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ECONOMIC CONSIDERATIONS OF CORN HANDLING
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ECONOMIC CONSIDERATIONS OF CORN HANDLING AND STORAGE SYSTEMS USED ON MICHIGAN DAIRY FARMS

By

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ABSTRACT

ECONOMIC CONSIDERATIONS OF CORN HANDLING
AND STORAGE SYSTEMS USED ON MICHIGAN DAIRY FARMS

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A mail survey was sent to 9,000 Michigan dairy farmers to determine at what point farmers will change from artificially drying corn grain to high moisture corn or low moisture ear corn storage systems under rising energy costs. Total annual costs per bushel for harvesting and storage systems were calculated for volumes from 1,000 to 20,000 bushels.

Expectations of higher milk production and increased mechanization were the primary reasons to change storage systems. Rising energy costs were not important reasons to switch storage systems.

Cribs were the lowest cost storage system followed by bin dryers with stirrators, concrete silos, automatic and portable batch dryers and sealed storage units. Snapper heads were the most inexpensive harvesting systems followed by picker-shellers, pickers and 4 row combines. At annual inflation rates greater than 20% for energy inputs, dairy farmers can economically justify changing from artificially drying corn grain to high moisture corn storage systems.

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INTRODUCTION

The increased mechanization of American agriculture has resulted in a growing dependence on petroleum and petroleum based products. In recent years, there has been a significant trend towards artificially drying corn for grain instead of allowing the corn to dry in the field and harvesting as low moisture ear corn. Artificially drying corn has permitted an earlier harvest and a 10 to 15 percent increase in yields. Earlier harvest reduces field losses due to weather and insects, allows the use of high yielding "full season hybrids" and enables the farmer to operate his harvesting equipment under more ideal weather and crop conditions (American Society of Agricultural Engineers, 1978). Over 80 percent of the corn produced in the United States is artificially dried using heat (American Society of Agricultural Engineers, 1978). With increased mechanization, large acreages can be harvested faster as shelled corn instead of picking and storing in cribs.

Liquified petroleum (LP) gas, natural gas and fuel oil are the primary sources of heat in crop dryers (Economic Research Services, 1977). LP-gas refers primarily to the hydrocarbons propane and butane. Both occur in combination with underground deposits of natural gas and oil. They are extracted from natural gas and produced in production of crude oil. In 1975, 74 percent of total domestic LP-gas production came from natural gas processing plants and the balance was produced by oil refineries (National LP-Gas Association). Domestic propane production totalled 71.6 percent of the LP-gas production in 1975 (National LP-Gas Association). Due to undesirable physical properties, butane and propane-butane mixes are not utilized in agriculture. Approximately 90-95 percent of the fuel used in high temperature crop dryers was supplied by LP-gas (Council for Agricultural Science and Technology, 1977).

Dwindling stocks of American petroleum reserves have resulted in a growing dependence on foreign petroleum sources. According to a 1978 study, known natural gas and petroleum reserves will be depleted with 48 and 26 years, respectively, if consumption continues at 1977 rates (Energy Research and Development Administration, 1978). Although production agriculture accounts for only 3 percent of the United States energy consumption, it appears that increased mechanization could increase agriculture's energy needs (Economic Review, 1978). Rising energy costs due to limited supplies pose a serious threat to American agriculture.

More energy is consumed in corn production than in any other crop. In 1974 corn grain utilized an estimated 499.2 trillion BTU while its closest competitors, winter wheat and alfalfa, consumed 158.6 and 121.5 trillion BTU (American Society of Agricultural Engineers, 1978). A 1978 Michigan study reported 8.75 gallons of gasoline and 32.7 gallons of propane were used for plowing, planting, harvesting and drying grain for one acre of 100 bushel corn (Maddex and Bakker-Arkema, 1978).

Although supplies are limited, petroleum and natural gas prices are currently regulated by the Federal Government. Under regulated prices, gasoline and LP-gas prices rose 69 and 130 percent from 1973-1977 (Economic Review, 1978). When the ceilings are lifted, there could be dramatic price rises. Consequently, rising energy prices could force farmers to change corn harvesting and storage systems.

This study has three purposes:

1. To develop an economic framework in which a dairy farmer will be able to determine the total annual cost on a per bushel basis in constant dollars for alternative harvesting (e.g. corn picker, combine, snapper head) and storage systems (ear corn, dry shelled corn, high moisture corn) that are under consideration for implementation on his farm.

2. To determine, with rising energy costs, at what point it is economically feasible for dairy farmers to switch from artificially drying corn to high moisture corn systems.
3. Tabulation of the results of a survey sent to Michigan dairy farmers regarding corn harvesting, handling and storage systems being used on Michigan dairy farms. On the basis of survey results, projections will be made with respect to the point at which dairy farmers would be willing to change harvesting and storage systems.

LITERATURE REVIEW

There are many components which interact in the selection of corn grain harvesting and storage systems used on dairy farms. This review of literature analyzes the problems encountered in the selection of corn grain harvesting, storage and feeding systems for dairy farms. Economic and nutritional aspects of corn grain storage and feeding systems are included in the review.

Harvesting and Storage Systems

Several factors should be taken into consideration in the selection of a corn grain harvesting and storage system which is to be used on a dairy farm. The major considerations are volume of corn grain currently harvested and anticipated future volume of corn grain. Other factors include age and size of existing machinery and storage facilities, availability of labor and capital, total acreages of other grain crops and whether the grain will be sold or fed to livestock (Midwest Plan Service, 1968; Hoglund, 1965). The difference in field and storage losses between various harvesting and storage systems also affects the choice.

Harvesting systems are generally designed on the premise that there is a 90% probability that there will be 20-25 operating days. This calculation has been based on a normal 45-50 day fall harvest season after rainy days and Sundays have been subtracted. Normally, other crop harvesting, livestock feeding and machine breakdowns cut down the number of harvest days on many farms (Midwest Plan Service, 1968). Consequently, a 15-day operating system gives a realistic harvesting season for many farms.

By artificial drying, shelled corn can be harvested at moisture levels up to 30 to 35% compared to 20% for ear corn. This allows harvesting to begin two to three weeks earlier than for cribbing (Dum et al., 1978). Early harvest would tend to reduce the likelihood of harvest losses that are caused by lodging, fallen ears and harvest delay due to wet weather. Dum et al. (1978) reported that early harvest has potential savings of 5 to 15 bu per acre. The relationship between moisture content and harvest loss is shown in Appendix II.

Harvest Losses

In a study by Davis (1964) field losses for picking ear corn, under ideal conditions, were about 8%, whereas losses for high moisture shelled corn were three to four percent less. It was difficult to accurately estimate total field and harvesting losses because there were a variety of factors which influence them. Field losses included number of ears fallen to the ground before harvest and harvest losses.

In a study by Burrowtridge and Heopner (1965), several categories of harvest losses were reported. These included: machine ear loss which were ears of corn that were still attached to the stalk after harvest; loose kernel losses when kernels came from the snapping rolls, the racks, and the shoe; cylinder losses which were kernels left on the cob due to incomplete shelling; and invisible losses which have been defined to include chips of kernels and kernel tips which remain in the cob, scavenger losses due to the action of wildlife and maturity losses due to immature kernels. Harvesting losses were influenced by ground speed of the harvesting machine, skill of the machine operator, state of repair and adjustment of the machine, corn variety, insect infestations and stalk and weather conditions before and at the time of harvest. As moisture level decreases, machine harvesting losses increase (Johnson and Lamp, 1966).

Davis (1964) reported total field losses increased from 5.0% to 18.4% by delaying harvest from October to December.

Corn Storage Systems

Selection of a corn storage system for a dairy farm is greatly influenced by harvesting rate and annual volume. Shelled corn can be ensiled as high moisture corn in oxygen limiting silos, concrete stave silos or bunker silos. It can also be artificially dried and stored in grain bins or sprayed with proprionic acid or an acetic-proprionic mixture to prevent spoilage while stored in wooden or metal bins. Ear corn can be ground and stored as high moisture ear corn in silos or as low moisture ear corn in cribs.

There are a variety of drying systems that have been utilized on farms. According to Maddex (1966) daily volume was the most important factor in the selection of a drying system. Harvest delays were minimized by expanding drying facilities when the rate of harvest increased due to the utilization of larger harvesting equipment. Maddex (1966) stated a system's capacity was influenced by field conditions, moisture content of the corn, handling methods and down time. The rate of artificial drying depended upon temperature of drying air, humidity of the air, rate of air flow through the corn and to a lesser extent, the moisture content of the kernel.

Brooker et al. (1968) recommended moisture levels for dry shelled corn were as follows:

1. storage for 12 months or longer with no aeration, 13% moisture
2. storage for 10-12 months with aeration, 14-15% moisture
3. storage with aeration for less than 10 months, 15% moisture
4. short-term storage (3-5 months) with aeration, 15.5-16.0% moisture
5. winter storage (2-3 months) with aeration, 16.5-18.0% moisture

Recommended moisture levels for storage were based on adequate cooling of grain in the drying system and regular inspection of the grain (Maddex and Bakker, 1978; Midwest Plan Service, 1968).

Brooker et al. (1974) recommended aeration of stored grain with low airflow rates (1 cfm/bu) to maintain grain quality. Aeration serves to prevent moisture migration by maintaining uniform temperature throughout the grain mass and to cool the grain for minimizing mold and insect activities.

Corn Drying Systems

Dryers were categorized as batch in bin, automatic batch, continuous flow and low temperature bin dryers. Various degrees of mechanization have been added to bin drying systems. Brooker et al. (1974) classified bin drying systems into the additional categories of full bin, full bin with recirculators or stirrators, bin layer drying and batch in bin with recirculators or stirrators. In the batch system, grain was dried in one bin and transferred to another bin for storage. In the full bin system, the grain was usually stored in the drying bin. Batch in bin systems were developed for two reasons. Mechanical grain spreaders evenly distributed the grain and sweep and unloading augers quickly unloaded the bin.

According to Brooker et al. (1974) a batch in bin drying system operates under the following principles:

1. placing a layer of grain in the bin of not more than 3-4 feet,
2. forcing heated air (120-160 degrees F) through the grain until the desired moisture content of the batch is reached,
3. cooling the grain with the fan,
4. moving the grain to market or another storage bin.

Brooker et al. (1974) mentioned that grain recirculators can be used in either full bin or batch in bin systems. A recirculator consists of a sweep auger which removes grain from the drying floor at some preselected moisture content and elevates the grain through an enclosed auger to the top of the bin or to another bin where it is cooled. Recirculators eliminate over-drying of the grain closest to the drying floor.

Schwart and Hill (1977) indicated the advantages and disadvantages of batch in bin systems are as follows:

Advantages:

1. Drying bins may vary from 18' to 48' diameter with a variety of dryer units.
2. It allows flexibility in harvest schedule.
3. The bin may be used for storage at the end of the season.

Disadvantages:

1. The grain at the bottom may be 3-5% drier than the grain at the top.
2. Operators may over-dry a portion of the batch to be sure that all the grain is sufficiently dry.
3. The system operates 24 hours a day and requires supervision beyond normal working hours.
4. The grain must be handled at least twice, and this can seriously damage grain that is over dried.

Stirrators (augers) were used in batch in bin and full bin dryers to eliminate the problem of over-drying and to break up areas where wet grain may be packed. Stirrators reduce the moisture gradient in the bin by moving dry corn near the drying floor to the top of the bin so that the drying capacity is increased.

A major problem of stirrators in batch in bin systems is the possibility of mechanical malfunction.

Additionally, the stirrators take up 1-1½ rings of the bin which may not be used for drying (Brooker et al., 1974).

An alternative to bin drying systems was the use of automatic batch or continuous flow dryers. In both systems, the corn was dried by forcing large amounts of heated air (200^{+} degrees F) through the grain until average moisture level in the grain reached the desired level. In continuous flow dryers, wet and dry grain was constantly flowing through the system. Both systems were easily moved and could be operated on a 24-hour a day basis with minimal supervision. By including a large holding bin for wet corn into the system, flexibility in the amount harvested each day was gained. Brooker et al. (1974) indicated that automatic batch systems automatically transferred the batch of dried grain from the dryer into a storage bin when drying was completed. Then a batch of wet corn was automatically conveyed into the system to begin drying. Thus in an automatic batch system, the grain handling equipment was operated intermittently.

Low temperature drying is a recent innovation to reduce energy requirements for artificial drying. Air temperature was increased 10 degrees F. or less by electric heaters and was blown through a full bin of corn whose moisture levels were 24% or lower. The drying period was extended over 30 to 50 days. Low temperature drying is practical only in those geographic regions where the average daily temperature during harvest is between 30 and 50 degrees F. and moisture content of the grain is 24% or lower (Brooker et al., 1974). It appears that low temperature systems are not applicable to Michigan farms because a majority of the shelled corn is harvested in the 25 to 30% moisture range. If farmers wait for the corn to field dry to 24%, they significantly increase the chances of losing the crop due to harvesting under adverse weather conditions.

Low Moisture Ear Corn

Johnson and Lamp (1966) recommended that ear corn be harvested at moisture levels of 20% to reduce the chances of spoilage in the crib. Wiggans and French (1958) reported that ear corn could be safely stored at moisture levels up to 35% in cribs 4.5 feet wide and 8 feet high. They cautioned that, when cribs are wider or higher, it would be safer to crib the corn at moisture levels under 30%.

High Moisture Corn Storage Systems

Ensiling high moisture corn provides an alternative method of storage. High moisture corn (HMC) is fed as either high moisture ear corn (HMEC). HMEC must be ground before being stored in any type of structure (Merrill, 1971).

In order to successfully ensile high moisture grain, the handling and storage system must provide conditions which exclude or minimize oxygen penetration, prevent mold growth and protect against the weather (Merrill, 1971). Once these conditions are met, the grain can be successfully stored in oxygen limiting structures (sealed storage), conventional concrete silos or horizontal silos (Merrill, 1971).

Harvesting, storing and feeding high moisture grain have recently been reviewed by Merrill (1971). The most generally recommended moisture levels for harvesting, storing and feeding high moisture corn are as follows:

Moisture levels	HM shelled corn % moisture	HM ear corn % moisture
average	28	33
range	25-30	30-35
limits	25-35	28-40

The cob raises the moisture content of HMEC about 5% higher than for HMSC because it comprises about 20% of the dry matter in the corn ear (Merrill, 1971).

Merrill (1971) indicates that the upper limits are based on the desirability of having corn dry down to the point of reaching physiological maturity, which is attained at approximately 35% kernel moisture. This achieves maximum dry matter yield per acre and allows the chemical composition to reach the levels which are typical for mature grain. A final point to consider is high moisture levels can cause bridging in sealed silos and heating in conventional silos (Merrill, 1971).

If the moisture content is below recommended levels the corn might not ferment. Molding and heating are likely to occur due to the poor packing at the low moisture levels (Fox, 1976). Davis (1964) recommended that corn harvested below 24% for ensiling in a conventional silo and 22% for sealed storage should have water added to insure safe storage. In addition, he noted that water added to kernels that are ground, cracked or rolled will be more readily absorbed. Water should be added prior to ensiling so that the excess may drain off.

