storing grain for 6 months, systems of volumes 20,000 and 30,000 bushels which operate at 125 percent throughput rates have costs equal to commercial storage charges.

When grain is stored for 9 months, farm storage is at lower cost than commercial charges for each volume level. The 5,000 bushel system must have a throughput of over 100 percent, however. For 12 month storage periods farm storage has cost advantages to the commercial alternative at each volume level. Only the 5,000, 10,000 and 20,000 bushel systems used at less than 75 percent throughput have higher costs.

Storage and Drying

The costs of storing grains which require drying on the farm and the corresponding rates farmers must pay for commercial storage and drying are shown in Figure 4.2. Note that the annual total cost per bushel for the three farm storage and drying systems reported here are only for 100 percent utilization.

The commercial charges represent the least cost alternative at some sizes less than 40,000 bushels for the 3 month storage period. However, when managing farm storage and drying systems farmers may consider many alternatives since they may store grains which require drying for safe storage of grains which are already at safe moisture contents. A diversified grain farmer may store wheat on the farm for three months (July, August, and September) and then remove it to make room for feed grains harvested in the fall. Under these conditions the farmers' wheat may be stored for only $0.038 per bushel to cover vaiable cost which is lower than the $0.06 per bushel required for three months storage in the commercial elevator.

For six month storage periods the commercial elevator alternative is lower cost for annual volumes up to 40,000 bushels for the in-bin and in-bin continuous flow system. At 60,000 bushel sizes the in-bin, and in-bin continuous flow systems offer cost advantages to the commercial alternative.

Storing grain for 9 months revealed that all the farm storage systems have cost advantages to the commercial alternative at nearly all sizes. The cost advantages begin at 10,000 for the in-bin and in-bin continuous flow storage and drying systems.

Storing grain for 12 month periods in farm storage and drying systems was lower cost for all systems, compared to the commercial storage and drying alternative.

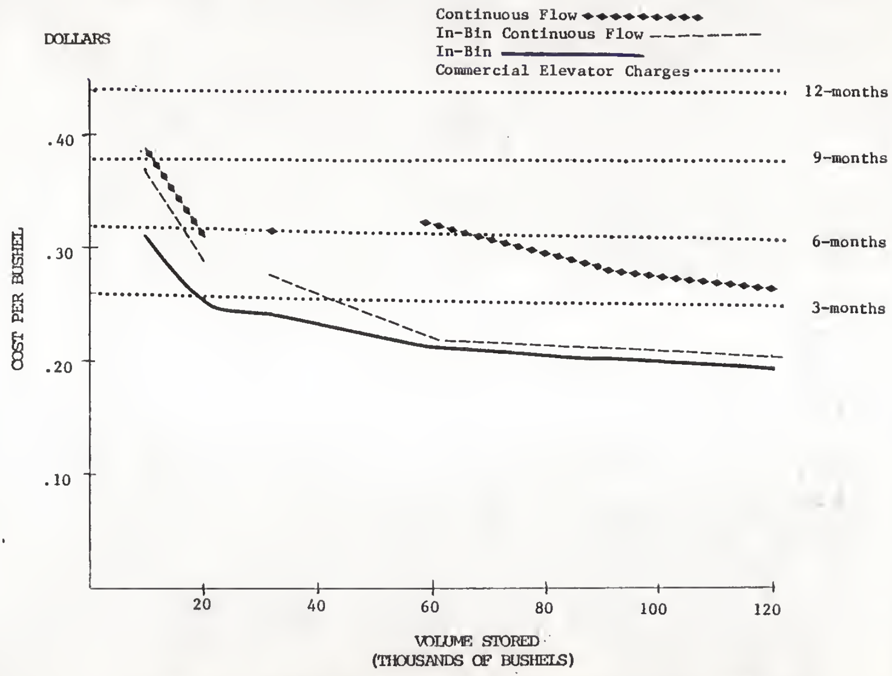

FIGURE 4.2: COMPARISON OF FARM STORAGE AND DRYING COSTS TO COMMERCIAL ELEVATOR CHARGES FOR DRYING GRAIN AND STORING FOR 3, 6, 9 AND 12 MONTH PERIODS.

Summary

Farm grain storage systems are the least cost storage alternative for systems of sizes 15,000 through 120,000 bushels when storing grain for 9 month and 12 month periods. The commercial storage alternative may become lower cost for storage periods less than nine months depending on the volume, utilization rate and storage strategy of the farm storage systems.

Storage and drying in commercial elevators has cost advantages to farmers who store and dry 10,000 bushels or less for storage periods up to 9 months. The batch-in-bin system is lower cost than commercial storage at all sizes for periods of storage 6 months or longer. The in-bin continuous flow is the lower cost alternative at all sizes for 9 months storage periods or longer. Continuous flow systems offer cost advantages for 20,000 through 120,000 bushel systems for 9 month storage periods and longer.

Appreciation of Inventory

Increases in the value of stored grain caused by seasonal price variation can be a major benefit from storage. An index of seasonal variation and index of irregularity were used to analyze seasonal price patterns for wheat and grain sorghum in Kansas (Figures 4.3 and 4.4).

The solid line represents the seasonal index and the broken lines the upper and lower bounds for index of irregularity in the series of prices. The seasonal index was obtained by the ratio to moving average method.[1] This technique is useful in isolating the seasonal pattern to serve as a factual basis for marketing decisions. The band formed around the index of Seasonal Variation contains approximately 68 percent of the variation which could normally be expected to occur in the series of data analyzed.

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[1]Cecil H. Meyers, Elementary Business & Economic Statistics, 2nd Ed. (Wadsworth Publishing Co., Inc., 1970), p. 502-508.

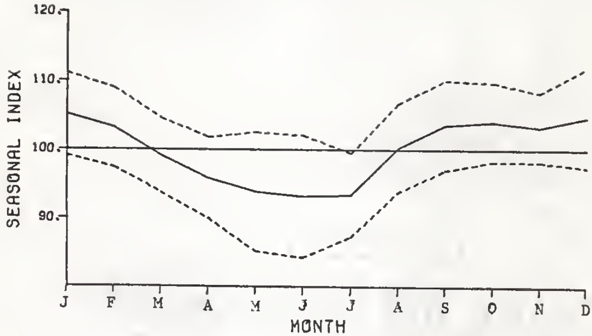

FIGURE 4.3: INDEX OF SEASONAL VARIATION AND INDEX OF IRREGULARITY FOR PRICES OF NO. 1 HARD WINTER WHEAT AT KANSAS CITY, 1967-1977.

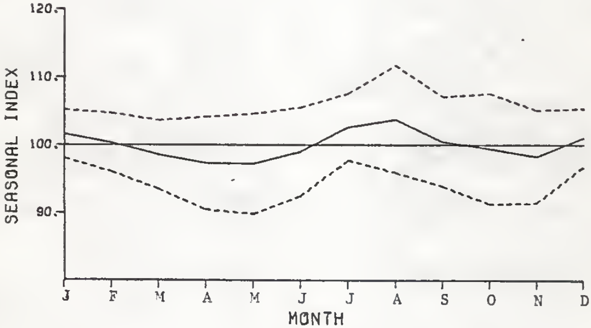

FIGURE 4.4: INDEX OF SEASONAL VARIATION AND INDEX OF IRREGULARITY FOR PRICES OF NO. 2 YELLOW SORGHUM AT KANSAS CITY, 1967-1977.

The period of low wheat prices tends to come during the harvest months June and July. The months September through February tend to be the high priced months for wheat. The variation in prices is the largest in the months of May and June. This is reasonable due to the adjustments the market makes before the new crop is harvested.

Grain sorghum prices experience seasonal lows two periods during the year; the harvest season during October and November and the end of spring during April and May. The months July and August tend to be the high priced months for grain sorghum. The variations in these price data over the years were largest in May, August and October.

The seasonal index was useful to illustrate systematic variations in prices originating from seasonal factors. In prices for agricultural commodities it cannot be expected that the pattern will repeat itself in an identical manner, year after year. Many factors affect agricultural prices in any given year, e.g., domestic demand, volatile foreign demand, supplies, carryover and weather. For this reason it is relevant to look at what has happened to prices each year over a given period. Figures 4.5 and 4.6 show the change in price from harvest to each subsequent month for wheat and grain sorghum during the period 1967-1977.

During the 10 year period observed wheat prices generally increased from July to subsequent months, as may be seen by the concentration of dots in the upper portion of the graph. This increase showed much variation from year to year; e.g., the seasonal index found December to be a high priced month for wheat, this graph shows that for December, 7 of the 10 years had positive changes but the actual change ranged from $2.32 to $0.03 per bushel. During the three years showing negative changes, the changes varied from $0.03 to $1.00.