Dum et al. (1978) stated that management is the key to successful storage in conventional silos. Although it has been reported that whole kernel storage has been successful in conventional silos, McGuffey and Hillman (1976) recommended that HMSC be ground before storage. Grinding facilitates packing and reducing mold and spoilage by excluding air from the ensiled grain.

Dum et al. (1978) reported that grinding increased storage capacity up to 14% in concrete and horizontal silos. According to Stevenson (1975), conventional tower and horizontal silos should be filled as rapidly as possible to minimize exposure to the air. It was recommended that plastic or caulking be placed around the doors in concrete silos to minimize oxygen seepage into the structure (Otterby and Hutjens, 1978). Dum et al. (1978) suggested that silage distributors be used to prevent separation of kernels, fines and cob. A more uniform density expedites unloading and enhances fermentation, consequently reducing spoilage. Upon completion of filling concrete and horizontal silos, the tops should be covered with plastic to reduce spoilage (Dum et al., 1978).

It is difficult to precisely determine storage losses for a silo because the losses are influenced by rate of fill, moisture content of the corn, silo condition and rate of unloading. Storage losses on a dry matter basis for sealed storage, concrete silos and horizontal silos are listed as follows:

Sealed Storage % D.M. loss	Concrete Silo % D.M. loss	Horizontal silo % D.M. loss
4.17 (Baker, 1969)	7.0 (Chandler et al., 1975)	15 (Knoblaugh et al., 1978)
5.0 (Knoblaugh et al., 1978)	8.0 (Knoblaugh et al., 1978)	
6.0 (Hoffman and Self, 1975)	12.5 (Hoffman and Self, 1975)	
9.0 (Logan and Hillman, 1975)	13.0 (Logan and Hillman, 1975)	

Sealed storage for HMC offers several advantages over concrete and horizontal silos. HMSC can be stored whole and does not have to be ground or rolled prior to ensiling (Merrill, 1971). Thus harvest rate is not affected by the capacity of the conditioning units. HMC, whose moisture content is several percentage units above or below the recommended moisture levels, can be safely stored, thus allowing for extended harvest periods (Davis, 1964). Fox (1976) stated that minimum daily amounts of HMSC did not have to be removed to prevent spoilage. Thus, a farmer had the option to vary rations depending on the amounts and types of forages that are available throughout the year.

Fox (1976) stated that before switching to a HMC storage system, a dairyman should consider the limitations of HMC systems. The moisture level of the corn must be carefully monitored at harvest to minimize harvest and storage losses. Dum et al. (1978) reported that TDN yield per acre can be reduced by 10 to 12% when HMSC is fed instead of HMEC. Sometimes, extra equipment must be acquired to handle HMC. For example, HMEC must be ground before ensiling regardless of storage system (Merrill, 1971).

Stevenson (1975) recommends that dairymen consider several management factors when using concrete or horizontal silos. These include rapid fill, grinding before storage, good packing, careful coverage of ensiled grain and an adequate feeding system once the structure is opened to avoid spoilage and molding. Top spoilage in concrete and horizontal silos can be great if an adequate amount is not fed daily (Otterby and Hutjens, 1978). When designing HMC systems for concrete and horizontal silos, a dairyman needs to balance the number of animals, the silo diameter and the amount fed to minimize spoilage losses (Merrill, 1971). This can be a problem in warm weather. It is recommended that 4-6 inches be removed daily from the exposed silo face during the summer, while in the winter the removal rate may be reduced to 2-3 inches per day (Fox, 1976).

In the past several years, much interest has focused on using proprionic acid or acetic-proprionic acid mixtures as a method of preserving HMSC. The acid kills fungi, inhibits further growth of microbes almost indefinitely and prevents germination of the grain (McGuffey and Hillman, 1976). The amount of acid required to preserve the corn depends on the moisture content of the corn and the length of storage. Saur (1973) reported that 16-24 pounds of proprionic acid are required for a ton of 30% moisture corn (HMSC) compared to 6-12 pounds of 18% HMSC. Jorgensen et al. (1975) recommended that the acid should be applied at the higher level for a recommended moisture level to insure sufficient coverage if the grain and acid was not thoroughly mixed. Unless the grain is treated within several hours after harvest, it will start to heat and spoil.

One of the major advantages of acid treated corn is that it is a temporary storage system for HMC that is to be fed to livestock (Schwart and Hill, 1977). Unlike HMC ensiled in silos, acid treated corn can be mixed with large batches of feed during warm weather and then fed several hours later without the risk of spoilage (McGuffey and Hillman, 1976). Since the acid is corrosive, the life of metal grain bins and handling equipment is reduced (Campbell, 1972).

Trends in Corn Harvest and Storage Systems

The Michigan Crop Reporting Service has conducted several mail surveys from 1970-1977 on corn harvesting and marketing on Michigan farms. Combine harvesting has increased from 45% in 1970 to 70% in 1977 while the use of mechanical corn pickers has dropped from 42% in 1970 to 21.7% in 1977. The use of field picker-shellers has remained nearly constant at 8%. As acreage increased, larger farms tended to harvest more of the crop with combines. The surveys grouped corn cribs and storage bins into the same category, thus it was impossible to determine the number of corn cribs that are still in use. In the earlier surveys, no distinction was made between HMEC and HMSC storage. Thus, it was impossible to establish trends in the handling of HMC on Michigan farms.

Nutritional Aspects of Ear Corn, Dry Shelled Corn and High Moisture Corn

The composition of dry ear corn and dry shelled corn as specified in the Nutrient Requirements of Dairy Cattle (1978) are as follows:

	Ground Corn Cob	U.S. No. 2 54 lb/bu
Dry Matter %	87.0	89.0
N.E. for Lactating Cows Mcal/kg	1.84	2.03
Crude Protein %	9.30	10.0
Calcium %	0.05	0.03
Phosphorous %	0.26	0.31
Crude Fiber %	9.0	2.0

Due to the presence of the cob in ground ear corn, net energy, and crude protein are lower than in shelled corn. The major advantage of feeding low moisture ear corn is the increased fiber in the diet. The value of the cob as a means of increasing the fiber level in the diet should be considered in low fiber rations.

High Moisture Corn Feeding Trials

Numerous feeding trials have studied the effect of HMC vs dry shelled corn (DSC) on butterfat levels, milk production, dry matter intakes and solids not fat composition of milk. Several researchers have shown no differences in milk production from HMSC (Chandler et al., 1975; Clark and Harshbarger, 1972; Clark et al., 1975; Harshbarger, 1961; Lassiter et al., 1960), HMEC (Harshbarger, 1961; Lassiter et al., 1960) or DSC (Clark and Harshbarger, 1972) on a dry matter basis. Harshbarger (1961) reported that feeding HMEC did not affect dry matter intakes or butterfat levels. When compared to DSC on a dry matter basis, HMSC did not affect butterfat levels (Chandler et al., 1975; Clark and Harshbarger, 1972; Clark et al., 1975; Harshbarger, 1961; Hansen et al., 1959) and solids not fat composition of milk (Clark and Harshbarger, 1972; Clark et al., 1975).

On the other hand, studies by McCafree (1968) and Palmquist (1970) have shown that feeding HMSC causes a butterfat depression. In McCafree's experiment, HMSC, HMEC and DSC were supplemented with soybean meal while hay, corn silage and grass silage were fed ad libitum. In all groups, dry matter intakes were low but were significantly decreased for the HMSC group. The lowest forage dry matter intakes occurred very near the week of maximum dry matter intakes and peak production. It appeared that increases in milk production could be accounted for by the increased net energy concentration in the ration which was a result of the slightly increased concentrate to forage ratio. In the Palmquist study (1970), equal parts of hay, 32% dry matter corn silage and HMSC were fed on an as fed basis. Palmquist concluded that liberal feeding of high quality forage and limiting HMC to less than one third of the total dry matter intake may help alleviate the problem of milk fat depression. Macleod et al. (1973) observed in Canadian studies that severe milk fat depression with HMSC is only likely when 50 percent or more of total ration dry matter is from concentrates.

Several researchers have compared DSC and proprionic acid treated HMSC on a dry matter basis and have concluded that feeding acid treated corn does not affect milk production (Clark et al., 1975; Clark and Harshbarger, 1972; Jones, 1972; Forsyth et al., 1972; Jorgensen et al., 1975), butterfat (Clark et al., 1975; Clark and Harshbarger, 1972; and Macleod et al., 1973), dry matter intakes (Clark et al., 1975; Forsyth et al., 1972; Macleod et al., 1973) or solids not fat composition of milk (Clark et al., 1975).

HMC can be successfully integrated into rations for lactating cows if its use is carefully monitored. When switching from a balanced commercial feed to HMC, the dairyman must understand the cow's nutritional requirements and how HMC will fulfill some of these needs.

Several precautions must be taken when feeding HMC. HMC is a palatable feed and when it is fed in the bunk some animals may over consume HMC at the expense of other feeds (Otterby and Hutjens, 1978) and become over conditioned. Protein and mineral supplementation (calcium, phosphorous) may be required in order to meet nutritional requirements (Merrill, 1971). Otterby and Hutjens (1978) recommended grinding HMSC before feeding because 10-20% of the kernels pass through undigested unless the corn is ground before feeding. Clark et al. (1975) reported increases in milk production of approximately two kilograms per day when HMSC was rolled prior to feeding. Over feeding should be avoided because high intakes of HMC may cause over conditioning and butterfat depressions. Fiber levels should be maintained at levels of 15% or higher of dry matter intakes to reduce the incidence of butterfat depression (Hillman et al., 1975). If butterfat depression continues, feeding sodium bicarbonate or magnesium oxide may help alleviate the problem (Otterby and Hutjens, 1978).

Goodrich and Meiske (1976) reported that beef cattle fed highly fermented rations consisting of wet corn silage or corn silage plus HMC may put animals under acid stress and lower performance. From this study it appears that high acid feeds caused reduced feed intakes. Fox (1976) reported that excessive fermentation occurs at moisture levels that are higher than the recommended levels. This resulted in increased energy loss during storage and increased protein breakdown.

High Moisture Corn Rations

Otterby and Hutjens (1978) reported several ways HMC can be incorporated into the ration. In some herds, a constant amount of HMC was fed to all cows as a "top dress" to the grain mix in order to supply additional energy to high producing cows. This method can result in excessive energy levels in the ration for cows late in lactation which can cause over conditioning and the problems of the fat cow syndrome. Cows should be split into groups and fed the additional HMC on the basis of production and body condition. A second method was mixing HMC with protein, minerals and vitamin supplements to provide a complete grain mix. A fourth method is mixing HMC with supplements and forages and feeding as a complete ration. Blending and feeding HMC should take place as soon as possible after removal from the silo to reduce heating and spoilage. Heating may become a problem in hot humid weather. The use of 0.1%-0.2% sodium proprionate or a commercial mold inhibitor may be used if heating or spoilage problems occur (Otterby and Hutjens, 1978). Mixing supplements containing urea with HMC can result in palatability problems if not fed immediately after mixing because of ammonia release from the urea (Dum et al., 1978; Merrill, 1971; Otterby and Hutjens, 1978; and Snyder, 1968).

Palatability is the keystone of all feeding programs.

Moldy HMC will be rejected by many dairy cows and this could result in decreased feed intakes. Lynch et al. (1970) reported that under field conditions, high intakes of HMSC produced symptoms of tetany in lactating dairy cows. Attempts to reproduce these symptoms were unsuccessful.

Theoretically, feeding HMSC will result in higher energy intakes compared to HMEC because of the absence of the cob. The premise that absence of the cob will allow more space in the digestive tract for consumption of other feeds to achieve a higher total energy intake and consequently increased production has not been supported by the results of feeding trials (Merrill, 1971). However, the cob appears to be useful in helping maintain a minimum of 15% fiber level in the ration where forage dry matter and crude fiber intakes may be minimal. After reviewing the literature on feeding HMSC, HMEC, and proprionic acid treated HMC; it appears to the author that on a dry matter basis one pound of dry shelled corn equals one pound of HMEC or HMSC or proprionic acid treated HMC.

Cost Analysis

Costs were broken down into two categories: fixed and operating. Fixed or annual costs are defined to include depreciation, interest on investment, insurance, repairs, taxes and housing. Operating or variable costs fluctuate with amount of use and include fuel, oil and operating supplies.

Ritchey et al. (1961) calculated total repair costs as a percentage of new costs for various farm implements. These costs were derived from a review of literature and from farm surveys in various states. Interest, housing, taxes and insurance can be expressed by a fixed annual charge as follows:

	Cost per year for each $100 value
Interest	5.00
Housing	1.60
Taxes	2.00
Insurance	.40

Ritchey et al. (1961) noted that expressing all costs as a percentage of new cost has the advantage that data for various sizes of machines was not needed. Thus, repair costs were calculated as a percentage of the new investment cost. Ritchey et al. (1961) estimates of repair costs are widely used as a basis to approximate the fixed and operating costs of new farm machinery.

Schwart and Hill (1977) calculated the cost of ownership and repairs on a per hour basis as a percent of the list price. The cost of ownership and repair per hour are based on the assumed number of years of use and assumed annual hours of use. Fuel requirements are determined by

multiplying P.T.O.H.P. X .069 for gasoline
.0504 for diesel
.0823 for L.P. gas

Economic Analysis of Drying and Storage Systems

Casler (1975), Madsen et al. (1978), Schwart and Hill (1977), Davis (1964), Speicher (1965) and Burrowbridge and Heopner (1961) studied the economics of on the farm drying and storage systems for corn grain. In the studies, fixed costs were estimated as a percentage of purchase price. In each analysis, operating costs were calculated by making assumptions on drying times, operating efficiencies and prices of energy inputs. Speicher (1965), Madsen et al. (1978), Schwart and Hill (1977) and Davis (1964) determined total annual costs of storage systems on the basis of 20-year planning periods. Mechanical components of the storage systems and harvesting equipment were replaced at 10-year periods. Casler (1975) used an eight-year planning interval for the storage system. Burrowbridge and Heopner (1961) capitalized storage systems over 30 years while harvesting equipment were replaced at 10-year intervals.

Davis (1964) and Speicher (1965) calculated the total annual costs for the following harvesting and storage systems: full bin dryer, portable batch dryer, cribs, 1- and 2-row pickers, 2-row picker-sheller, 2-row combine, concrete silo and metal grain bins. Burrowbridge and Heopner (1961) analyzed total annual costs for 1- and 2-row pickers, 2-row combine, portable batch dryer, cribs and metal bins. Field losses were included in the total annual costs of harvest systems.

The 1961 Virginia study (Burrowbridge and Heopner, 1961) concluded that full bin dryers were the least cost alternative for volumes under 10,000 bushels while portable batch dryers were the most economical for volumes greater than 10,000 bushels. The study reported that farms with less than 60 acres of corn and 180 acres of grain crops would be best suited to using a 1-row picker and custom harvesting the grain. On farms with more than 250 acres of corn and grain crops, owning and operating a combine would be the most economical system.