The benefit of seasonal price variations accrues to stored grains only when it is greater than the storage cost. The storage systems analyzed had

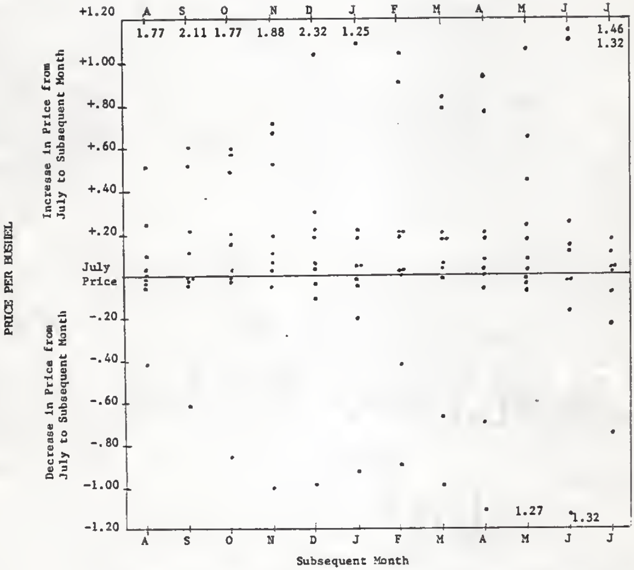

FIGURE 4.5: CHANGE IN PRICE OF NO. 1 KANSAS CITY HARD WINTER WHEAT FROM JULY TO SUBSEQUENT MONTHS, 1967-1977.

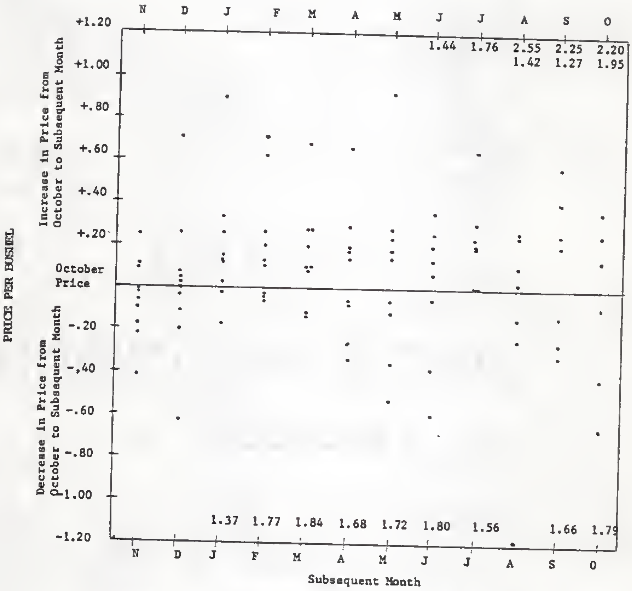

FIGURE 4.6: CHANGE IN PRICE OF NO. 2 YELLOW SORGHUM FROM OCTOBER TO SUBSEQUENT MONTHS, 1967-1977.

total costs per bushel ranging from $0.25 to $0.11 for 100 percent utilization. Therefore the price must increase at least $0.11 per bushel to generate benefits.[1] Under this condition farmers could have profited, seasonal price increase - farm storage cost of $0.11 per bushel, 6 years out of the 10 in October, with profits ranging from $1.66 to $0.05 per bushel. Profits could have been obtained 5 years out of 10 from sale in December, February, and March. With farm storage costs at the high end of the cost range ($0.25 per bushel) seasonal price increases exceed cost only 2 years out of 10 in December, February, and March.

Most of the losses due to price decreases were concentrated in an area less than $0.10 per bushel. However, the 1976-77 marketing year provided large declines in prices for subsequent months. The declines occurred in each month during the downswing in the market and reached $1.32 per bushel in June.

The grain sorghum prices did not experience as large a variation in prices as wheat. The seasonal index showed July and August to be the high priced months. Figure 4.6 shows that the price increases 7 out of 9 years and 6 out of 9 years from October to July and August, respectively. These increases varied from $0.01 to $2.55 per bushel.

The cost of farm storing and drying grain sorghum ranged from $0.20 to $0.40 per bushel for the systems analyzed in this study. When using $0.20 as the basis for breakeven point, it can be seen that profits from storage and drying could have been made in 5 out of 9 years during July and 4 out of 9 years in August. These profits may have reached as high as $2.35 per bushel in August.

Benefits from Government Programs

Government programs play an important role in the marketing of grains. Benefits may be obtained from commodity loans and farm storage facility loans.

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[1] Inventory ownership costs were not considered since this analysis dealt with costs of owning and operating storage. However, store or sell decisions must also consider the cost of interest on inventory.

Commodity Loans

Producers may obtain loans on stored grains at harvest.[1] The producer then has the alternative of selling the grain and repaying the loan or allowing the loan to mature and forfeiting the grain. In some cases the loan period may be extended and the grain resealed in storage. Benefits may be obtained if the loan price is greater than the market price. However, if the market price is greater than the support price and service charges and loan fees it is more profitable to sell the grain.

The interest rate as of August 1977 is 6 percent on these loans and the average loan rate for wheat in Kansas is $2.22 per bushel.[2] A farmer who knows his storage costs can then decide whether to put his wheat into storage or sell it by simply subtracting the costs of carrying grain for the 12 month loan period from the loan rate. The carrying cost includes the storage cost (including insurance) plus the interest cost on the inventory investment. If storage cost is $0.11 per bushel (least cost system) and the interest cost is $0.12 per bushel ($2.00 per bushel X 6% annual interest) then most wheat will be stored at $1.99 per bushel ($2.22 - (.11 + .12)). Prices below this level enable farmers to put wheat into storage cover all carrying costs and make a profit if it can be stored for $0.11 per bushel.

The present farm program allows loans on the 1976 wheat crop to be renewed for up to 3 additional years. During these three years the government will pay $0.20 per bushel for storage. The systems analyzed in this study had total costs ranging from $0.11 to $0.25 per bushel. For those costs the government

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[1] U.S. Department of Agriculture, Commodity Credit Corporation, General Regulations, Governing Price Support for the 1976 and Subsequent Crops, (Reprinted from the Federal Register of June 3, 1976; (41 F. R. 22334).

[2] U.S. Department of Agriculture, 1977 Crop Wheat Schedule of Basic County Loan and Purchase Rates and Premiums and Discounts (U.S. Government Printint Office; 1977, 0-241-464/ASCS - 60).

storage payment would mean $0.09 per bushel direct profit for least cost storage and only $0.05 per bushel annual loss for higher cost storage, respectively, to farmers using the program.[3]

Farm Storage Facility Loans

The current government program encourages the construction of additional farm storage facilities for farm commodities. Commodity Credit Corporation (CCC) funds are now available for loans to producers for storage bins and dryers. Farmers may borrow up to $50,000 at 7 percent interest. Loans are scheduled for repayment in 4 annual payments that pay off the loan in 5 years.

The $50,000 loan would finance complete storage systems up to nearly 90,000 bushel capacities and storage and drying systems up to 60,000 bushels. The loan rate of 7 percent is lower than the 8.5 percent interest rate used in this study. If 90,000 bushels of storage was purchased for $50,000, the annual cost per bushel for interest is $0.019 and $0.024 for 7 and 8.5 percent interest rates, respectively. Thus $0.005 per bushel may be saved by using the loan program.

Other Benefits

The benefits obtained from farm grain storage may include numerous others which are unique to a specified farming operation. These benefits may be difficult to measure, but merit consideration. The benefits may include:

1. Quality premiums; e.g., protein premiums for high protein wheat,
2. Flexibility in marketing; e.g., full use of futures,
3. Flexibility in farming operation; e.g., sell crops for cash or use grain in feeding operation,

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[3]This assumes that facilities will be used throughout their useful life. If facilities are put in place only for carryover of grain on loan renewal, uncertainty concerning continuation of government programs in present form must be considered.

4. Eliminates uncertainties of commercial storage; e.g., elevator filling up before completion of harvest and waiting for trucks in elevator lines.

CHAPTER V

SUMMARY AND CONCLUSIONS

Modern farm grain storage systems require large initial capital investment. Major cost of farm storage is associated with the capital expenditures and hence become fixed costs over the life of the investment.

Farm storage units of various sizes are designed by combining components of systems to achieve various storage capacities and storage or storage and drying objectives. Combining components into representative systems in this study, for which fixed and variable costs of farm storage were subsequently determined, indicated relevant unit cost economies of size were found to exist beyond that size largely because expansion beyond 60,000 bushels involved addition of component units of equal size and operating characteristics as those used at the 60,000 bushel level.

Investment in buildings and equipment per bushel of storage space provided decline more rapidly as size of the system increased up to 60,000 bushels than beyond that size. Investment per bushel of space provided for storage systems not accompanied by drying systems varied from $1.05 per bushel for a 5,000-bushel system to $0.55 per bushel for 120,000 bushels. Where drying systems are included in the storage/drying system, total investment per bushel varied from $1.32 for a 10,000-bushel system to $0.65 for a 120,000 bushel system for low investment systems and from $1.63 to $0.95 for higher investment, more highly mechanized systems.