The results of the Burrowbridge and Heopner (1961) study may be limited in value. Labor and capital were valued on the basis of the rate they would earn if utilized elsewhere on the farm. This may tend to enlarge the competitive advantage of custom hiring and diminish investment in harvesting and storage facilities. This study assumed custom hiring as an alternative would be available for all farms. This assumption may not be factual. Secondly, full bin drying and high moisture corn facilities were not analyzed in the study.

Davis (1963) in an Illinois study concluded that cribbing ear corn was the least cost system for volumes less than 4,400 bushels while HMSC in concrete silos was the most economical system for 4,400 to 22,000 bushels. Batch in bin drying systems provided an alternative to high moisture corn systems with higher annual costs ranging from $1.12 to $4.89 per 100 bushels, picker-sheller units were most economical while combines were the least expensive at the higher volumes (Davis, 1964).

Speicher (1965) noted in a Michigan study that dairymen should not compare ear corn and shelled corn on an equal nutritional basis because of the energy value of the cob in the ration. He suggested annual costs of harvesting, handling and processing be calculated on a per cow rather than a per bushel basis. This would be more meaningful when the entire crop is to be fed to the dairy enterprise.

The Michigan study (Speicher, 1965) concluded that for volumes below 17,600 bushels a picker-sheller was the least cost harvesting system while over 17,600 bushels a combine was the most economical system. HMSC harvested with a picker-sheller and stored in a concrete silo was the least cost method of harvesting and storing 4,400 to 22,000 bushels. HMEC harvested with a picker-grinder and stored in a concrete silo was the next lowest cost harvesting and storage system. The difference between the two systems for 4,400 to 22,000 bushels ranged between $2.88 and $3.39 per hundred bushels. A comparison of HMSC harvested by picker-shellers and stored in concrete silos and full bin drying systems indicated higher costs for the dried corn which ranged from $3.52 to $7.80 per hundred bushels for 4,400 to 22,000 bushels. Speicher (1965) noted that HMEC stored in concrete silos was the highest profit system for harvesting and storage on dairy farms. The energy furnished by the corn allows a greater number of cows to be fed from the same corn crop compared to HMSC.

A 1977 Illinois study (Schwart and Hill) compared total annual costs on volumes of 5,000 to 100,000 bushels for the following systems: batch in bin dryer, batch in bin stir dryer, low temperature dryer, gas tight silo, acid treated bin storage, low moisture ear corn in crib and local elevator. Ear corn was competitive under 5,000 bushels. The higher field losses as a result of a delayed harvest make it more costly than other systems for larger volumes.

The Illinois study (Schwart and Hill, 1977) concluded that batch in bin systems were the least expensive storage systems for volumes between 10,000 to 80,000 bushels per year. At volumes greater than 60,000 bushels, automatic batch and continuous flow dryers became comparable with bin drying systems. Acid treated corn was competitive with other systems for volumes up to 10,000 bushels. The corrosive action of the acid reduced the life of metal bins by about one half which increased storage costs. The major cost was the acid which increased operating costs above other storage systems. The difference in cost between the acid treated corn and the least cost storage system for 5,000 to 100,000 bushels ranged from $.80 to $1.00 per hundred bushels.

A 1978 Minnesota study (Madsen et al.) considered the following drying systems: continuous flow dryer, automatic batch dryer, batch in bin, high/low temperature continuous flow, high/low temperature automatic batch, dryeration continuous flow and dryeration automatic batch.

In combination high temperature-low temperature systems, corn is discharged from the dryer when it is hot at approximately 22% into a drying bin (Madsen et al., 1978). The corn is cooled in the drying bin which reduces the moisture content 1%. Drying is completed in the drying bin using either natural air or air heated to increase its temperature several degrees above natural air temperature. In dryeration systems, the corn is discharged hot from a high temperature dryer to a bin where it steeps for 8 to 10 hours. The corn is then cooled with an airflow of 1 c.f.m. per bushel and transferred to storage (Madsen et al., 1978).

Madsen et al. (1978) assumed the dollar was declining in value throughout the period of the analysis. The nominal costs for each year were adjusted for inflation in that year to arrive at constant dollar cost. All costs subject to inflationary pressures were considered on the basis of prices for the beginning year of the analysis. The costs were grouped into the following categories:

1. Costs that were not influenced directly by the inflation rate because they were based on prices negotiated at a specific time.
2. Costs that were subjected to inflationary pressures.
3. Costs that were affected by electricity prices.
4. Costs that were subject to yearly changes in propane prices.

Examples of these costs are as follows:

Category 1	Category 2	Category 3	Category 4
Initial down payment	Payments for Replacement Parts	Electricity	Propane
Finance payment	Insurance Premium		
Income Tax Deduction			

In the Madsen et al. (1978) analysis, alternative energy price scenarios with a 7% inflation rate are listed as follows:

	Modest	Significant
Rate of electric price increase	.08	.09
Rate of propane price increase	.08	.12

On farms with volumes of 10,000 bushels, the low temperature systems had lower cost of $.03 per bushel over batch-in-bin systems under modest energy price increases.

This advantage increased to $.05 per bushel over automatic batch dryers with significant energy price increases (Madsen et al., 1978).

Madsen indicated as volumes increased to 20,000 and 40,000 bushels, batch in bin and automatic batch dryers had savings of $.004 and $.012 per bushel over low temperature systems for modest energy price increases. However, under significant energy price increases, the low temperature system saved $.015 and $.002 per bushel over automatic batch dryers for 20,000 and 40,000 bushels. The least cost system for farms with 60,000 bushels or more was the dryeration continuous flow dryer (Madsen et al., 1978).

Madsen et al. (1978) concluded as energy prices increase propane and electricity become an increasingly larger proportion of total annual costs. As energy prices increase, savings on fuel costs were realized by systems which rely on grain aeration for moisture removal during part of the drying operation.

Low temperature systems offer farmers savings in total annual costs through the use of cheaper energy inputs for volumes under 60,000 bushels (Madsen et al., 1978). Schwart and Hill (1977) noted that moisture contents above 24% were not recommended for low temperature drying systems. Field losses increase because harvest must be delayed until the corn dries in the field to 24% moisture (Johnson and Lamp, 1966). The savings in supplemental heat was offset by the increased amounts of electricity required to meet the high airflow requirements for drying the grain (Schwart and Hill, 1977). Economies of scale were not available for volumes greater than 60,000 bushels (Madsen et al., 1978) because drying bins are limited to a maximum 16 foot height due to the excessive power requirements for necessary airflows at greater depths (Schwart and Hill, 1977). Each bin must have a drying unit because drying time may extend for one month or longer. Larger volumes require greater investments in storage-drying bins than would be needed for alternative systems. Consequently, total annual costs were higher at larger volumes for low drying systems than for alternative systems (Madsen et al., 1978; Schwart and Hill, 1977).

Casler (1975) provided a system by which corn growers can estimate the total annual costs of on farm drying systems. This system enabled a farmer to determine the break-even investment for on farm drying facilities compared to commercial drying. This system did not consider the availability of labor and commercial drying at harvest and management skills required to operate drying systems.

To the best of the author's knowledge, there has been no research which has considered the impact of deregulation of natural gas on the production of steel, concrete, plastics and other raw materials. The question must be addressed because raw material prices could change as a result of natural gas deregulation. Consequently, corn grain storage and harvesting systems could be altered due to changes in raw material prices.

Previous researchers have primarily concentrated on the economic analysis of harvesting and storage systems which process volumes of 20,000 bushels or more. Current research is limited on the total annual costs of harvesting and storage systems for volumes of 20,000 bushels or less. Past research has assumed that cost is the major criteria in the selection of corn harvesting and storage systems.

Materials and methods describes the research methods and procedures used to generate total annual costs of harvesting and storage systems which handle volumes up to 20,000 bushels. The second part of the chapter outlines the methods and procedures used to analyze the results of a mail survey on corn harvesting and storage systems sent to 9,000 Michigan dairy farmers.

MATERIALS AND METHODS

The data for this research project were obtained from two sources. A detailed questionnaire was sent to 9,000 dairy farms in Michigan. The questionnaire consisted of 19 questions which considered the types of corn harvesting and storage systems being used on Michigan dairy farms.

In the second segment of the project, the net present value method of cost analysis was used to determine the relative economic feasibility of the systems under consideration. Rising energy costs were calculated on a constant dollar basis using price escalators (inflation factors). Budgets for corn handling and storage systems were compiled depicting average total costs on a per bushel basis for the systems, and the point at which rising energy costs cause high moisture corn systems to hold an economic advantage.

The Questionnaire

A questionnaire requiring approximately 15 minutes to complete was designed. Questions were categorized as follows: farm location by county and township, number of animals in milking herd, crop acreages, harvesting and storage systems used on the farm, advantages and disadvantages of present storage systems, reasons to change harvesting and storage systems and high moisture corn feeding practices.

After initial completion, the questionnaire was submitted to each graduate committee member for critical review and suggestions. Following this initial review a second questionnaire was prepared. The revised questionnaire was tested during personal interviews with ten dairy farmers. Additional changes in the questionnaire's construction were made on the basis of the dairymen's critiques. The final questionnaire contained 19 questions. Twelve of the questions consisted of filling in the blanks while the remaining seven questions were multiple answer questions. A copy of the questionnaire is included in Appendix I.

The questionnaire was sent to dairymen for several reasons. The primary goal was to determine when dairymen would consider changing harvesting and storage systems. Were there other reasons besides investment and input costs which influenced the dairy farmer's decision to change harvesting and storage systems? Another goal was to determine the most important advantages and disadvantages for each type of storage system.

Questionnaire design was deficient in that it did not distinguish the extent to which corn grain was custom harvested, nor did it differentiate between the types of harvesting equipment used for custom harvesting. The questionnaire did not provide space for listing multiple structures of a storage system.

Questionnaire Procedure

The questionnaire was mailed to 9,000 Michigan dairy farmers during the first week of November, 1978. The list of Michigan dairy farmers utilized included all those that sold milk between September 1977 and January 1, 1978.

Methods of Analysis

Questionnaire data were summarized and presented by tables in Results and Discussion. Some of the data were categorized by region. Counties were classified according to region as delineated by the Michigan Agricultural Reporting Service. By using the same regions, data collected in this study could be compared to past and future research projects conducted by the Michigan Agricultural Reporting Service.

The null hypothesis that the average importance attached to the advantages of storage systems in question 10, Appendix I, was tested across systems. This will be tested against the hypothesis that certain advantages were more important than other advantages. The disadvantages of storage systems in question 11, Appendix I, will be tested in a similar manner. Chi-square analysis will be used to test questions 10 and 11, Appendix I.

Economic Analysis

Net present cost analysis was incorporated into a decision making framework to calculate the relative economic feasibility of potential harvesting and storage systems. The harvesting and storage systems incorporated into this study are as follows: 1 and 2 row corn pickers, 1 and 2 row snapper heads, 2 row picker-sheller, 4 row combine, low moisture ear corn, full bin dryer with stirrators, automatic batch and portable batch dryers, steel grain bins, concrete silo and sealed storage for high moisture corn. These systems were included because they are the most prevalent storage and harvesting systems currently being used on Michigan dairy farms.

Costs may be broken down into two groups. Fixed costs are constant and are not subject to change. They are the result of past commitments. Fixed costs include taxes, insurance, interest and depreciation. Variable costs change with the level of production and with what is produced. In contrast to fixed costs, management is able to determine whether or not the variable costs should be incurred. Fuel, repairs, and supplies are examples of variable costs.

Total annual costs (fixed and variable) of an investment are affected by its useful life. This problem must be addressed when comparing costs for sealed storage and concrete silos. Sealed storage units may be used for 20 years or longer. Their glass lined steel walls rarely deteriorate or develop air leaks which cause spoilage of the ensiled grain. Concrete silos tend to develop holes around doors and between cracks in silo walls after several years of use. Generally after ten years of service, concrete silos are not used for high moisture grain storage due to the increased incidence of air leaks in the structure which cause high spoilage losses. Sealed storage units are priced two to three times higher than similar sized concrete silos. The dairy farmer is faced with the decision whether to make the large investment in the sealed storage or purchase a concrete silo and replace it with a new concrete silo in the eleventh year.

Although a ten-year planning period was used in this analysis, it may be argued that dairy farmers utilize planning periods longer than ten years for large capital investments. If a twenty-year planning period was used for comparing sealed and concrete silos, a new concrete silo would be constructed in the eleventh year of the analysis. The purchase price of the concrete silo in the eleventh year may be considerably different than originally estimated due to unforeseen events (e.g. energy and raw material shortages, new technology). Thus projected annual costs for concrete silos could differ dramatically from actual annual costs incurred during the twenty-year planning period. In this study, sealed storages with a twenty-year planning period were compared to sealed storages, concrete silos, cribs, and drying systems which had ten-year planning periods.

The dairy farmer must project inflation rates for investment and total annual variable costs over the next twenty years as part of the decision making process. He asks, "will profits be maximized by purchasing a sealed storage unit instead of two concrete silos over a twenty-year period?"

Total annual variable costs are lower during the first three to four years of an investment due to lower levels of repair costs. The trade off between investment and total annual variable costs for the two systems is shown in Figure 1.

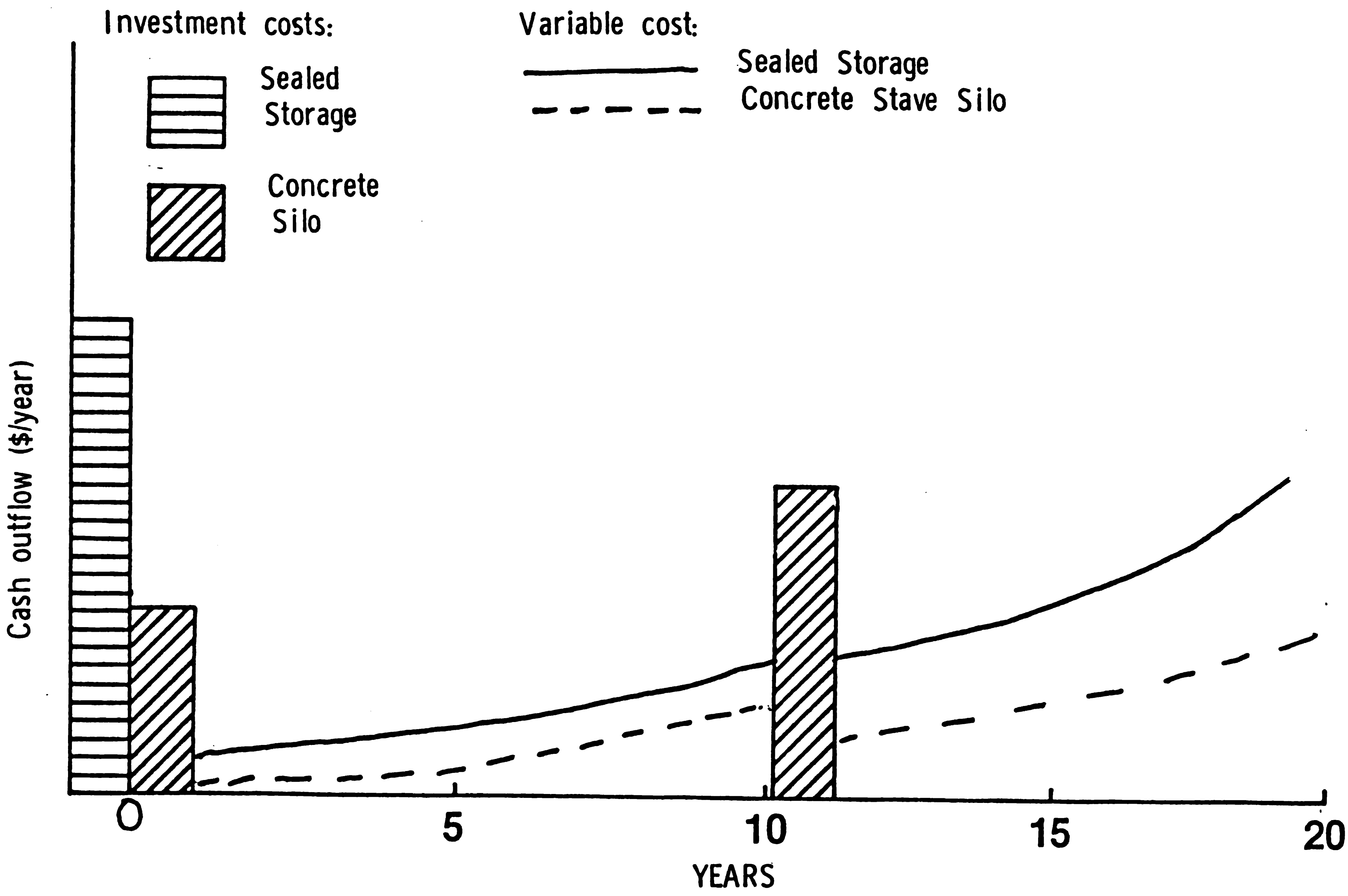

Figure 1. Cash outflow for concrete silos and sealed storage over 20 year planning period.