Facilities for storage that were designed to add drying facilities at a later time resulted in slightly higher investment. With a system size of

30,000 bushels, investment per bushel was increased from $0.67 to $0.77. This indicates the investment necessary to maintain flexibility of future decisions.

Variable costs associated with receiving grain into storage, storing and loading out where no drying occurs ranged from $0.034 per bushel to $0.038 per bushel depending on size of storage system and related equipment. Variable costs per bushel do not increase significantly for longer storage periods within the marketing year, once suitable storage conditions have been achieved. Variable costs are thus quoted in bushels placed in storage rather than bushel/month for which grain is stored. Because grain may be removed from storage with the possibility of replacement in the same marketing year storage costs were analyzed in cases varying from 50 percent utilization of facilities up to 125 percent utilization, e.g., bushels entering storage up to 125 percent of rated capacity of the facilities.

The range of annual total costs per bushel for farm storage encompassing both size of facilities and annual utilization was from $0.35 for 50 percent utilization of a 5,000-bushel facility to $0.09 for 125 percent utilization of a 120,000 bushel facility.

Drying costs were calculated for facilities suited for drying and filling the associated storage facility during a 2-week period. Variable costs of drying were calculated on the basis of a reduction in moisture content of grain from 25.5 to 15.5 percent.

Costs of operating storage and drying systems at an annual grain volume equal to 100 percent of the rated capacity of storage varied for the lower cost system from $0.310 per bushel at the 10,000 bushel size to $0.195 per bushel for the 120,000 bushel size. The highest cost system varied from $0.388 per bushel to $0.265 per bushel. Variable costs of drying and storage ranged from $0.115 to $0.102 per bushel over various size and types of systems.

The total costs of farm grain storage systems were significantly effected by the utilization rate of the system. A large system utilized at low rates may cost more than full utilization of a smaller system.

The type of dryer selected had a significant impact on total costs of storing and drying systems. The study showed that systems designed to dry grain at a faster rate have higher total costs per bushel--due to higher fixed costs derived from larger investment requirements.

The economic cost relationships presented in this study provide only guidelines and insights into the farm storage decision making process. However, the economic engineering approach to farm storage cost analysis used in this study is an accurate and thorough technique which may be adapted by farm managers to analyze farm storage costs on their own farms.

Identifying annual costs of various farm storage and drying systems indicated that investments in farm storage produce many potential benefits. This study measured benefits from farm storage cost advantages relative to commercial charges, appreciation of inventory due to seasonal price variations, and government programs.

The study showed that farm storage systems offer cost advantages to producers who store grain for 6 months or longer. The exact savings depends on the size of the system, the utilization rate and the length of the storage period.

Cost advantages from farm storage and drying systems, relative to commercial elevator charges are more significant. The low investment farm storage/drying system has lower cost than does commercial storage for 3-month storage periods. The high investment farm storage/drying system is lower cost than commercial charges at most sizes for a 6 month storage period. Farmers may develop storage/marketing strategies which increase the utilization rate of their storage/drying facility and lower the per bushel cost of storage; e.g., diversified grain farmers may store wheat in farm storage, removing it later to receive the fall feed grains.

Analyzing wheat and grain sorghum prices for the 1967-1977 period indicate that seasonal variations in price can result in benefits from storing grain. Benefits were obtained 5 years out of 10 from selling wheat in December, February, or March. Benefits from storing grain sorghum from harvest for sale in July were obtained 5 out of 9 years.

Profits from storing grain for inventory appreciation due to seasonal variations in prices was an effective strategy in some years. However, variations in profits were large and losses occurred in some years. The market price for farm commodities was affected by many factors which shift supply and demand for the commodities. Farmers must be cognizant of the prevailing market conditions, before they make marketing decisions for a given year.

Farmers may obtain as large as $0.09 per bushel profit from government payments for storage under the reseal program. Conversely, higher cost storage may result in storage costs that exceed government payments for storage by as much as $0.05 per bushel. Other benefits may come from low interest rates on storage facility loans and the government commodity loan program.

Potential benefits from farm storage which were not measured in this study may have significant economic impact on the decision-process of many farmers. Farmers producing high protein wheat obtain premiums in the market place which are foregone when the wheat is mixed in with average protein wheat in commercial elevators. The storage facilities of commercial elevators may be inadequate to handle farm production efficiently. In such cases farm storage generates benefits from convenience, less waiting time and faster harvesting, which are difficult to measure.

The potential of estimating farm grain storage and drying costs has many economic ramifications. Many farmers who are presently discouraged with the low prices for grain want to know if they should invest in farm storage for long-term holding of grain, speculating that the price will increase. Farmers who produce feed grains need to know the cost performance of various types of dryers to select the one suited for their enterprise. If the costs of fossil fuel energy for drying grain rise and farm building costs continue to rise, farmers will be interested in the economic impact of these changes. Consequently, use of this study could be helpful to many farmers as a factual basis for their storage/marketing decision process.

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Appendix

Supporting Data

APPENDIX TABLE 1

COMPONENTS AND 1977 PRICES OF STORACE SYSTEM BUILDINCS AND EQUIPMENT.

	5,000 Bushel	10,000 Bushel	20,000 Bushel	30,000 Bushel	40,000 Bushel	50,000 Bushel	60,000 Bushel	90,000 Bushel	120,000 Bushel
Building design:									
Storage bins:[a]				-Bushels-					
1	5,225	10,175	10,175	10,175	21,900	21,900	32,625	32,625	32,625
2			10,175	21,900	21,900	32,625	32,625	32,625	32,625
3								32,625	32,625
4									32,625
Total capacity	5,225	10,175	20,350	32,075	43,800	54,525	65,250	97,875	130,500
Building cost:					-Dollars-				
Bins	1,960	3,368	6,736	10,645	14,554	16,554	18,554	27,831	37,108
Assembly	418	814	1,628	2,108	2,588	3,904	5,220	7,830	10,440
Concrete floor	419	778	1,556	3,110	4,664	4,169	3,674	5,511	7,348
Flush floor aeration[b]	176	367	734	367	-	611	1,222	1,833	2,444
Ladders	88	88	176	88	-	133	266	399	532
Control pipe	105	165	330	165	-	213	426	639	852
Sub-total	3,166	5,580	11,160	16,483	21,806	25,584	29,362	44,043	58,724
Cost/bu.	.61	.55	.55	.51	.50	.47	.45	.45	.45
Equipment:									
Aeration fans	277	514	1,028	1,890	2,752	2,670	2,588	3,882	5,176
Unloading auger	226	431	862	431	-	520	1,040	1,560	2,080
Sweep auger	240	459	918	459	-	430	860	1,290	1,720
Portable auger	1,603	1,603	1,603	2,344	2,344	2,344	2,344	2,344	2,344
Sub-total	2,346	3,007	4,411	5,124	5,096	5,964	6,832	9,076	11,320
Cost/bu.	.45	.30	.22	.16	.12	.11	.10	.09	.09
Total Cost	5,512	8,587	15,571	21,607	26,902	31,548	36,194	53,119	70,044
Cost/bu.	1.05	.85	.77	.67	.62	.58	.55	.54	.54

[a]Capacity used is the dry weight capacity at eave height, but not coned.

[b]The 21,900 bushel bin has a coned floor. Aeration is included in previous costs and unloading and sweepaugers are not used.

APPENDIX TABLE 2

ANNUALIZED FIXED COST AND PER BUSHEL VARIABLE COST OF STORAGE SYSTEMS OF SELECTED SIZES.

	5,000 Bushel	10,000 Bushel	20,000 Bushel	30,000 Bushel	40,000 Bushel	50,000 Bushel	60,000 Bushel	90,000 Bushel	120,000 Bushel
					-Dollars-				
Capital investment	5,512	8,587	15,571	21,597	26,892	31,458	36,194	53,119	70,044
Fixed cost:									
Depreciation [a]									
Buildings	142.47	251.10	502.20	741.74	981.27	1,151.28	1,321.29	1,981.94	2,642.58
Equipment	234.60	300.70	441.10	511.40	508.60	596.40	683.20	907.60	1,132.00
Insurance [b]	33.07	51.52	93.43	129.58	161.35	189.29	217.16	318.71	420.26
Interest [c]	234.26	364.95	661.77	917.87	1,142.91	1,340.79	1,538.25	2,257.56	2,976.87
Taxes [d]	110.24	171.74	311.42	431.94	537.84	630.96	723.88	1,062.38	1,400.88
Repairs & maintenance [e]	55.12	85.87	155.71	215.92	268.92	315.48	361.94	531.19	700.44
Annual fixed cost	809.76	1,225.88	2,165.63	2,948.50	3,600.89	4,224.20	4,845.72	7,059.38	9,273.03
Variable cost: [f]					-Dollars per Bushel-				
Grain insurance	.011	.011	.011	.011	.011	.011	.011	.011	.011
Insect control	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022
Aeration [g]	.0015	.0022	.0022	.0022	.0022	.0031	.0025	.0025	.0025
Handling [h]	.0072	.0072	.0072	.0057	.0034	.0047	.0047	.0047	.0047
Weight loss [i]									
Shrink	.005	.005	.005	.005	.005	.005	.005	.005	.005
Invisible loss	.01	.01	.01	.01	.01	.01	.01	.01	.01
Variable cost	.0369	.0376	.0376	.0361	.0338	.0360	.0354	.0354	.0354

[a] Depreciation calculated at .045 and .10 of original capital investment for buildings and equipment, respectively.

[b] Insurance calculated at .006 of original capital investment.

[c] Interest calculated at .0425 of original investment.

-Footnotes continued on next page-

FOOTNOTES FOR APPENDIX TABLE 2. (continued)

[d]Property taxes calculated at .02 of original capital investment.

[e]Repair and maintenance calculated at .01 of original capital investment.

[f]See footnotes Appendix Table 16.

[g]See Appendix Table 19.

[h]See Appendix Table 21.

[i]See Chapter III, page 27.

APPENDIX TABLE 3

AVERAGE ANNUAL FIXED COST, VARIABLE COST AND TOTAL COST FOR ALTERNATIVE STORAGE SYSTEMS AT SELECTED UTILIZATION.

	5,000 Bushel	10,000 Bushel	20,000 Bushel	30,000 Bushel	40,000 Bushel	50,000 Bushel	60,000 Bushel	90,000 Bushel	120,000 Bushel
					-Dollars-				
Total fixed cost[a]	809.76	1,225.88	2,165.63	2,948.50	3,600.89	4,224.20	4,845.72	7,059.38	9,273.03
					-Dollars per Bushel-				
Average fixed cost:[b]									
50% utilization	.310	.241	.213	.184	.164	.156	.150	.146	.144
75% utilization	.210	.161	.142	.123	.110	.104	.100	.097	.096
100% utilization	.155	.120	.106	.092	.082	.078	.075	.073	.072
125% utilization	.124	.096	.085	.074	.066	.062	.060	.058	.057
Average variable cost[c]	.037	.038	.038	.036	.034	.036	.035	.035	.035
Average total cost:[d]									
50% utilization	.347	.279	.251	.220	.198	.192	.185	.181	.179
75% utilization	.247	.199	.180	.159	.144	.140	.135	.132	.131
100% utilization	.192	.158	.144	.128	.116	.114	.110	.105	.107
125% utilization	.161	.134	.123	.110	.100	.098	.095	.093	.092

[a] See Appendix Table 2.

[b] Average fixed cost is total fixed cost divided by respective bushels. Total bushels are multiplied by .50, .75, 1.00, and 1.25 to obtain bushels at various utilizations.

[c] Variable costs are estimated to be constant at all utilization levels.

[d] Average fixed cost plus average variable cost equals average total cost.

APPENDIX TABLE 4

COMPONENTS AND 1977 PRICES OF IN-BIN SYSTEM BUILDINGS.

	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Building design;						
Storage bins:[a]			-Bushels-			
1	6,040	6,040	10,900	21,900	21,900	21,900
2		10,900	10,900	21,900	21,900	21,900
3					21,900	24,800
4						24,800
Drying tank[b]	3,600	3,600	7,200	17,500	27,000	27,000
Total capacity	9,640	20,540	29,000	61,300	92,700	120,400
Building cost			-Dollars-			
Bins	$ 2,870	$ 7,299	$ 8,860	$ 14,554	$ 21,830	$ 31,161
Assembly	554	1,294	1,478	2,587	3,881	5,544
Hopper and concrete	968	2,728	3,520	4,664	6,996	9,328
Drying tank	2,667	2,667	4,474	8,082	12,082	12,082
Assembly	800	800	1,400	2,400	3,200	3,200
Concrete floor	400	400	720	1,920	2,800	2,800
Total investment	$ 8,259	$ 15,188	$ 20,452	$ 34,206	$ 50,788	$ 64,114
Cost/bushel	.86	.74	.71	.56	.55	.53

[a]Capacity used in this study is the dry weight capacity at eave height, but not coned.

[b]The drying tank is included as a storage cost since it may be used for a storage bin upon completion of drying.

APPENDIX TABLE 5

COMPONENTS AND 1977 PRICES OF IN-BIN CONTINUOUS FLOW SYSTEM BUILDINGS.

	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Building design:						
Storage bins:[a]			-Bushels-			
1	5,225	5,225	10,175	10,175	10,175	10,175
2		10,175	10,175	10,175	10,175	10,175
3				32,625	32,625	32,625
4					32,625	32,625
5						32,625
Drying tank[b]	5,040	5,040	8,245	8,245	8,245	8,245
Total capacity	10,265	20,440	28,595	61,220	93,845	126,970
Building cost:			-Dollars-			
Bins	$ 1,960	$ 5,328	$ 6,736	$ 16,016	$ 25,296	$ 34,576
Assembly	418	1,233	1,629	4,239	6,850	9,460
Concrete floor	419	1,198	1,557	3,394	5,230	7,067
Flush floor aeration	176	543	734	1,346	1,957	2,568
Hopper w/gate	50	110	122	182	243	304
Control rod & pipe	16	38	43	69	94	120
Underbin tube	40	122	165	291	418	544
Ladder	88	176	176	309	442	574
Drying tank[b]	2,274	2,274	3,381	3,381	3,381	3,381
Assembly	403	403	660	660	660	660
Concrete floor	419	419	778	778	778	778
Drying floor	450	450	748	748	748	748
Floor supports	332	332	528	528	528	528
Ladders	88	88	88	88	88	88
Total investment	$ 7,133	$ 12,714	$ 17,345	$ 32,029	$ 46,713	$ 61,396
Cost/bushel	.69	.62	.61	.52	.50	.49

[a]Same as Appendix Table 4.

[b]Same as Appendix Table 4.

APPENDIX TABLE 6

COMPONENTS AND 1977 PRICES OF CONTINUOUS FLOW SYSTEM BUILDINGS.

	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Building design:						
Storage bins:[a]			-Bushels-			
1	5,185	9,877	9,877	29,477	29,477	29,477
2	5,185	9,877	9,877	29,477	29,477	29,477
3			9,877		29,477	29,477
4						29,477
Drying tank[b]	-	720	680	3,020	3,020	3,020
Total capacity	10,370	20,474	30,311	61,974	91,451	120,928
Building cost:			-Dollars-			
Bins	$ 4,434	$ 7,108	$ 10,662	$ 16,680	$ 25,020	$ 33,360
Assembly	1,502	2,664	3,996	6,388	9,582	12,776
Concrete floor	1,244	1,980	2,970	6,880	10,320	13,760
Flush floor aeration	396	462	693	764	1,146	1,528
Install aeration	140	164	246	446	669	892
Ladders	134	158	237			
Control pipe	19	24	36	41	61	82
Total investment	$ 7,869	$ 12,560	$ 18,840	$ 31,199	$ 46,798	$ 62,398
Cost/bushel	.76	.61	.62	.51	.51	.51

[a]Same as Appendix Table 4.

[b]A wet holding tank which could be used for storage.

APPENDIX TABLE 7

COMPONENTS AND 1977 PRICES OF IN-BIN SYSTEM EQUIPMENT.

Equipment	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Aeration fans	$ 455	$ 1,143	$ 1,376	$ 2,753	$ 4,129	$ 5,505
Auger[a]	1,603	1,603	1,603	2,344	2,344	2,344
Total investment	$ 2,058	$ 2,746	$ 2,979	$ 5,097	$ 6,473	$ 7,849
Total bushels	9,640	20,540	29,000	61,300	92,700	120,400
Cost/bushel	.21	.13	.10	.08	.07	.07

[a]A portable 6" auger used to load trucks.

APPENDIX TABLE 8

COMPONENTS AND 1977 PRICES OF IN-BIN CONTINUOUS FLOW SYSTEM EQUIPMENT .

Equipment	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Aeration fans	$ 195	$ 583	$ 776	$ 1,622	$ 2,469	$ 3,315
Entrance collar	36	72	72	216	360	504
Transition	46	136	181	485	789	1,093
Powerhead	63	168	210	314	419	524
Unloading auger[a]	162	489	637	955	1,274	1,592
Sweep auger	108	130	107	294	480	666
Motor	96	198	205	448	691	934
Flighting	36	131	126	223	320	417
Portable auger[b]	1,603	1,603	1,603	2,344	2,344	2,344
Hopper and auger[c]		246	246	614	981	1,348
Motor		318	318	637	955	1,274
Total investment	$ 2,345	$ 4,074	$ 4,481	$ 8,152	$ 11,082	$ 14,011
Total bushels	10,265	20,470	28,595	61,220	93,485	126,410
Cost/bushel	.23	.20	.16	.13	.12	.11

[a]Include the motor to operate the unloading auger.