Dairy farmers are faced with the problem of uncertainty when comparing the relative profitability of potential investments. In this study, it was assumed that profit maximization was the primary criterion used in the selection of harvesting and storage systems.

The problem of uncertainty in investment decision making can be handled using three different methods. With the decision analysis framework, managers attach probabilities to alternative outcomes of each potential investment. The potential outcomes are totaled and the sum is the expected value of a decision. Probabilities may be determined through empirical analysis, deductive and subjective reasoning. Net present cost and sensitivity analyses incorporate the time value of money concept into the decision making process. This concept states that a dollar received today is preferable to a dollar received at some future date because of uncertainty, inflation and alternative uses for today's dollar (Aplin and Casler, 1973). A dollar today is worth more than a dollar to be received in the future because today's dollar can be invested so it will "grow."

The net present cost method of investment analysis enables the decision maker to calculate the value of expected cash flows into present dollars. Cash flows are the costs and benefits associated with an investment during its economic lifetime. An appropriate discount rate must be selected for net present cost analysis. The discount rate may be determined from several sources. It can be the interest rate the firm pays on borrowed funds for potential investment projects. The discount rate may also be interpreted as the firm's cost of capital which is the weighted average of the component costs of debt and equity in the firm's capital structure.

Net present cost is defined as the sum of future cash inflows and outflows, discounted at the cost of capital, minus the cost of the investment. Investments with positive net present values may be considered as potential investments because the present value of net cash inflows is greater than the capital outlays for the investments. If capital is limited, management will select those investments with the highest net present values so that profits will be maximized for the firm. Thus, the net present value of an investment indicates the potential profits or losses from an investment.

There is a computer model available which does all the calculations for net present cost and it is called Teleplan III (Harsh, 1972). The following equations represent Teleplan III:

Discounted Cash Flow =

$$-Io + \sum_{t=1}^{n} \frac{CR(1+QCR)^t(1-g)-VC_1(1+Q_1)^t(1-g)-VC_2(1+Q_2)^t(1-g)}{(1+r)^t}$$

$$\ldots \frac{VC(1+Q_4)^t(1-g)}{(1+r)^t} K + \sum_{t=1}^{n} \frac{depreciation(g)+interest(1-g)+principal}{(1+r)^t}$$

$$+ \frac{salvage(1+Q_s)^t}{(1+r)^n} + \frac{investment\ credit}{(1+r)^1}$$

Io = initial investment cost
CR = custom rate
Q_1 ... Q_4 = inflation rate for labor, gasoline, propane, repairs
g = tax rate
VC_1 ... VC_4 = labor, gasoline, propane, repairs
r = after tax cost of capital
t = time periods
n = last year of investment
s = salvage value inflation rate

When all or part of the investment is borrowed the following equations represent amortization of the loan:

$$M = \frac{L}{PUIF}$$

where M = equal loan payment
L = total loan
PUIF = present value annuity factor

Loan balances are calculated as follows:

Balance x i = interest payment

M - interest payment = principal payment

Balance - principal payment = new loan balance.

The custom rate represents those savings in costs or income generated per machine unit (e.g. acre, bushel) if the investment is made. Savings generated from owning a crop dryer instead of custom drying is an example of a reduction in costs. An illustration of an income generating investment is the purchase of a combine for custom harvesting. Receipts from custom hire minus costs per acre (e.g. labor, hauling grain) are considered as income. However, fixed and variable costs associated with the investment are not deducted from the income. Fixed and variable costs related to the investment are considered in another part of Teleplan III.

If management expects a second category of expenses or income to be affected by the investment, an additional custom rate may be incorporated into the model. For example, a farmer believes that grain stored on the farm has higher storage losses than storage at the local elevator. A negative custom rate for the additional storage losses would be included in the analysis of on-farm grain storage facilities. Conversely, a positive custom rate for a reduction in storage losses could be used if on-farm storage has lower losses.

The coefficient Q_i represents the inflation rates for the variable costs in the analysis. Inflation rates may fluctuate among variable costs depending upon economic conditions and the decision maker's preferences. The inflation rate for custom hire represents a weighted average of the inflation rates for all variable costs used in the analysis.

Tax rate selection can alter the net present cost of an investment. Incorporation of a high tax rate distorts the relative profitability of the analysis because the tax savings incurred by depreciation from the investment accrue as cash inflows in the analysis. Depreciation is a non-cash expense. The federal government and not the investment is generating large cash inflows for the investment when high tax rates are used in net present cost analysis. With a high tax rate, the impact of variable costs and interest costs in the analysis are under estimated because they are multiplied by the coefficient (1-g).

To adjust for rising machinery costs, salvage values are multiplied by an inflation rate. This model does not consider the impact of taxes on the salvage value. If the impact of taxes are considered on the salvage value, the coefficient (1-g) would be included in the numerator.

The annual number of units per year on which the investment will be used is represented by the coefficient K. As the value of K increases, total annual costs (variable and fixed) per unit decrease since fixed costs are spread over a larger number of units.

The net present cost of investment credit is discounted for one year in the model. This is due to tax savings from the investment credit being realized on the following year's tax return.

The model enables the decision maker to modify variable costs and their inflation rates according to changes in economic conditions. Whenever significant changes are made in the inflation rate of a variable cost, the inflation rate for the custom rate will be adjusted since it is calculated as the weighted average of variable costs' inflation rates.

Various custom rates may be substituted in the model. The break-even price is represented by the custom rate which indicates a net present value of zero profits for the investment. Total annual cost per machine unit (e.g. bushel, acre) comprises the breakeven price. In this study, total annual costs per bushel were calculated for harvesting and storage systems at the following volumes: 1,000, 5,000, 10,000, 15,000, and 20,000.

Principal and interest payments may be incorporated into the analysis if all or part of the investment was financed. In Teleplan III, interest was included on a pretax basis.

The model does not permit management to determine the portion of total annual cost that is composed of variable cost. Furthermore, the model cannot breakdown total variable cost into its component variable costs.

Selection of the discount rate is crucial because it represents the "cut off criterion" for determining whether an investment is economically feasible. Projects with a negative net present cost will yield a rate of return lower than the discount rate (i.e. cost of capital) used as a standard in the analysis of potential investments.

Decision makers may use several discount rates to reflect differences in risk among investments in net present cost analyses.

The net present cost method is useful when comparing investments with unequal lives. Salvage values of investments are incorporated into analyses when comparing projects with uneven economic lifetimes. The salvage value represents the value of the investment at the end of the investment period.

Sensitivity analysis is a technique in which the net present cost of potential investment projects can be analyzed for different values of kay factors. For example, the expected return of an investment could be calculated for several different assumptions regarding input costs. Sensitivity analysis indicates which variables and assumptions are most critical in the analysis. Consequently, it tells management where to focus its analytical efforts. It encourages decision makers to consider the impact of uncertainty on the outcomes of potential investments. Finally, it identifies areas on which management should concentrate its attention after approval and during implementation of a project.

Net present cost analysis was incorporated into this study because discount rates for net present cost analyses can be documented by examining interest rates charged on loans for similar projects. Therefore, interest rates were used as discount rates in net present cost analyses. It was difficult to locate empirical evidence which supports the probabilities utilized in decision rule analyses. It appears that the probabilities were determined by deductive and subjective reasoning which may differ among individuals.

A discount rate of 14% was used in the study. This was comparable to the interest rate charged to dairy farmers by agricultural credit institutions. The 14% rate includes a 7% general inflation rate, 4% return on funds to the lender and 3% risk premium. Interest rate components were determined by the author's subjective reasoning. Different discount rates may be substituted into the study depending upon changes in the economic conditions, desired rates of return and risk premiums.

The dairy farmer is faced with the problem of asset fixity in a storage system if a major technological advancement for lower cost storage systems is discovered sometime after but before the storage system is worn out. Although the investment is technologically outmoded, the marginal value product of the investment is greater than the salvage value but is less than its acquisition price. Consequently, the asset is fixed. When the marginal value product is equal to or less than the salvage value, disinvestment will occur by selling the storage system for either scrap metal or concrete stone. If total costs are amortized over planning periods greater than ten years and new technological advancements are discovered several years after investment, potential losses in ownership costs will be greater because only a small part of the investment will have been amortized during the first few years of the investment.

The user cost problem of determining the optimal rate to extract services from fixed assets is difficult to address because of imperfect knowledge. Producers will invest or disinvest in durables to maximize profits.

In an era of rapidly escalating petroleum prices, there is an economic incentive to develop alternative forms of energy. It appears to the author that mankind is on the threshold of major technological breakthroughs in the development of alternative energy forms that are cheaper than petroleum and petroleum based fuels. Currently, thousands of researchers around the world are studying the use of coal, solar, wind, electrical and nuclear energy as alternative sources of power. If an energy substitute that is cheaper than petroleum and propone is developed within the next few years, current petroleum based technology may be outmoded. The invention and introduction of low cost substitutes for petroleum and propane could make present corn storage and handling systems obsolete. The author believes the incidence of asset fixity and obsolescence in an era of rapid technological change can be minimized by the use of a ten-year planning period.

Salvage value determination is a difficult problem because of imperfect knowledge. In this analysis it was assumed that there was a 10% salvage value on steel grain bins and equipment and a 30% salvage value on concrete and sealed silos. A 30% salvage value was assumed for sealed storages at the end of a twenty-year planning period. The 10% salvage value on equipment represented the value of the equipment for either replacement parts or scrap metal at the end of the ten- and twenty-year planning periods. It must be recognized that the salvage value of the concrete and sealed silos for HMC would be a function of the energy price scenario at the end of the planning period. Thus, if there are dramatic price rises in the price of propane during the ten-year planning period, the salvage value of these structures could be higher than their initial cost.

Prices for inputs and products are influenced by several factors. Some agricultural products such as corn have government price supports which establish a minimum price for the commodity while the price limit is determined by supply and demand on national and international markets. At the present time petroleum and propane prices are regulated by the federal government. As deregulation occurs, these inputs will be priced on the basis of supply and demand on world markets. Since oil is a finite resource and OPEC nations control much of the discovered oil reserves in the world, they have a monopoly on oil supplies for the world market. Once petroleum and propane deregulation occurs in the United States, alternative forms of energy such as solar, wind, nuclear, and coal will be substituted at a greater rate for propane and petroleum. The ceiling price on propane can be expected to be influenced by the cost of coal gasification. The ceiling prices for alternative energy sources will be determined by propane and petroleum prices on world markets. Otherwise, consumers will utilize petroleum if it is cheaper than alternative energy sources.

Electricity rates are assumed to increase at the same rate as gasoline and oil since oil is used to power some electrical generating facilities. Since 1974, utility companies have attached a fuel and purchased energy adjustment charge to consumer's electrical bills (Surbrook, 1979). This charge is used to make adjustments for the often fluctuating costs of fuel used to generate electricity. As utility companies switch to coal operated generating facilities, electrical rates will probably increase. Transportation costs will increase due to higher fuel costs which will raise coal prices. Utility companies pass along the higher input costs to the consumer by raising electrical rates through rising petroleum prices.

Labor was included as a variable cost for harvesting and storage systems due to the opportunity cost principle. Labor was charged to the corn harvesting and storage enterprises at the cost of $4.00 per hour. This figure delineates the current price of farm labor. Also, this rate represents the return labor might generate if it was utilized elsewhere on the farm for activities such as managing and caring for the dairy herd.

Low moisture ear corn had a shorter harvesting season than HMSC because harvest must be delayed until the moisture content dries to 25%. At moisture levels greater than 25%, there is the risk of spoilage when ear corn is stored in cribs.

Harvesting systems were designed so that corn harvesting was completed by the end of the third week in November. Corn harvest may be extended beyond this date, however, harvest losses rise due to the increased likelihood of harvesting corn under adverse weather conditions. Consequently, it was assumed that harvest losses increase .005% per day for each day harvest continued beyond the scheduled harvest season. Conversely, savings generated from a reduction in harvest losses by the start of harvest before the scheduled harvest season may be offset by increased drying costs for shelled corn and higher storage losses for HMSC, HMEC and low moisture ear corn.

Harvesting and storage losses were incorporated into net present cost analysis. The total annual cost per bushel for harvesting and storage systems included harvesting and storage losses.

Appendix IV lists the electricity, labor, propane and gasoline costs per 100 bushels for the harvesting and storage systems considered in this study. The harvesting costs were based on harvesting 90 bushels of corn per acre.

Appendix III lists the capacities for storage systems included in this analysis. Capacities for concrete silos, sealed storages, grain bins and cribs were calculated using values provided by the Midwest Plan Service. The approximate storage space requirements are listed as follows:

Material Description	lb/cu ft	lb/bu
Corn shelled		
28% moisture	41.1	65.7
25% moisture	43.1	63.0
15.5% moisture	44.8	56.0
Ear corn		
15.5% moisture	28.0	70.0
33.0% moisture	36.5	88.8

$$\text{Capacity} = \frac{\pi \times \text{radius} \times \text{radius} \times \text{silo height} \times \text{lb/cu ft}}{\text{lb/bu}}$$

Capacities for concrete silos were determined using 28% moisture content while a 25% moisture content was used for sealed storage. Cribs and grain bin capacities were calculated using a 15.5% moisture content.