[b]Portable 6" or 8" auger to load trucks.

[c]Connecting auger between bins with hoppers to allow automatic filling of bins in the connection.

APPENDIX TABLE 9

COMPONENTS AND 1977 PRICES OF CONTINUOUS FLOW SYSTEM EQUIPMENT.

Equipment	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Aeration fans	$ 456	$ 918	$ 1,377	$ 894	$ 1,341	$ 1,788
Hopper, tube & auger	264	294	441	1,648	2,472	3,296
Install	70	70	105	646	969	1,292
Horizontal powerhead[a]	88	88	88	736	1,104	1,472
Motor	158	187	187	606	909	1,212
Sweep auger	101	115	115	2,046	3,069	4,092
Install	50	50	75	-	-	-
Motor	111	136	136	-	-	-
Leg[b]	-	-	-	7,189	7,189	7,189
Install	-	-	-	3,450	3,450	3,450
Spouting	-	-	-	514	691	868
Distributor	-	-	-	438	438	438
Install	-	-	-	414	414	414
Structural	-	-	-	4,835	4,835	4,835
Pit	-	-	-	4,000	4,000	4,000
Total investment	$ 1,298	$ 1,858	$ 2,524	$ 27,416	$ 30,881	$ 34,346
Total bushels	10,370	20,474	30,311	61,960	91,451	120,928
Cost/bushel	.125	.091	.083	.44	.34	.28

[a]The 10,000, 20,000, and 30,000 bushel systems are equipped with portable horizontal powerhead, while the 60,000, 90,000, and 120,000 bushel systems have permanent powerhead for each bin due to the large size.

[b]Elevator leg is added at 60,000 bushels and beyond and portable augers necessary for filling the dryers are used to unload bins in the 10,000, 20,000, and 30,000 bushel systems.

APPENDIX TABLE 10

COMPONENTS AND 1977 PRICES OF IN-BIN SYSTEM DRYERS.

Drying	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Heat unit[a]	$ 1,920	$ 1,920	$ 1,920	$ 3,888	$ 3,888	$ 3,888
Spreader[a]	108	108	521	777	844	844
Unloading auger	335	335	560	905	983	983
Total investment	$ 2,363	$ 2,363	$ 3,001	$ 5,570	$ 5,715	$ 5,715
Total bushels	9,640	20,540	29,000	61,300	92.700	120,400
Cost/bushel	.25	.12	.10	.09	.06	.05

[a]Equipment necessary to equip the drying tank.

APPENDIX TABLE 11

COMPONENTS AND 1977 PRICES OF IN-BIN CONTINUOUS FLOW SYSTEM DRYERS.

Drying	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Heat unit	$ 1,068	$ 1,068	2,136	$ 2,136	$ 2,136	$ 2,136
Entrance collar	36	36	36	72	72	72
Transition	97	97	97	194	194	194
Stirway	1,202	1,202	1,202	1,302	1,302	1,302
Down auger	147	147	147	147	147	147
Foreway	2,114	2,114	2,611	2,611	2,611	2,611
Foreway vertical	383	383	460	460	460	460
Transfer auger	456	456	456	456	456	456
Install[a]	-	-	320	320	320	320
Extension	102	102	102	102	102	102
Two-way valve	55	55	65	65	65	65
Motors	445	445	541	541	541	541
Heat sensor	168	168	168	168	168	168
Spreader	204	204	204	204	204	204
Total investment	$ 6,477	$ 6,477	8,778	$ 8,778	$ 8,778	$ 8,778
Total bushels	10,265	20,470	28,595	61,220	93,485	126,410
Cost/bushel	.63	.32	.31	.14	.09	.07

[a]Installation cost included in previous prices at the 10,000 and 20,000 bushel levels.

APPENDIX TABLE 12

COMPONENTS AND 1977 PRICES OF CONTINUOUS FLOW SYSTEM DRYERS.

Drying	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
Dryer[a]	$ 4,976	$ 4,976	$ 9,962	$ 14,635	$ 14,635	$ 14,635
Auger & motor[b]	2,181	2,395	2,395	-	-	-
Starters	537	587	587	-	-	-
Wet holding tank[c]	-	1,076	1,076	3,261	3,261	3,261
Assembly	-	268	468	981	981	981
Auger	-	1,259	1,259	-	-	-
Total investment	$ 7,694	$ 10,561	$ 15,747	$ 18,877	$ 18,877	$ 18,877
Total capacity	10,370	20,474	30,311	61,960	91,457	120,928
Cost/bushel	.74	.52	.52	.31	.21	.16

[a]Dryers are automatic for 10,000 and 20,000 bushel systems, and continuous flow column dryers for all other size systems.

[b]Two augers used to fill the dryer and then unload it into bins, automatically regulated by starters.

[c]Wet holding tanks necessary to allow storage of wet grain so dryer unit can keep up with the harvest rate.

APPENDIX TABLE 13

ANNUAL FIXED COSTS OF BUILDINGS FOR SELECTED FARM STORAGE AND DRYING SYSTEMS.

Buildings	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
			- Dollars -			
In-bin total cost[a]	12,680.00	15,188.00	20,452.00	34,206.00	50,788.00	64,114.00
Depreciation[b]	371.66	683.46	920.34	1,539.29	2,285.46	2,885.15
Insurance[c]	49.56	91.13	122.71	205.24	304.73	384.69
Interest[d]	351.02	645.49	869.21	1,453.77	2,158.49	2,724.86
Taxes[e]	165.18	303.91	409.25	684.47	1,016.27	1,282.93
Repairs & maintenance[f]	123.89	227.82	306.78	513.10	761.82	961.72
Total fixed cost[g]	1,061.35	1,951.81	2,628.29	4,395.87	6,526.77	8,239.35
Average fixed cost[h]	.11	.095	.091	.073	.072	.068
In-bin continuous flow total cost*	7,133.00	12,714.00	17,345.00	32,029.00	46,713.00	61,396.00
Depreciation*	321.05	572.18	780.52	1,441.31	2,102.98	2,762.86
Insurance*	42.81	76.29	104.07	192.17	280.28	368.38
Interest*	303.21	540.40	737.15	1,361.23	1,985.29	2,609.36
Taxes*	142.76	254.43	341.07	640.58	934.72	1,228.55
Repairs & maintenance[i]	178.36	317.88	433.62	800.73	1,167.82	1,534.92
Total fixed cost*	988.19	1,761.19	2,402.43	4,436.02	6,470.19	8,504.07
Average fixed cost*	.096	.086	.084	.072	.069	.067
Continuous flow total cost*	7,869.00	12,560.00	18,840.00	31,199.00	46,798.00	62,398.00
Depreciation*	354.11	565.20	847.80	1,403.96	2,105.91	2,807.91
Insurance*	47.21	75.36	113.04	187.19	280.79	374.39
Interest*	334.43	533.80	800.70	1,325.96	1,988.92	2,651.92
Taxes*	157.46	251.33	376.99	624.29	936.43	1,248.58
Repairs & maintenance[i]	196.73	314.00	471.00	779.98	1,169.45	1,559.95
Total fixed cost*	1,089.94	1,739.63	2,609.52	4,321.38	6,482.50	8,642.75
Average fixed cost*	.105	.085	.086	.070	.071	.071

See footnotes on following page.

Footnotes for Appendix Table 13.

[a]Refers to total investment cost of all buildings.

[b]Annual depreciation charge computed by straight line method over a 20 year uselife with 10 percent salvage value; the rate of 4.5 percent.

[c]Includes fire, lightning, wind, hail, and vandalism. Cost rate based on premium of $ 1.20 for every $ 100.00 value; .6 percent.

[d]Calculated at 8.5 percent of half the purchase price or 4.25 percent.

[e]Calculations based on 30 percent of market price at a millage rate of 66.7($ 66.70 per $ 1,000.00 valuation).

[f]Cost computed at 1.5 percent of the purchase price for the in-bin system with few moving parts.

[g]Total fixed cost is the sum of the fixed costs itemized above.

[h]Average fixed cost is total fixed cost divided by the actual bushel storage capacity of the respective system.

[i]Cost computed at 2.5 percent of the purchase price for both in-bin continuous flow and the continuous flow system since high levels of automation require greater maintenance time.

*See previous footnotes.

APPENDIX TABLE 14

ANNUAL FIXED COSTS OF EQUIPMENT FOR SELECTED STORAGE AND DRYING SYSTEMS.

Equipment[a]	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
			-Dollars-			
In-bin total cost	2,058.00	2,746.00	2,979.00	5,097.00	6,473.00	7,849.00
Depreciation[b]	205.80	274.60	297.90	509.70	647.30	784.90
Insurance	12.35	16.48	17.87	30.58	38.84	47.09
Interest	87.47	116.71	126.61	216.61	275.10	333.57
Taxes	20.58	54.95	59.61	101.99	129.52	157.05
Repairs & maintenance	30.87	41.19	44.69	76.45	97.09	117.73
Total fixed cost	357.09	503.95	546.68	935.31	1,187.85	1,440.32
Average fixed cost	.037	.025	.019	.016	.013	.012
In-bin continuous flow total cost	2,345.00	4,074.00	4,481.00	8,152.00	11,082.00	14,011.00
Depreciation[b]	234.50	407.50	448.10	815.20	1,108.20	1,401.10
Insurance	14.07	24.45	26.89	48.91	66.49	84.07
Interest	99.68	173.19	190.46	346.46	470.97	595.48
Taxes	46.93	81.54	89.67	163.12	221.74	280.36
Repairs & maintenance	58.64	101.88	112.04	203.80	227.04	350.28
Total fixed cost	453.86	788.56	867.20	1,577.49	2,144.04	2,711.31
Average fixed cost	.044	.039	.03	.026	.023	.021
Continuous flow total cost	1,298.00	1,858.00	2,524.00	27,416.00	29,777.00	31,474.00
Depreciation[b]	129.80	185.80	252.40	2,741.60	2,977.70	3,147.40
Insurance	46.49	11.15	15.14	164.50	178.66	188.84
Interest	55.17	78.97	107.27	1,165.18	1,265.52	1,337.65
Taxes	25.97	37.18	50.51	548.59	595.84	1,259.59
Repairs & maintenance	32.45	46.45	63.10	685.40	744.43	786.85
Total fixed cost	249.88	359.55	488.42	5,305.27	5,762.15	6,720.33
Average fixed cost	.024	.018	.016	.086	.063	.056

[a] See footnotes Appendix Table 13.

[b] Annual depreciation charges computed by straight line method over ten year uselife with zero salvage value.

APPENDIX TABLE 15

ANNUAL FIXED COST OF DRYERS FOR SELECTED STORAGE AND DRYING SYSTEMS.

Drying[a]	10,000 Bu.	20,000 Bu.	30,000 Bu.	60,000 Bu.	90,000 Bu.	120,000 Bu.
			- Dollars -			
In-bin total cost	2,363.00	2,363.00	3,001.00	5,570.00	5,715.00	5,715.00
Depreciation	236.30	236.30	300.10	557.00	571.50	571.50
Insurance	14.18	14.18	18.00	33.42	34.29	34.29
Interest	100.44	100.44	127.53	236.71	242.90	242.90
Taxes	47.29	47.29	60.00	111.45	114.36	114.36
Repairs & maintenance	35.45	35.45	45.01	83.45	85.73	85.73
Total fixed cost	433.73	433.73	550.64	1,022.03	1,048.80	1,048.80
Average fixed cost	.045	.021	.019	.017	.012	.009
In-bin continuous flow total cost	6,477.00	6,477.00	8,778.00	8,778.00	8,778.00	8,778.00
Depreciation	647.70	647.70	877.80	877.80	877.80	877.80
Insurance	38.87	38.87	52.67	52.67	52.67	52.67
Interest	275.30	275.30	373.65	373.65	373.65	373.65
Taxes	129.60	129.60	175.64	175.64	175.84	175.84
Repairs & maintenance	161.94	161.95	219.44	219.44	219.44	219.44
Total fixed cost	1,253.49	1,253.49	1,699.16	1,699.16	1,699.16	1,699.16
Average fixed cost	.122	.061	.028	.018	.018	.013
Continuous flow total cost	7,694.00	10,561.00	15,747.00	18,877.00	18,877.00	18,877.00
Depreciation	769.40	1,056.10	1,574.70	1,887.70	1,877.70	1,877.70
Insurance	46.15	63.37	94.48	113.26	113.26	113.26
Interest	326.40	448.81	669.25	802.27	802.27	802.27
Taxes	153.96	211.33	315.10	377.73	377.73	377.73
Repairs & maintenance	192.35	264.03	393.68	471.93	471.93	471.93
Total fixed cost	1,488.85	2,043.64	3,047.21	3,652.89	3,652.89	3,652.89
Average fixed cost	.144	.099	.101	.059	.04	.03

[a]See footnotes Appendix Table 14.

APPENDIX TABLE 16

AVERAGE VARIABLE COST OF STORING AND DRYING GRAIN FOR SELECTED 10,000, 20,000, AND 30,000 BUSHEL STORAGE AND DRYING SYSTEMS.

Variable cost	10,000 Bushel			20,000 Bushel			30,000 Bushel		
	In-Bin	In-Bin Continuous Flow	Continuous Flow	In-Bin	In-Bin Continuous Flow	Continuous Flow	In-Bin	In-Bin Continuous Flow	Continuous Flow
Insurance[a]	.011	.011	.011	.011	.011	.011	.011	.011	.011
Insect control[b]	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022
Aeration[c]	.0022	.0015	.0045	.0033	.0019	.0022	.0022	.0022	.0022
Handling:[d]									
Load-in									
Labor	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029
Electric	.00015	.0031	.0002	.00015	.0005	.0003	.00015	.0005	.0003
Load-out									
Labor	.0029	.0035	.0035	.0029	.0035	.0035	.0029	.0035	.0635
Electric	.00015	.0005	.0003	.00015	.0005	.0005	.00015	.0006	.0005
Total	.00610	.0072	.0069	.00610	.0074	.0072	.00610	.0075	.0072
Drying:[e]									
Fuel	.029	.025	.036	.029	.025	.036	.029	.025	.036
Electric	.0034	.0053	.0012	.0034	.0053	.0012	.0034	.0045	.0023
Labor	.0053	.0032	.0032	.0053	.0037	.0027	.0053	.0018	.0025
Handling	.0061	-	-	.0061	-	-	.0061	-	-
Total	.0438	.0335	.0404	.0438	.0340	.0399	.0438	.0313	.0408
Weight loss:[f]									
Shrink	.04	.04	.04	.04	.04	.04	.04	.04	.04
Invisible loss	.01	.01	.01	.01	.01	.01	.01	.01	.01
Total	.05	.05	.05	.05	.05	.05	.05	.05	.05

Footnotes on following page.

Footnotes for Appendix Table 16.

[a]Secures protection against loss of grain from wind, fire, and theft. Based on \$ .53 per \$ 100.00 of grain which is assumed to be valued at \$ 2.00 per bushel.

[b]Recommendation from entomologist to treat with malathion as a protectant. Computation based on one quart of malathion at \$ 4.38 which treats 2,000 bushels - cost is \$ .0022 per bushel.

[c]See Appendix 18.

[d]See Appendix 20.

[e]See Appendix Tables 22.

[f]Based on 2 percent shrink and .5 percent actual loss of grain valued at \$2.00 per bushel.

APPENDIX TABLE 17

AVERAGE VARIABLE COST OF STORING AND DRYING GRAIN FOR SELECTED 60,000, 90,000, AND 120,000 BUSHEL STORAGE AND DRYING SYSTEMS.

	60,000 Bushel			90,000 Bushel			120,000 Bushel		
Variable cost[a]	In-Bin	In-Bin Continuous Flow	Continuous Flow	In-Bin	In-Bin Continuous Flow	Continuous Flow	In-Bin	In-Bin Continuous Flow	Continuous Flow
Insurance	.011	.011	.011	.011	.011	.011	.011	.011	.011
Insect control	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022	.0022
Aeration	.0019	.0020	.0019	.0017	.0026	.0019	.0017	.0030	.0019
Handling:									
Load-in									
Labor	.0014	.0014	-	.0014	.0014	-	.0014	.0014	-
Electric	.0003	.0005	.0003	.0003	.0005	.0003	.0003	.0006	.0003
Load-out									
Labor	.0014	.0019	.0019	.0014	.0019	.0019	.0014	.0019	.0019
Electric	.0003	.0008	.0009	.0003	.0008	.0009	.0003	.0008	.0009
Total	.0034	.0046	.0031	.0034	.0046	.0031	.0034	.0047	.0031
Drying:									
Fuel	.029	.025	.036	.029	.025	.036	.029	.025	.036
Electric	.0034	.0045	.0023	.0034	.0045	.0023	.0034	.0045	.0023
Labor	.0026	.0018	.0011	.0027	.0018	.0011	.0026	.0018	.0011
Handling	.0034	-	-	.0034	-	-	.0034	-	-
Total	.0384	.0313	.0394	.0385	.0313	.0394	.0384	.0313	.0394
Weight loss									
Shrink	.04	.04	.04	.04	.04	.04	.04	.04	.04
Invisible loss	.01	.01	.01	.01	.01	.01	.01	.01	.01
Total	.05	.05	.05	.05	.05	.05	.05	.05	.05

[a]See footnotes on Appendix Table 16.