It was assumed that 5 feet at the top of concrete silos and sealed storage units would be used for either an unloader or breather bags. Thus, the capacity listed for a 20' x 60' silo is the capacity of a 20' x 55' silo filled to the top. Capacities for cribs and grain bins did not include space above the eave line.

Horizontal silos were not considered in this study. It is difficult to remove 4 to 6 inches of silage daily from the exposed silo face without loosening and exposing additional silage to the air. Silo dimensions must be tailored to animal numbers and feeding programs. Fox (1976) concluded that horizontal silos were best suited for farms with over 500 cattle so that spoilage losses can be minimized.

Acid treated corn was not included in the study because the corrosive action of acid reduces the life of handling equipment and storage bins.

Budgeting

Harvesting and storage systems considered in this project are as follows:

Harvesting	Handling and Storage
1 row corn picker	crib
2 row corn picker	automatic batch dryer
2 row picker-sheller	portable batch dryer
1 row snapper head	steel grain bin
2 row snapper head	concrete silo for HMC
4 row combine	full bin dryer with stirrators
	sealed storage

Assumptions:

1. <u>Dryer efficiencies</u>:

   full bin - 1800 - BTU/lb water removed or
   21.30 gal/100 bu

   automatic batch - 2800 BTU/lb water removed or
   33.14 gal/100 bu

   portable batch - 2800 BTU/lb water removed or
   33.14 gal/100 bu

2. <u>Moisture percentages</u>:

   Grain harvested at 28% moisture and dried to 14% moisture content.

3. <u>Input costs</u>:

labor	$4.00 per hour
propane	$0.40 per gallon
gasoline	$0.75 per gallon
oil	$2.40 per gallon
electricity	$0.041 per kilowatt hour

4. <u>Drying rate</u>:

   Drying systems considered in this analysis dry at least 1500 bushels per day of grain from 28% down to 14% moisture content.

5. <u>Harvesting rate</u>:

1 row picker or snapper head	0.8 acre per hour
2 row picker, picker-sheller or snapper head	1.53 acre per hour
4 row combine	4.00 acre per hour

   8 hour harvest day
   20 day harvest season - HMSC
   10 day harvest season - low moisture ear corn
   4% harvesting loss - HMSC
   8% harvesting loss - low moisture ear corn
   90 bushels corn per acre

Total harvest losses increase .005% per day for each day harvest continues past the scheduled harvest season.

6. Cost data:

ten year planning period
20% tax bracket
30% salvage value on concrete and sealed silos
7% inflation rate
9% electricity inflation rate
9% gasoline and oil inflation rate
11% propane inflation rate
annual repairs for storage and harvesting systems, 2% of initial cost
taxes for storage and harvesting systems, 1.5% of initial cost
insurance for storage and harvesting systems, 0.5% of initial cost
straight line depreciation
10% investment credit taken in the first year
10% salvage value on equipment and storage bins
no trade-in of old equipment on new equipment
one half of the cost of combines or forage choppers plus the cost of snapper heads or corn heads will be allocated for corn harvesting
labor inflation 7%
interest rate 14%
after tax rate of return on equity capital 13%
new machinery inflation rate 7%

7. Storage losses:

2% steel grain bin
6% sealed silo
10% concrete silo

8. Auxiliary Equipment:

No auxiliary equipment (e.g. augurs, elevators, silage blowers, and tractors to operate corn pickers, and haul wagons, will be purchased.

Variable costs for tractors and electric motors needed to operate storage and harvesting were included in the budgets.

9. Corn price:

$2.40 per bushel

10. Power requirements:

    70 horsepower tractors were used to operate harvesting and drying equipment. Fuel requirements on a per hour basis were calculated as follows:

    P.T.O.H.P. X .069 gal/hr gasoline
    .0504 gal/hr diesel
    .9 kilowatt/hr electricity

The calculation of all costs in this study was based upon 1979 prices obtained by the author. The prices include both the current cost of harvesting and handling equipment and the current cost of propane, electricity and gasoline. Since the study projects costs over a ten year planning period, the use of 1979 prices would be unrealistic due to the impact of inflation. Inflation factors were incorporated into the study to adjust for rising price levels. Inflation rates for gasoline and propane were higher than the general inflation rate due to their limited supplies. The inflation factor is a constant percentage from year to year.

Determining the Change-over Point from Dry Shelled Corn to High Moisture Corn Systems

Inflation rates of 10%, 20%, 40%, 60%, and 80% for electricity propane and gasoline are incorporated into the analysis to determine when farmers could economically justify changing from drying corn to high moisture corn systems. Total annual costs per bushel for portable batch dryers, automatic batch dryers and full bin dryers are calculated under the spectra of rising energy prices. All other assumptions regarding investment and input costs are not changed in the computation of total annual costs for these systems. The change-over point for the drying systems was calculated at volumes of 5,000, 10,000, 15,000 and 20,000 bushels. The cost curves are illustrated in the Results and Discussion.

It was difficult to compare the total annual costs of sealed storage units, concrete silos, batch in bin dryers and grain bins because these systems were not designed to store exactly 5,000, 10,000, 15,000 and 20,000 bushels. A regression line was fitted to the total annual costs of these systems so that comparisons could be made at the previously mentioned increments. Thus, the total annual costs for these systems were determined from the regression line. Total annual costs for batch in bin dryers for volumes greater than 10,000 bushels were not included in the analysis. The author felt dairymen would have increased flexibility from two smaller bins instead of one large bin if several grain crops were grown on the farm.

RESULTS AND DISCUSSION

This section was divided into two parts. The first portion of this section analyzes the results of budgeting for harvest and storage systems. The second portion discusses tabulation and interpretation of mail questionnaire data.

Cost Analysis of Harvest Systems

Total annual cost per bushel for corn harvesting systems are shown in Table 1 and Figure 2 for input prices outlined in materials and methods and Appendices II to IV. The annualized cost was the cost at which the net present cost of the investment had 0 profits.

Table 1 shows the annual cost per bushel for each harvesting system. As shown in Appendix II, field losses rise as the length of harvest season increases. Field losses are incorporated into the annual cost per bushel for harvesting systems.

Pickers had higher costs at larger volumes due to a delayed harvest. The onset of low moisture ear corn harvest must be delayed until the corn's moisture content reached the desired level for cribbing. Since only one

Table 1. Annual Cost Per Bushel for Corn Harvesting Systems (For 90 Bushels per Acre)

Harvesting Systems	Bushels 1,000	5,000	10,000	15,000	20,000
1 Row Picker	$ .8929	$.4038	$.4000	$.4586	$.5175
2 Row Picker	1.460	.4718	.3484	.2957	.3561
2 Row Picker-Sheller	1.410	.4052	.2803	.2387	.2178
1 Row Snapper Head	.9096	.3485	.2783	.3070	.3648
2 Row Snapper Head	1.330	.3912	.2733	.2340	.2143
4 Row Combine	3.600	.8030	.4523	.3354	.2769

picker was used to harvest the larger volumes, the harvest season was extended due to the relatively slow harvest rate. Consequently field losses mounted as harvesting continued beyond the scheduled harvest season. This was reflected in the higher annual costs per bushel at the larger volumes.

Two row snapper heads and two row picker-shellers were the lowest cost corn harvesting systems due to longer harvest seasons and lower investments. Snapper heads were used to harvest HMEC. The four row combine had the highest annual costs because of the small volumes relative to the large initial investment.

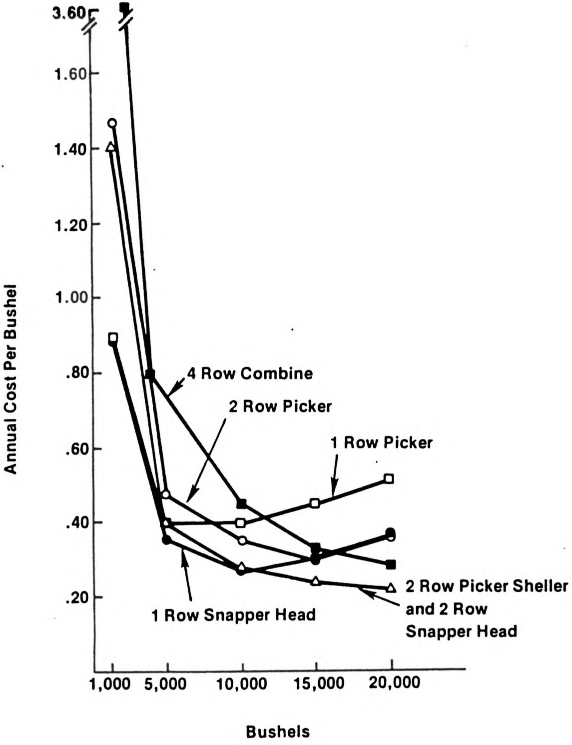

Figure 2. Harvesting system costs for 5,000 to 20,000 bushels.

The repair costs for one row pickers and one row snapper heads could increase beyond the estimated 2% of initial investment. These costs could be higher due to the extended harvest seasons for volumes greater than 10,000 bushels. The result would be higher annual costs.

Cost Analysis of Storage Systems

Annual costs per bushel for corn storage systems are shown in Table 2 through Table 9. Storage losses were included in the annual cost per bushel for all storage systems. Losses ranged from 2% for cribs and steel grain bins to 6% for sealed storages and 10% for concrete silos. Table 10 compared the costs of automatic batch and portable batch drying systems.

Table 2. Annual Cost Per Bushel for Sealed Storage and Unloader

Bushels HMSC	Dimensions	Sealed Storage	Unloader	Total Costs
4943	20' x 28'	$ .5832	$ .3688	$.9520
9671	20' x 50'	.4725	.2473	.7198
16119	20' x 80'	.4462	.2102	.6562

Table 3. Annual Cost Per Bushel for Sealed Storage and Unloader over a Twenty Year Period

Bushels HMSC	Dimensions	Sealed Storage	Unloader	Total Costs
4943	20' x 28'	$ .4263	$ .1743	$.6006
9671	20' x 50'	.3490	.0975	.4465
16119	20' x 80'	.3290	.0740	.4030

Table 4. Annual Cost Per Bushel for Concrete Silo and Unloader

Bushels HMSC	Dimensions	Silo	Unloader	Total Cost
1,768	12' x 30'	$.4407	$.2850	$.7257
5,031	16' x 45'	.3964	.1260	.5224
10,810	20' x 60'	.3533	.0758	.4291
15,722	20' x 85'	.3190	.0657	.3847

Table 5. Annual Cost Per Bushel for Steel Grain Bin With Aeration Systems

Bushels DSC	Total Costs
2,415	$ .2614
4,910	.1854
9,676	.1575
16,783	.1355
20,580	.1318

Table 6. Annual Cost Per Bushel for Full Bin Dryer with Stirring Devices

Bushels DSC	Total Costs
3,000	$ .5775
5,000	.4974
9,200	.3929

Table 7. Annual Cost Per Bushel for Portable Batch Dryer

Bushels DSC	Total Cost
1,000	$ 1.5900
5,000	.5009
10,000	.3641
15,000	.3185
20,000	.2957

Table 8. Annual Cost Per Bushel for Automatic Dryer and Wet Holding Bin

Bushels DSC	Automatic Batch Dryer	Wet Holding Bin	Total Costs
1,000	$ 1.37	$ .3501	$1.7201
5,000	.4326	.0768	.5074
10,000	.2955	.0426	.3381
15,000	.2558	.0310	.2868
20,000	.2459	.0255	.2714

Table 9. Annual Cost Per Bushel for 960 Bushel Corn Crib

	Cost per bushel
Low moisture ear corn	$ .1640

Table 10. Approximate Annual Cost Per Bushel for Portable Batch Dryer--Storage Bin (System 1) and Wet Holding Bin--Automatic Batch Dryer--Storage Bin (System 2)

	Bushels HMSC				
	$1,000	5,000	10,000	15,000	20,000
System 1	$ 1.85	$ .6806	$ .5268	$ .4642	$ .4244
System 2	1.98	.6871	.5008	.4325	.4011

Although full bin drying systems with stirrators for volumes greater than 9,200 bushels are available, they were not considered in this analysis for several reasons. Equipment manufacturers indicated many farmers preferred the increased flexibility in a drying system offered by two smaller drying bins instead of one large drying bin. This was desirable if several crops used the drying system each year. Larger bins required more supervision and management. Equipment dealers reported that larger bins had a higher incidence of mechanical problems with stirrators than in smaller bins.

A wet holding bin was required to operate an automatic batch dryer because grain flowed intermittently through the system.

Storage bins, wet holding bins and drying systems must be considered as one unit when comparing ear corn, HMC and dry shelled corn systems. Wet holding bins, storage bins with aeration systems and automatic batch dryers were considered as one unit while portable batch dryers and storage bins with aeration systems were considered as another unit. These systems were compared in Table 10.

It was difficult to compare storage systems on a per bushel basis because the systems were not always designed to hold exactly 1,000, 5,000, 10,000, 15,000, and 20,000 bushels. Linear regression was used to calculate storage system costs at the previously mentioned increments. Total annual costs for cribs, batch in bin dryers, steel grain bins, concrete silos and sealed storages were determined using linear regression. These costs are illustrated in Figure 3.

Cribs were the lowest cost storage system. Cribs had savings of $.32 and $.12 per bushel for 5,000 and 20,000 bushel volumes compared to concrete silos. When compared to automatic batch dryers, cribs had an advantage of $.50 and $.21 for 5,000 and 20,000 bushel volumes. Although higher labor costs were reported in Appendix IV for cribs compared to shelled corn systems, annual costs were lower due to the lower investment cost. While cribbing corn required more physical labor for loading and unloading, shelled corn systems still required labor to monitor and manage unloading and loading. From Appendices III and IV it was shown there was a trade-off between labor and investment costs. As labor saving devices were implemented in storage systems, investment costs increased. Farmers must decide how much they are willing to pay for labor saving conveniences when designing storage systems.