APPENDIX TABLE 18

CALCULATIONS OF ELECTRICAL COST PER BUSHEL FOR AERATION IN SELECTED STORAGE AND DRYING SYSTEMS

System	Horse Power Per 1,000 Bushels Capacity[a]	Connected Horse Power	Kilowatt Hours Consumed[b]	Electrical Cost[c]	Cost Per Bushel
In-bin w/stir					
10,000	.20	2	396	14.85	.00149
20,000	.25	5	990	37.13	.00186
30,000	.30	9	1,782	66.83	.00222
60,000	.267	16	2,168	118.80	.00198
90,000	.36	32	6,336	237.60	.00264
120,000	.40	48	9,504	356.40	.00030
In-bin					
10,000	.30	3	594	22.28	.00222
20,000	.45	9	1,782	66.83	.00334
30,000	.30	9	1,782	66.83	.00223
60,000	.25	15	2,970	111.38	.00186
90,000	.233	21	4,158	155.93	.00173
120,000	.225	27	5,346	200.48	.00167
Continuous flow					
10,000	.60	6	1,188	44.55	.00446
20,000	.30	6	1,188	44.55	.00223
30,000	.30	9	1,782	66.83	.00222
60,000	.25	15	2,970	111.38	.00186
90,000	.25	22.5	4,455	167.06	.00186
120,000	.25	30	5,940	222.75	.00186

Footnotes on following page.

Footnotes for Appendix Table 18

[a]Engineers recommend .25 HP/1,000 bushels for heavy aeration.

[b]Fans operated 33 hours per month for six months (198 hours). 1 Horsepower operated for 1 hour equals 1 Kilowatt hour of electricity consumed.

[c]At $0.0375 per Kilowatt hour.

APPENDIX TABLE 19

CALCULATIONS OF ELECTRICAL COST PER BUSHEL FOR AERATION

IN SELECTED STORAGE SYSTEMS

Aeration[a] Formula	Horse Power Per 1,000 Bushels	Connected Horse Power	Electrical Cost	Cost Per Bushel
System:				
5,000 bu.	.20	1	$ 7.425	$.00149
10,000 bu.	.30	13	22.275	.00223
20,000 bu.	.30	6	44.55	.00223
30,000 bu.	.30	9	66.825	.00223
40,000 bu.	.30	12	89.10	.00223
50,000 bu.	.42	21	155.925	.00312
60,000 bu.	.33	20	148.50	.00248
90,000 bu.	.33	30	222.75	.00248
120,000 bu.	.33	40	297.00	.00248

[a]See Footnotes from Appendix Table 18.

APPENDIX TABLE 20

CALCULATION OF PER BUSHEL HANDLING COST FOR SELECTED

STORAGE AND DRYING SYSTEMS

Formula	Receiving				Load-Out				TOTAL	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
System	Hrs. X	HP X	Elec[a] $.0375 per KWH	Labor[b] $3.50 per Hr.	Hrs. X	HP X	Elec[c] $.0375	Labor[c] $3.50 per Hr.	Total[d] Cost	Cost per Bushel
In-bin										
10,000	8.33	5	$ 1.56	$ 29.16	8.33	5	$ 1.56	$ 29.16	$ 61.44	$.0061
20,000	16.67	5	3.13	58.35	16.67	5	3.13	58.35	122.96	.0061
30,000	25.00	5	4.69	87.50	25.00	5	4.69	87.50	184.38	.0061
60,000	24.00	20	18.75	84.00	24.00	20	18.75	84.00	205.50	.0034
90,000	36.00	20	27.00	126.00	36.00	20	27.00	126.00	306.00	.0034
120,000	48.00	20	36.00	168.00	48.00	20	36.00	168.00	408.00	.0034
In-bin Continuous Flow										
10,000	8.33	10	3.12	29.16	10.00	13	4.50	35.00	71.78	.0072
20,000	16.67	15	9.38	58.35	20.00	13	9.75	70.00	147.48	.0074
30,000	25.00	15	14.06	87.50	30.00	16.5	18.56	105.00	225.12	.0075
60,000	24.00	30	27.00	84.00	33.33	37	46.25	116.66	273.91	.0046
90,000	36.00	35	47.25	126.00	50.00	37	69.38	175.00	417.63	.0046
120,000	48.00	40	72.00	168.00	37.00	37	92.05	233.35	565.40	.0047
Continuous Flow										
10,000	8.33	5	1.56	29.16	10.00	7.5	2.81	35.00	68.53	.0069
20,000	16.67	10	6.25	58.35	20.00	13.5	10.31	70.00	144.91	.0072
30,000	25.00	10	9.38	87.50	30.00	13.5	15.19	105.00	217.07	.0072
60,000	26.67	15	15.00	--	33.33	45	56.24	116.66	187.90	.0031
90,000	40.00	15	22.40	--	50.00	45	84.38	175.00	281.78	.0031
120,000	53.33	15	30.00	--	66.67	45	112.51	233.35	375.86	.0031

Footnotes for Appendix Table 20

[a]Electric Cost for loading-in grain is computed by:

Hr. x HP x $.0375 KWH = Electric Cost

where: Hr. = hours motors operate $\left(\frac{\text{Bushels loaded in}}{\text{Bushel per hour capacity of auger}}\right)$

HP = installed horsepower of motor

KWH = kilowatt hour

[b]Labor cost for loading-in grain is computed at a rate of $3.50 per hour.

[c]Load out costs are based on formulas in footnote a and b.

[d]Total cost is the sum of load-in and load-out operations electric cost and labor cost, respectively.

APPENDIX TABLE 21

CALCULATION OF PER BUSHEL HANDLING COST FOR SELECTED STORAGE SYSTEMS

Handling[a]	Receiving				Load-Out				TOTAL	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Formula System	Hrs. X	HP X	Elec. $.0375 per KWH	Labor $3.50	Hr. X	HP X	Elec. $.0375 per KWH	Labor $3.50 per Hr.	Total Cost	Cost per Bushel
5,000	4.17	10	$ 1.56	$ 14.60	5	13	$ 2.44	17.50	$ 36.16	$.0072
10,000	8.33	10	3.12	29.16	10	13	4.88	35.00	72.16	.0072
20,000	16.67	10	6.25	58.35	20	13	9.75	70.00	144.35	.0072
30,000	12.00	20	9.00	42.00	30	13	14.63	105.00	170.63	.0057
40,000	16.00	20	12.00	56.00	46	20	12.00	56.00	136.00	.0034
50,000	20.00	20	15.00	70.00	27.78	50	52.09	97.23	234.32	.0047
60,000	24.00	20	18.00	84.00	33.33	50	62.49	116.66	281.15	.0047
90,000	36.00	20	27.00	126.00	50.00	50	93.75	175.00	421.75	.0047
120,000	48.00	20	36.00	168.00	66.67	50	125.00	233.35	562.35	.0047

[a]See Appendix Table 20.

APPENDIX TABLE 22

CALCULATIONS OF PER BUSHEL DRYING COST FOR SELECTED

STORAGE AND DRYING SYSTEMS

Formula System	(1) lbs. of Water Removed	(2) BTU's to Evaporate 1 lb. water =	(3) BTU's Used (millions) ÷	(4) BTU's Hr. (millions) =	(5) Hr.s[a]	(6) Fuel[b]	(7) Electric[b]	(8) Labor[b]	(9) Handling[c]	(10) Drying Cost
							- Dollars per Bushel -			
In-bin										
10,000	65,882	1500	98.8	1.09	90.75	$.029	$.0034	$.0053	$.0061	$.0438
20,000	131,712	1500	197.6	1.09	181.42	.029	.0034	.0053	.0061	.0438
30,000	197,568	1500	296.4	1.09	272.13	.029	.0034	.0053	.0061	.0438
60,000	395,136	1500	592.7	2.18	272.13	.029	.0034	.0026	.0037	.0384
90,000	592,704	1500	889.1	2.18	408.20	.029	.0034	.0027	.0034	.0385
120,000	790,272	1500	1,185.4	2.18	544.26	.029	.0034	.0026	.0034	.0384
In-bin Continuous Flow										
10,000	65,882	1300	85.6	1.45	59.00	.025	.0053	.0032	--	.0335
20,000	131,712	1300	171.2	1.45	117.93	.025	.0053	.0037	--	.0340
30,000	197,568	1300	256.7	2.90	88.40	.025	.0045	.0018	--	.0313
60,000	395,136	1300	513.7	2.90	176.89	.025	.0045	.0018	--	.0313
90,000	592,704	1300	770.5	2.90	265.33	.025	.0045	.0018	--	.0313
120,000	790,272	1300	1,027.4	2.90	353.78	.025	.0045	.0018	--	.0313
Continuous Flow										
10,000	65,882	1850	121.9	2.96	41.23	.036	.0012	.0032	--	.0404
20,000	131,712	1850	243.7	2.96	82.43	.036	.0012	.0027	--	.0399
30,000	197,568	1850	365.5	2.96	123.64	.036	.0023	.0025	--	.0408
60,000	395,136	1850	731.0	6.9	106.03	.036	.0023	.0011	--	.0394
90,000	592,704	1850	1,096.5	6.9	159.05	.036	.0023	.0011	--	.0394
120,000	790,272	1850	1,462.0	6.9	212.07	.036	.0023	.0011	--	.0394

Footnotes for Appendix Table 22

[a]Hours to remove 10 points of moisture (25.5% to 15.5%) from grain weighing 56 pounds per bushel (e.g., grain sorghum and corn) is computed by the following steps:

Step 1 - Pounds of water removed

a) Wet bushels x weight per bushel = total weight

b) Total weight x $\frac{100 - \text{wet percentage}}{100 - \text{dry percentage}}$ = weight of dry grain

c) Total weight - weight of dry grain = Pounds of water removed

Step 2 - Total BTU's used

a) Pounds of water removed x BTU's required by dryer to evaporate 1 lb. of water = Total BTU's used

Step 3 - Hours to dry

a) Total BTU's used ÷ BTU's per hour of operation = Hours

where: BTU's per hour of operation based on various dryers operating temperatures. (120, 140, 200 F^{o} for the systems, respectively.)