After cribs, full bin dryers with stirrators provided the second least cost storage system followed by concrete silos, automatic and portable batch dryers and sealed storages. Full bin drying systems were competitive in price because they could be used for both drying and storage. The full bin dryer has an advantage of $.05 and $.07 per bushel over concrete silos at 5,000 and 10,000 bushel volumes. This advantage in cost could diminish if propane prices increase faster than anticipated. When compared to automatic batch dryers, concrete silos had savings of $.17 and $.09 per bushel for 5,000 and 20,000 bushels. In contrast, sealed storages had higher costs of $.12 and $.005 per bushel over automatic batch dryers for 5,000 and 20,000 bushels due to the high initial investment cost. Full bin drying systems were more efficient in the utilization of propane than batch drying systems. As a result, full bin systems have approximately $.20 and $.13 per bushel

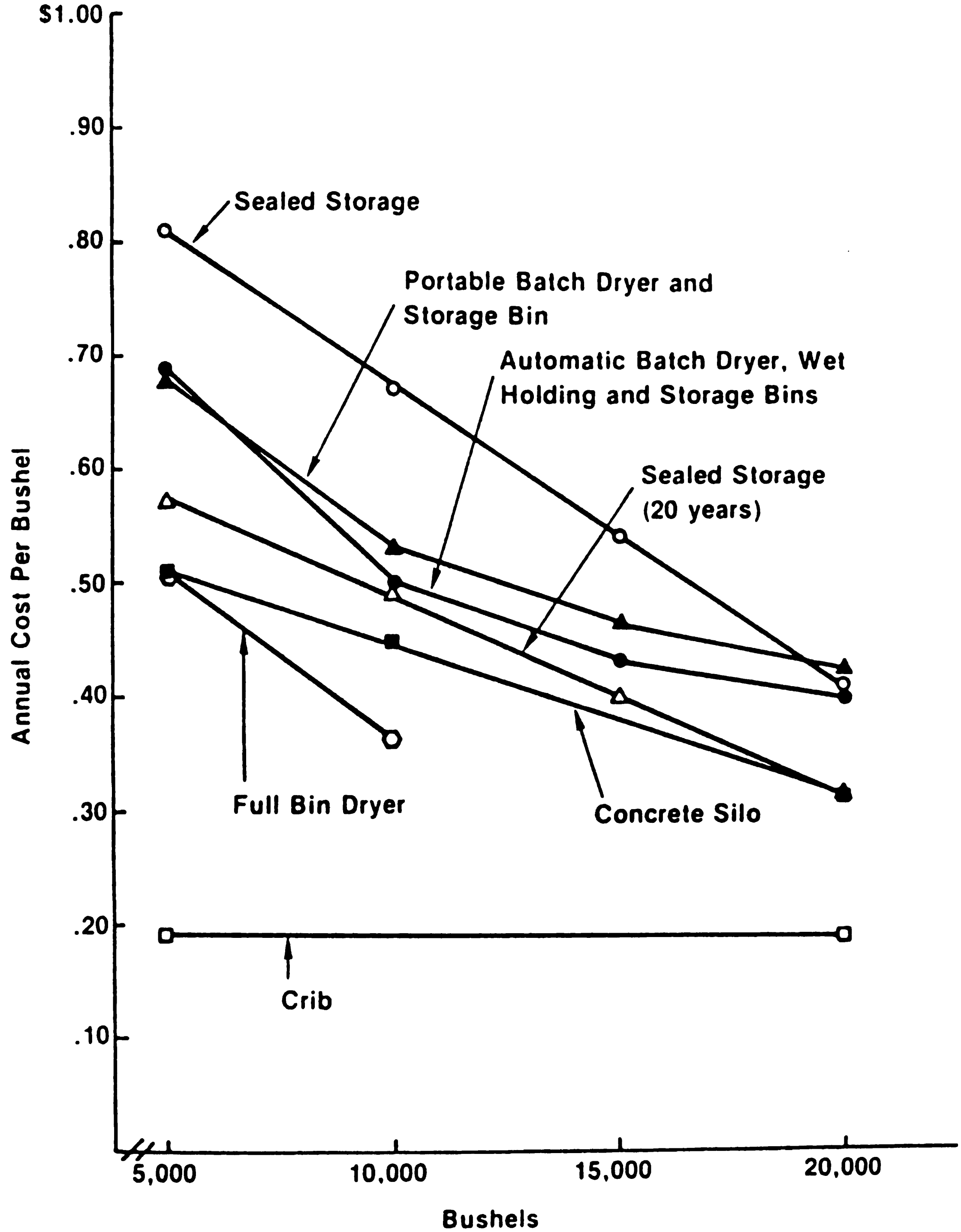

Figure 3. Storage systems costs for 5,000 to 20,000 bushels.

advantages over automatic batch systems for volumes of 5,000 and 10,000 bushels, respectively. Automatic batch and portable batch dryers were comparable in annual costs. Automatic batch systems had lower operating costs because electrical motors were substituted for gasoline powered tractors for the operation of the systems. Although automatic batch systems had higher initial investments they were cheaper than portable batch systems for larger volumes due to lower operating costs. Sealed storage systems were the most expensive storage systems due to high initial investments.

Low temperature systems were not included in this study. It was recommended that only corn whose moisture content was below 24% be used in these systems (Brooker _et_ _al_., 1974). Corn may not field dry to 24% every year in Michigan. If the harvest season was delayed until the corn reached 24% moisture, the harvest season could be significantly shortened during a wet harvest season. As a result, harvest losses will increase when harvesting is extended beyond the scheduled harvest season. Low temperature systems were not considered because they could not be used every year.

Tables 2 and 4 listed the capacities of sealed storage and concrete silos for HMSC at 25% and 28% moisture levels. If both systems were filled with 30% and 33% HMEC, storage capacities would be reduced by 34% due to the presence of the cob. Consequently, annual storage costs per bushel would increase by 50%.

The cob raises the moisture content of HMEC about 5% higher than for HMSC because it comprises about 20% of the dry matter in the corn ear (Merrill, 1971). However, due to the presence of the cob in HMEC, net energy and crude protein are lower than in shelled corn. The major advantage of feeding HMEC is the increased fiber in the diet. The author felt that dairymen could not justify a 50% increase in annual cost per bushel for HMEC over HMSC. Dairymen should be able to increase the fiber content of rations in a cheaper manner than by filling HMC storages with HMEC.

Most dairy farmers construct sealed storage systems on the premise that sealed storages will not become obsolete and that they can be used indefinitely due to their steel construction. As shown in Tables 2 and 3, there is approximately a 60% reduction in costs when the system is utilized over a twenty year planning period instead of a ten year planning period. This results in a savings of $.25 and $.10 per bushel for volumes of 5,000 and 20,000 bushels, respectively. In Table 3 it was assumed that one unloader would be used during the twenty year analysis because the silo would be unloaded once each year. As shown in Figure 3, costs for sealed storage systems over a twenty year planning period were comparable to concrete silos over a ten year period. At 20,000 bushels, concrete silos and sealed storages had equal costs.

Length of planning period is the critical assumption when comparing the costs of concrete silos and sealed storage systems. If a dairyman believes that current technology may be outmoded within several years, a ten year planning period should be used to minimize the incidence of obsolescence and asset fixity. Over a ten year planning period, concrete silos had savings of $.30 and $.15 per bushel for 5,000 and 20,000 bushel volumes, respectively, (Figure 3) compared to sealed storages due to their relatively low investment costs. It is difficult to predict future investment costs. Concrete silo costs in the next decade may be considerably higher than estimated at the beginning of a twenty year analysis due to unexpected energy and raw material shortages. Thus for a twenty year planning period, sealed storages may be the least cost HMC storage systems.

An analysis of proprionic acid treated HMSC was not contained in this study because it provided temporary storage of HMSC. Proprionic acid treated HMSC may be stored for up to one year (Lloyd Berkimer). It was recommended 2.78 gallons (23.46 pounds) of 100% prioprionate be applied to one ton of 28% HMSC to insure safe storage for up to one year (Lloyd Berkimer). The corrosive nature of the proprionate will reduce the life of handling and storage equipment. Application of proprionate must be carefully monitored. Losses will easily occur if <u>all</u> grain is not covered with a uniform application.

Proprionic acid is manufactured from petroleum and petroleum based products. Thus rising petroleum prices will be reflected in higher costs for proprionic acid.

At $.37 per pound, the cost of treating one bushel of 28% HMSC was $.2214 per bushel. If the storage costs in Table 5 were used as an approximate indicator of storage costs for acid treated HMSC, the acid treated corn would be competitive with other systems for volumes under 10,000 bushels. At larger volumes, the acid treated corn was not competitive because the proprionate was a high proportion of the total annual cost. Since no storage losses and costs for the corrosiveness on handling and storage equipment (augers, grain bins) were included in the annual costs of acid treated systems, total annual costs were underestimated.

Selection of a storage and harvesting system can be influenced by the utilization of the corn. If part of the corn crop is sold, market availability will affect the choice of harvest and storage system. Although HMC and acid treated HMC may have lower storage costs than alternative systems, market availability for non-livestock purposes may be limited.

Figure 4 illustrated the total annual costs for least cost combinations of harvest and storage systems. Ear corn, HMC, and dry shelled corn systems were compared

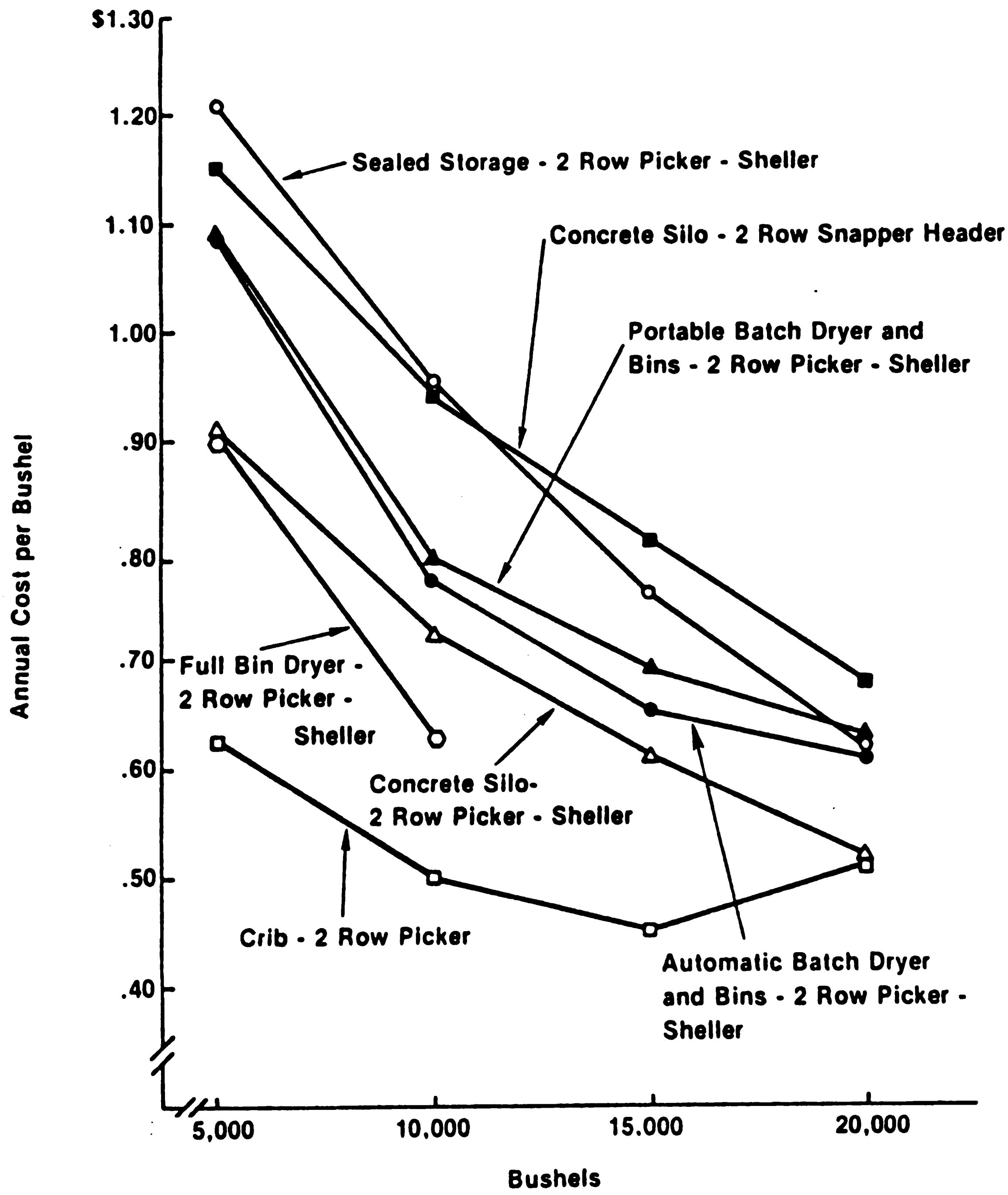

Figure 4. Least cost harvesting and storage system combinations for 5,000 to 20,000 bushels.

in Figure 4.

The lowest cost harvest and storage system for 5,000 to 20,000 bushels was the 2 row picker-sheller-crib system. Using a 2 row picker-sheller, the least cost harvest and storage systems were ranked as follows: full bin dryer with stirrators, concrete silos, automatic batch dryer with holding and storage bins, portable batch dryer with storage bin and sealed storage. Although 2 row snapper headers and picker-shellers have comparable annual costs per bushel (Table 1), HMEC systems had higher annual costs due to increased storage costs. HMSC harvest and storage systems for concrete silos had cost reductions of $.24 and $.16 per bushel at volumes of 5,000 and 20,000 bushels, respectively, compared to the HMEC systems. As shown in Figure 4, the ear corn picker system had approximately a $.27 and $.13 per bushel advantage over the full bin dryer-picker-sheller combination for volumes of 5,000 and 10,000 bushels. When compared to the automatic batch dryer system listed in Figure 4, the ear corn system had lower annual costs of $.45 and $.10 per bushel for 5,000 and 20,000 bushels, respectively. Total annual costs for the crib systems begin to rise at volumes greater than 15,000 bushels due to higher harvest losses. The concrete silo-snapper head system had higher costs of $.52 and $.17 per bushel over the ear corn-picker system for 5,000 to 20,000 bushels. The sealed storage system indicated higher costs of approximately $.30 and $.10 per bushel for HMSC over concrete silos for 5,000 and 20,000 bushels. In Figure 4 the ear corn system had savings of $.58 and $.10 per bushel over the sealed storage system for 5,000 and 20,000 bushels.

Sealed storage systems and portable and automatic batch dryers have approximately equal costs at volumes of 20,000 bushels in Figure 4. However, concrete silos maintain a $.10 per bushel advantage at the 20,000 bushel level over alternative drying and sealed storage systems due to their relatively low investment and operating costs.

Determining Breakeven Cost Between Drying Systems And Alternative Storage Systems

Dairy farmers are faced with the problem of trying to determine the breakeven point between drying systems, high moisture corn and low moisture ear corn systems in an era of rising energy costs. Annual energy inflation rates ranging from 10% to 80% were used to determine the breakeven points. When calculating the breakeven points, it was assumed that electricity, propane and gasoline had comparable inflation rates, while a static 7% inflation rate was used for repairs, labor and new machinery. Thus when a 40% inflation rate was used for energy inputs, the general inflation rate remained at 7% for repairs, labor and new machinery.

As shown in Figures 5 to 8, annual energy inflation rates greater than approximately 20% economically justify changing from drying systems to high moisture corn systems. When compared to drying systems, sealed storages and concrete silos had lower annual costs per bushel at higher inflation rates because minimal amounts of energy are required to operate these systems. In sealed and concrete silos, energy usage is limited exclusively to mechanical loading and unloading. Due to greater investment costs, sealed storage systems had higher annual costs per bushel than concrete silos.

Cribs had the lowest annual cost due to the relatively nominal investment and operating costs. Cribs had the highest labor requirements of all storage systems. Consequently, considerable physical labor is required for loading and unloading. Cribs are not greatly affected by rising energy costs because substantial quantities of physical labor are substituted for energy inputs in the operation of these systems.