[b]Formulas given page 26 of text.

[c]The in-bin system requires double handling of grain since the grain must be placed in the drying bin and removed, in addition to normal handling charges. This task is accomplished automatically by the equipment in other systems.

APPENDIX TABLE 23

TYPES OF FARM GRAIN DRYERS

1. Batch-in-bin - Add only narrow layers of grain (2-3 feet deep) to a bin drying system consisting of grain bin, a perforated floor, fan and heater. The warm air moves up through the grain evaporating moisture.

2. Batch-in-bin-stir dryer - Same drying components as batch-in-bin dryer. Stirring devices are vertical augers suspended from the top of the bin. These devices loosen the grain and aid airflow.

3. Low-temperature dryer - A bin drying system as above, except that they employ only enough heat to raise air temperature 20 to 40° F. The object of low temperature drying is to save energy by making use of the drying ability of the atmospheric air. In Kansas, temperatures and humidity conditions limit its feasibility.

4. Automatic batch - Grain is held between perforated steel columns and heated air is passed through the grain. When the grain is dry, unheated air is moved through the grain to cool it after which grain is conveyed to storage.

5. Continuous flow - Differ from automatic batch dryers by having a continuous flow of grain through the columns at a controlled rate and usually have the lower part of the dryer as a cooling section.

6. Oxygen-free and acid-treated - Methods of storing high moisture feed grains in an oxygen-controlled or acid-treated environment, respectively. The object is to preserve feed quality, protect essential nutrients and control fermentation. These systems are used mainly in conjunction with cattle feeding.

APPENOIX TABLE 24

WEIGHTEO AVERAGE MONTHLY PRICE OF KANSAS CITY NO. 1

HARO WINTER WHEAT FOR MARKETING YEARS 1967-1977.

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
	(Dollars per Bushel)											
1967-68	1.61	1.56	1.57	1.59	1.56	1.58	1.60	1.61	1.60	1.54	1.53	1.44
1968-69	1.37	1.35	1.34	1.40	1.42	1.40	1.41	1.40	1.40	1.39	1.39	1.35
1969-70	1.28	1.31	1.39	1.43	1.46	1.46	1.46	1.46	1.45	1.47	1.44	1.40
1970-71	1.38	1.47	1.59	1.58	1.59	1.59	1.58	1.58	1.55	1.56	1.61	1.63
1971-72	1.54	1.54	1.53	1.56	1.56	1.58	1.58	1.57	1.58	1.61	1.62	1.52
1972-73	1.58	1.82	2.10	2.15	2.25	2.62	2.67	2.48	2.42	2.51	2.63	2.69
1973-74	2.90	4.67	5.01	4.67	4.79	5.22	5.68	5.87	5.01	4.07	3.59	4.05
1974-75	4.36	4.33	4.35	4.94	4.88	4.66	4.15	3.93	3.69	3.66	3.34	3.23
1975-76	3.61	4.12	4.21	4.09	3.71	3.50	3.57	3.81	3.81	3.61	3.57	3.75
1976-77	3.63	3.21	3.01	2.77	2.62	2.64	2.70	2.73	2.63	2.52	2.36	2.31

SOURCE: U.S. Oepartment of Agriculture, Agricultural Marketing Service, Grain Oivision, Wheat Situation, Market News 8ranch (Washington, O.C., 1967-1977).

APPENDIX TABLE 25

WEIGHTED AVERAGE MONTHLY PRICE OF KANSAS CITY NO. 2

YELLOW SORGHUM FOR MARKETING YEARS 1967-1977.

Year	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
	(Dollars per CWT)											
1967-68	1.89	1.93	2.03	2.10	2.10	2.07	2.04	1.97	1.91	1.76	1.77	1.82
1968-69	1.91	1.89	1.94	1.93	1.92	1.96	2.00	2.02	2.06	2.09	2.08	2.08
1969-70	2.06	2.05	2.06	2.04	1.96	2.00	1.96	2.03	2.09	2.18	2.29	2.22
1970-71	2.12	2.27	2.37	2.35	2.32	2.41	2.46	2.58	2.53	2.25	1.91	1.80
1971-72	1.91	2.06	2.06	2.07	2.07	2.09	2.08	2.06	2.11	2.05	2.21	2.17
1972-73	2.42	2.88	3.06	2.88	2.86	2.83	3.09	3.61	3.93	4.72	4.37	4.37
1973-74	4.31	4.37	4.71	4.99	4.64	4.03	3.84	3.99	5.02	5.79	5.64	6.32
1974-75	6.10	5.70	4.95	4.55	4.48	4.64	4.60	4.53	4.82	5.13	4.66	4.53
1975-76	4.36	4.33	4.36	4.47	4.62	4.47	4.47	4.66	4.73	4.29	4.27	3.88
1976-77	3.43	3.77	3.91	3.85	3.75	3.62	3.53	3.28	a	a	a	a

SOURCE: U.S. Department of Agriculture, Agricultural Marketing Service, Grain Division, Feed Grain Situation, Market News Branch (Washington, D.C., 1967-1977).

[a]Data not available at time of analysis.

THE ECONOMICS OF FARM GRAIN STORAGE AND DRYING IN KANSAS

by

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B.S., Kansas State University, 1976

AN ABSTRACT OF A MASTER'S THESIS

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The objective of this study was to determine the costs of on-farm storage and drying of grain in Kansas. Buildings, equipment, and dryer components were combined to form systems of different sizes and types to achieve storage and storage/drying objectives. Selected dealers across Kansas provided the prices for each component which permitted computation of total investment outlay and subsequent ownership and operating costs.

The economic engineering approach was used to estimate the ownership and operating costs by analyzing the fixed and variable costs of each system. The fixed cost categories included depreciation, interest, insurance, taxes and repairs. The variable costs analyzed were grain insurance, insect control, aeration, handling, drying, and weight loss. Engineering data on normative operations and engineering formulas served as the basis for computing many of the above costs.

Results indicated that economies of size in investments for farm storage and drying caused reduced unit costs through 60,000 bushel size facilities. Hereafter, unit costs were steady due to the addition of equal size components with similar operating characteristics. The utilization rate of each system was observed to have significant impact on total costs. A large system used at less than full capacity has higher unit costs than a slightly smaller system used at full capacity.

The costs were computed separately for buildings, equipment, and dryers. Analysis of cost of these components showed that unit costs for equipment decrease at a faster rate than building costs, as storage facility size increases, since less equipment is required to store additional quantities of grain. The costs of various dryer types were observed to be directly related to the drying capacity of the unit, e.g. purchase of systems with fast-drying rates requires larger unit costs relative to slower dryers.

The costs of farm storage and drying were then related to potential income gains to farmers from the operation of on-farm storage and drying systems. Benefits were measured from a commercial storage comparison, appreciation of inventory due to seasonal price variations, and government programs.

The results indicated that farm storage was the least cost alternative when compared to commercial elevator charges for storage periods of 6-months or longer. The exact cost savings varied with system size and length of storage period. Cost savings from farm storage and drying were more prominent than only the storage function, relative to the commercial elevator option. Cost saving began when grain was dried and stored for 3-month periods.

Seasonal patterns in prices for wheat and grain sorghum for 1967-1977 were indicated by using the index of seasonal variation technique. The benefits that were obtained from storing wheat and grain sorghum from harvest to subsequent months having seasonally high prices were measured. They showed large variations for each month examined during the period with losses occuring occasionally. However, farmers could have profited 5 out of 10 years by selling wheat in December and 5 out of 9 years from sale of grain sorghum in July.

Government programs offer benefits to farmers from storing grain through commodity loan programs, storage and drying facility loans and direct storage payments. These benefits were measured and amounted to as much as 9 cents per bushel profit.