Although portable and automatic batch dryers have comparable investment costs, portable batch dryers had the highest annual costs. The portable batch dryer is operated by a 70 horsepower gasoline tractor which has greater energy input costs than the electricity required to power the electrical motors on the automatic batch dryer. Even though batch in bin dryers have higher investment costs

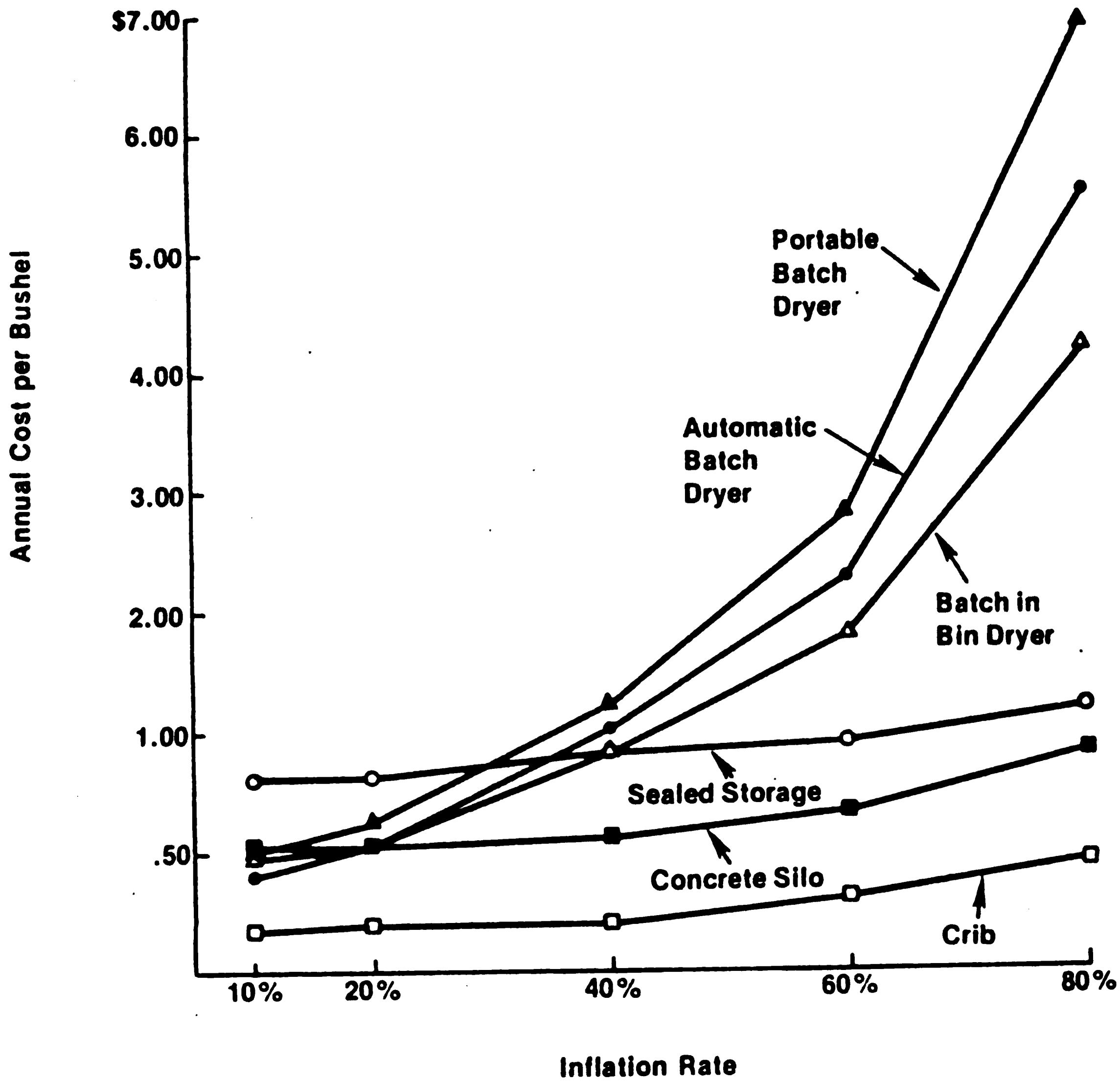

Figure 5. Ten percent to eighty percent inflation rates for energy inputs--5,000 bushels.

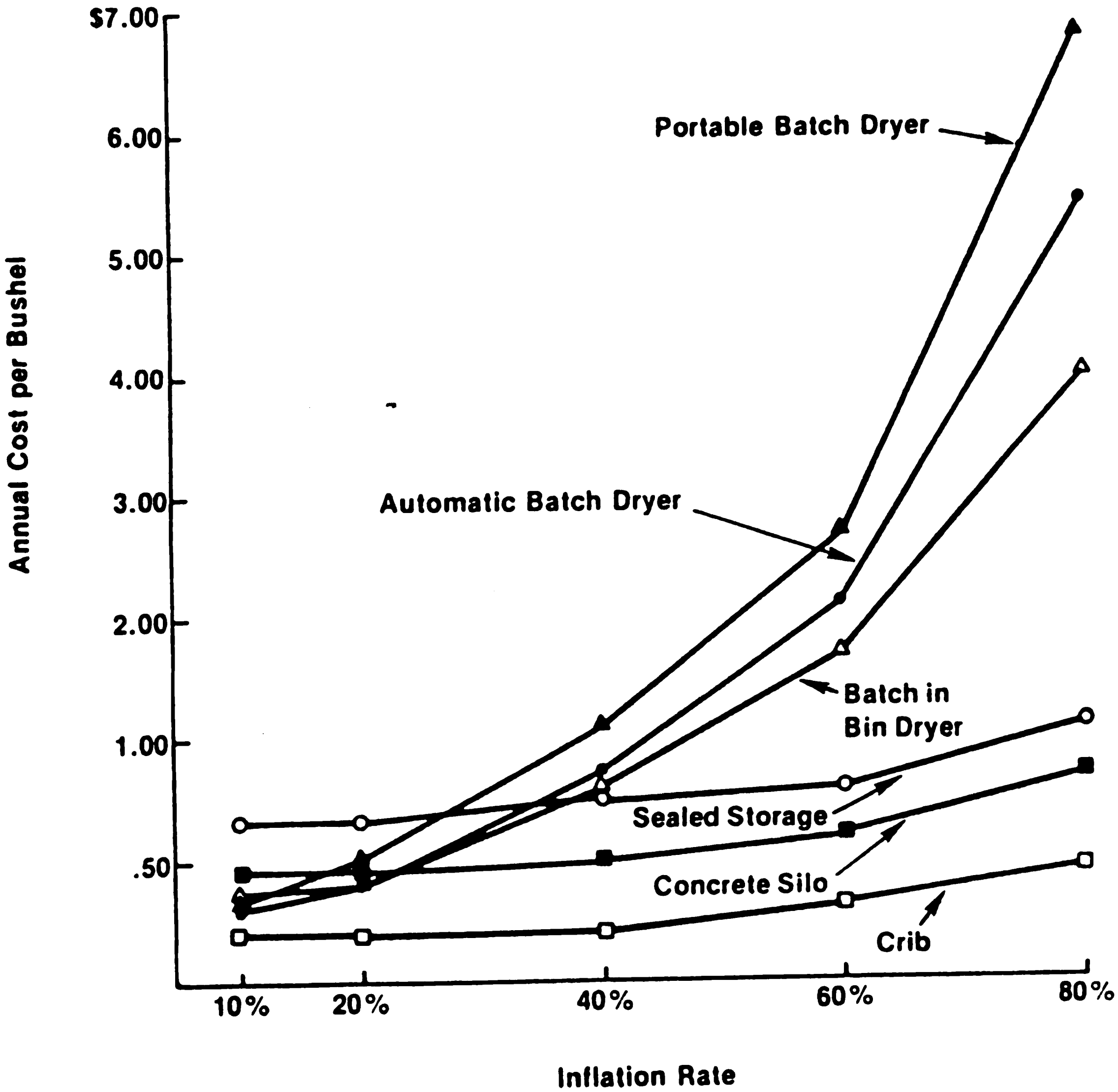

Figure 6. Ten percent to eighty percent inflation rates for energy inputs--10,000 bushels.

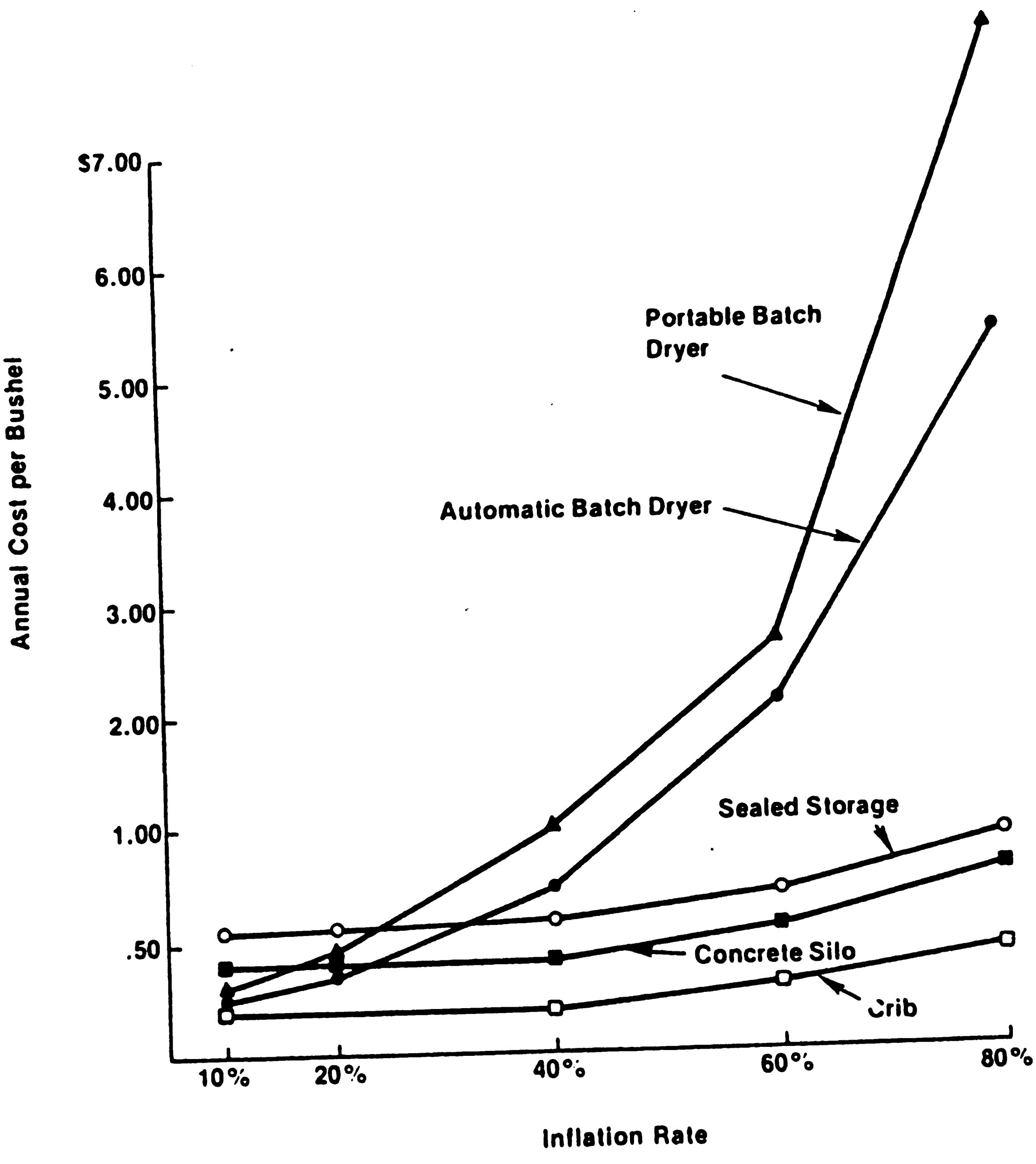

Figure 7. Ten percent to eighty percent inflation rates for energy inputs--15,000 bushels.

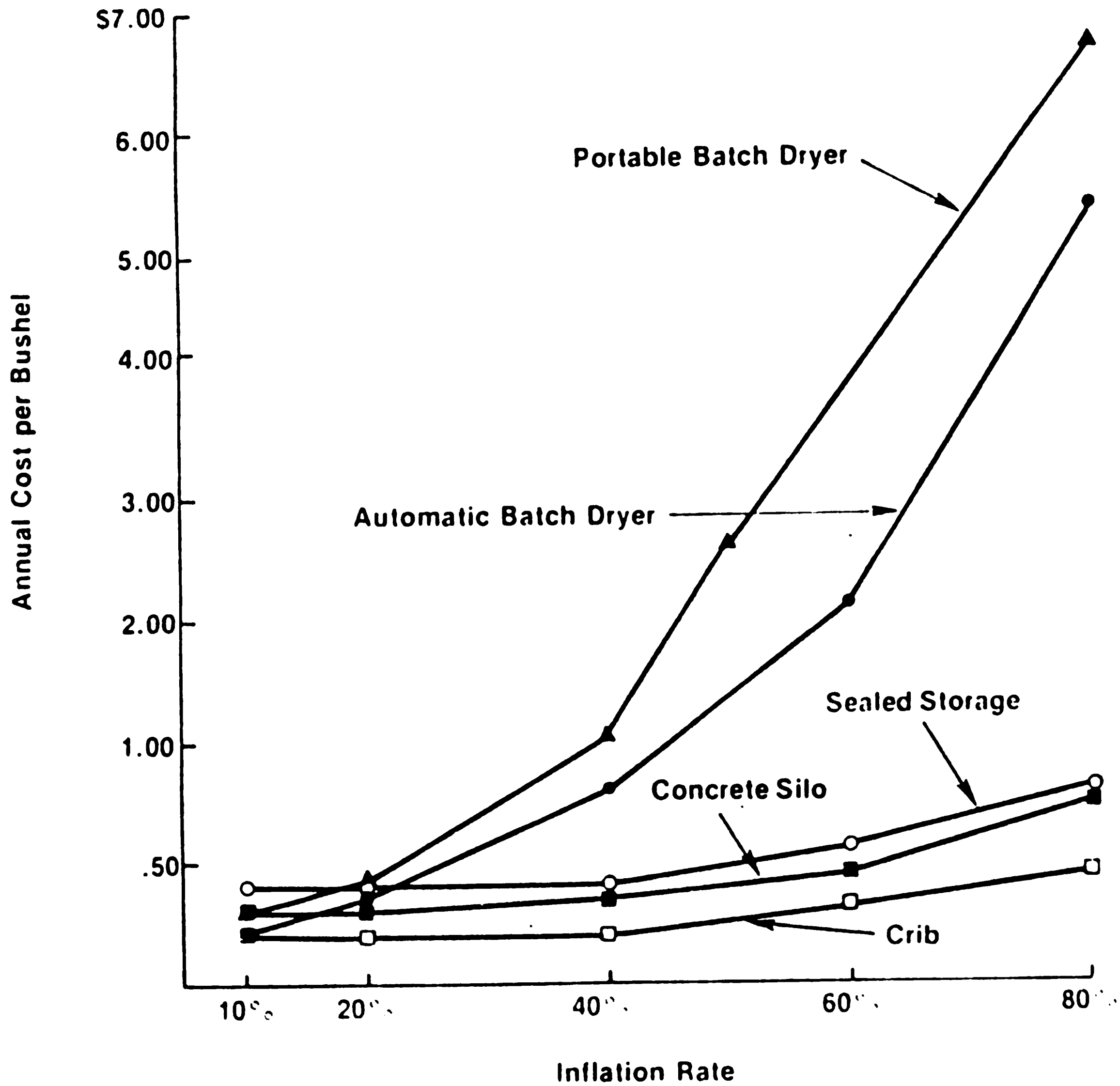

Figure 8. Ten percent to eighty percent inflation rates for energy inputs--20,000 bushels.

than automatic and portable batch dryers, greater efficiencies in propane utilization have resulted in lower annual costs at inflation rates greater than 40% for batch in bin systems.

Tabulation of Survey Data

In early November, 1978, a mail survey (Appendix I) was sent to 9,000 Michigan dairy farmers. A total of 1275 surveys (14.2% response rate) were returned by December 31, 1978.

Counties were classified according to region. The regions are shown in Figure 9. The regions being used in this study are the same as those delineated by the Michigan Agricultural Reporting Service. Thus, data compiled in this study may be compared to future Michigan Agricultural Reporting Service studies.

Corn acreages and herd sizes were grouped into five categories and are as follows: 1 to 50, 51-75, 76-100, 101-150 and 151 to high. The corn acreages and herd sizes were arranged in this manner because the author hypothesized that herd sizes and corn acreages were influenced by the types of corn storage systems utilized on dairy farms.

Soil capability and growing season are the limiting factors in the Michigan dairy industry. There is an increasing number of dairy farms and larger corn acreages as

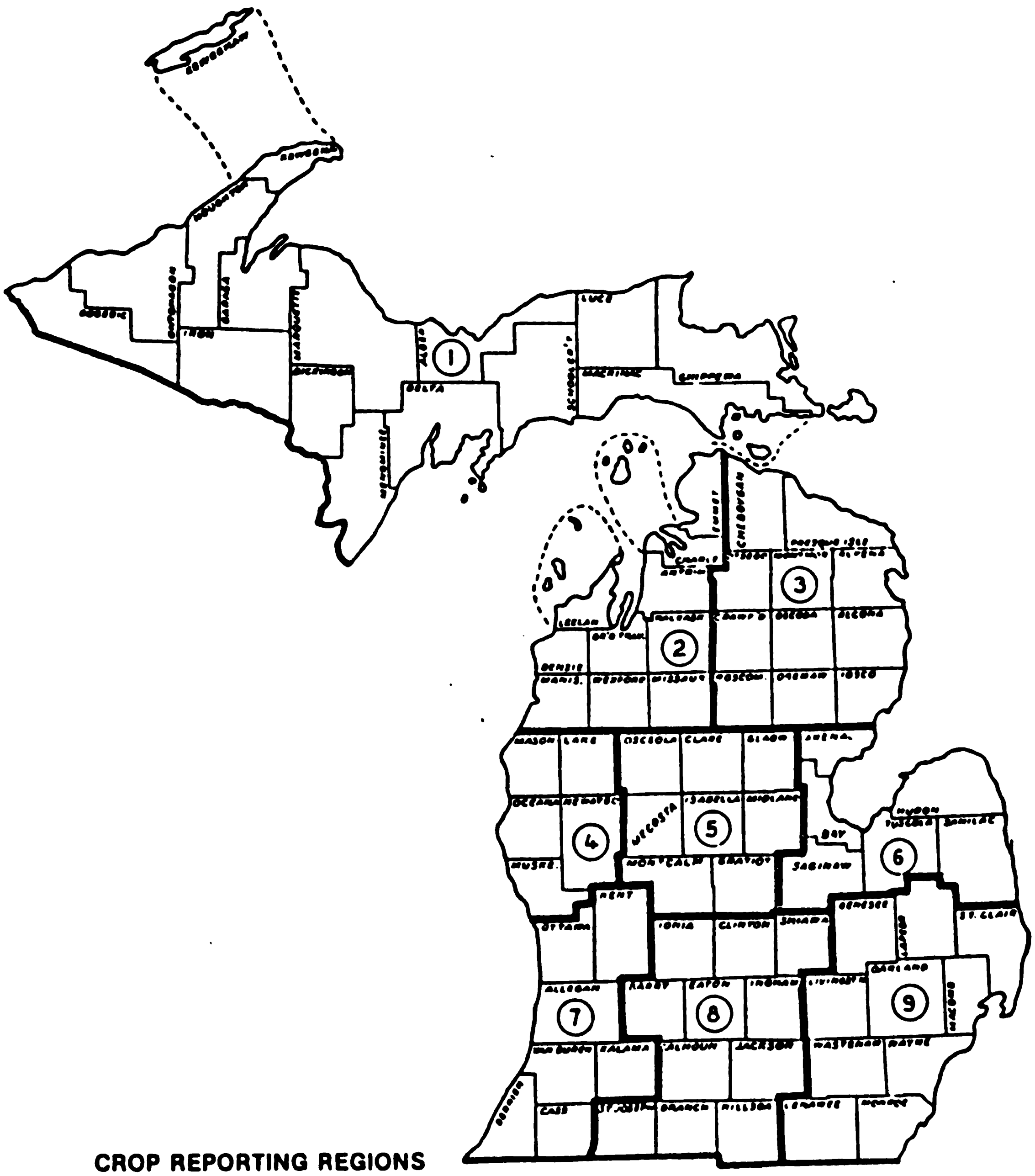

Figure 9. Michigan crop reporting regions.

one moves towards more intensive agriculture in southern Michigan. There is a smaller percentage of land capable of crop production in northern Michigan. As shown in Table 11, less corn is grown in the northern regions because of the shorter growing season and restricted acreage on which to grow corn.

Table 11. Farm Characteristics and Average Crop Acreage By Region and State

	Michigan	Region 1	2	3	4	5	6	7	8	9
Number of farms	1275	83	45	39	61	117	183	173	312	159
Average # cows	63	49	62	60	57	60	62	53	69	64
Crop (avg. acreage)										
Corn grain	116	74	52	58	81	104	122	106	148	113
Corn silage	55	44	55	60	47	61	63	40	58	56
Hay	111	175	140	122	106	124	93	98	115	107
Oats & new seeding	34	87	29	42	26	34	31	25	31	32
Pasture	49	66	46	66	27	46	36	30	29	25
Cash crops	57	40	24	63	26	91	77	45	48	62
Total tillable acreage (average)	334	272	305	358	267	433	328	289	361	339

Source: Survey data on 1275 farms.

Hay acreages increase as one moves north for two reasons. First, if a dairyman is to feed all his cows and has trouble growing corn due to soil limitations, he must grow more hay to replace corn silage. The cooler weather favors growing grass instead of corn. Oats can be grown as an energy crop in the north, particularly in the Upper Peninsula where corn cannot be easily grown.

As shown in Table 12, over 56% of the herds in the survey had herd sizes of 50 cows or less. The average herd size in this survey was 62.7 cows. This was similar to the state DHIA average of 65 cows.

Table 12. Frequency of Herd Size by Region and State

	50		51-75		76-100		101-150		> 150	
Region	No.	%	No.	%	No.	%	No.	%	No.	%
Michigan	660	56	223	19	126	11	103	9	60	5
1	64	77	8	10	4	5	3	4	4	4
2	25	55	9	20	6	13	3	7	2	5
3	25	64	4	10	5	13	3	8	2	5
4	31	51	17	28	7	11	5	8	1	2
5	66	56	20	17	17	14	10	9	4	4
6	108	59	32	17	20	11	14	8	9	5
7	86	50	46	27	15	9	19	11	7	3
8	159	51	63	20	31	10	37	12	22	7
9	96	60	24	15	21	13	9	6	9	6

Source: 1172 responses from survey data on 1275 dairy farms.

Table 13 illustrates that corn grain averages greater than 50 acres were not prevalent in northern regions. As one moves south, average corn grain acreage increased due to a longer growing season and a larger percentage of land available for producing crops.

Table 13. Frequency of Corn Grain Acreage by Region

	Corn Grain Acreage									
	50		51-75		76-100		101-150		>150	
Region	No.	%	No.	%	No.	%	No.	%	No.	%
Michigan	532	45	144	12	156	13	136	12	204	18
1	16	53	4	13	2	7	5	17	3	10
2	30	67	7	16	4	9	3	7	1	2
3	32	82	1	3	1	3	2	5	3	7
4	31	51	8	13	9	15	6	10	7	11
5	51	44	17	15	12	10	18	15	19	16
6	88	48	25	14	28	15	11	6	31	17
7	65	38	17	10	31	18	27	16	33	18
8	102	33	47	15	46	15	44	14	73	23
9	64	40	18	11	23	14	20	13	34	22

Source: 1172 responses from survey data on 1275 dairy farms.

Dairy farmers were asked (Appendix I, question 8) to mark the number and capacities of corn grain storage facilities used on their farms. Cribs were the most prevalent storage systems as shown in Table 14. Personal interviews and written comments on survey forms indicated low investment cost as the primary reason for the large number of cribs being used on dairy farms. Many dairy farmers which used cribs were 50 years old or more. They expressed the concern that they could not afford alternative storage systems in an era of high inflation and relatively low farm prices because they expected to retire within the next 5 to 10 years.

Many farms use more than one corn grain storage system. As shown in Table 15, 25% of the farms had a combination of cribs and concrete silos for storage systems. This was expected because Table 14 listed 36% and 22% of the farms having cribs and concrete silos.

Table 16 lists the total capacities for all the corn storage systems (Appendix I, question 8) being used on dairy farms. Although Table 14 showed 36% of the farms utilizing cribs, they accounted for only 5% of the total storage capacity listed in Table 16. It appears that cribs are primarily used on farms with smaller herd sizes and corn acreages. The relatively low popularity of bunker silos and wooden grain bins shown in Table 14 was reflected in the limited storage capacities of these systems in Table 16.

Table 14. Frequency of Corn Grain Storage Systems by Region and State

Region	System													
	Concrete silo		Bunker silo		Sealed storage		Steel grain bin		Wooden grain bin		Crib		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Michigan	351	22	65	4	244	15	203	13	105	6	578	36	62	4
1	9	16	2	3	12	21	8	14	14	25	9	16	3	5
2	16	28	3	5	13	23	4	7	1	2	19	33	1	2
3	8	14	4	7	10	17	9	16	6	11	15	26	5	9
4	19	25	0	0	14	18	5	7	2	3	33	43	3	4
5	43	28	5	3	19	12	19	12	12	9	49	32	6	4
6	58	22	14	5	32	12	29	11	20	8	102	38	11	4
7	57	22	14	5	34	13	35	13	13	5	102	39	8	3
8	89	19	16	3	76	17	67	15	24	5	168	37	17	4
9	52	23	7	3	34	15	27	12	13	6	81	37	8	4

Source: 1608 responses from survey data on 1275 dairy farms.

Table 15. Combinations of Corn Grain Storage Systems

System	Number	%
Concrete silo and crib	113	25
Concrete silo and sealed storage	24	5
Concrete silo and steel grain bin	19	4
Concrete silo and wooden grain bin	32	7
Sealed storage and steel grain bin	27	6
Sealed storage and wooden grain bin	5	1
Sealed storage and crib	33	7
Steel grain bin and crib	74	16
Bunk silo and steel grain bin	10	2
Bunk silo and crib	34	8
Bunk silo and other	0	0
Concrete silo and other	3	1
Sealed storage and other	15	3
Steel grain bin and other	7	2
Crib and other	44	10
Wooden grain bin and other	14	3
	454	100

Source: 454 responses from survey data on 1275 dairy farms.

Table 16. Capacities of Storage Systems

System	Material	Bushels	%
Concrete silo	HMSC	2,609,336	24
Bunker silo	HMSC	903,752	8
Sealed storage	HMSC	2,880,139	27
Steel grain bin	DSC	2,532,065	23
Wooden grain bin	DSC	798,768	8
Corn crib	low moisture ear corn	564,101	5
Other	DSC	546,101	5
Total		10,834,262	100

Source: Survey data on 1275 dairy farms.

Dairy farmers were asked (Appendix I, question 5) how corn grain was harvested on their farms. Pickers were inadvertently not included in this question. However, many survey respondents wrote pickers as the means for harvesting corn grain on their farms. Table 17 reported that pickers were used on 21% of the dairy farms. This was expected due to the large number of cribs reported in Table 14.

The budgeting process (Table 1) indicated snapper heads were one of the least cost harvesting systems. Table 17 reported a relatively low number of farms utilizing this system. As illustrated in Figure 3, there were higher total

Table 17. Frequency of Corn Harvesting Systems by Region

Region	System											
	Combine		Picker-Sheller		Snapper Header		Picker		Custom Harvest		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Michigan	425	34	266	21	147	12	256	21	133	11	10	1
1	8	25	7	22	7	22	4	12	6	19	0	0
2	6	14	6	14	12	28	11	26	1	18	0	0
3	39	62	6	10	9	14	6	10	3	4	0	0
4	19	29	12	18	12	18	13	20	10	15	0	0
5	41	34	26	22	12	10	27	23	13	11	0	0
6	61	31	46	23	31	16	44	22	12	6	3	2
7	58	30	39	20	23	12	39	20	32	17	1	1
8	132	39	69	20	26	8	74	22	33	10	4	1
9	61	35	43	24	15	9	38	22	16	9	2	1

Source: 1327 responses from survey data on 1275 dairy farms.

annual costs for HMEC storage and harvesting systems than for HMSC storage and harvesting systems.

It was difficult to justify the large number of combines reported on dairy farms in Table 17. The budgeting process indicated that combines had the highest annual cost per bushel for volumes less than 15,000 bushels. Since 70% of the survey responses were from dairy farms growing 100 acres of corn grain (9,000 bushels) or less, it appears that other factors in addition to cost entered into the decision for combine ownership. Dairymen have a shorter workday in the fields than cash crop farmers due to the time required for chores and management of the dairy herd. Thus high capacity harvesting equipment is required so that crops can be harvested during relatively short periods of time. In some areas custom harvest may not be available. If a dairyman grows corn grain and other cash crops (oats, wheat, dry beans, soybeans) he may be forced to own a combine so that he will be able to harvest his crops. Otherwise, he will be compelled to change his cropping program. Pride and prestige rather than economics could rationalize combine ownership on some farms.

The number of farms which utilized custom harvest may be misleading due to an error in the construction of the survey (Appendix I, question 5). From this question it was impossible to determine whether all or part of the corn grain was custom harvested.

The other category of harvest (Appendix I, question 5) included those farms which employed hand picking or the corn was shocked with a binder and shredded. This information was determined from reading survey responses. These harvesting systems were primarily found on farms with corn grain acreages of less than 50 acres.

Dairy farmers were asked (Appendix I, question 6) the reasons for using their present harvest system. Low labor requirements and no problems with the present harvest system were the major reasons for using present harvest systems as shown in Table 18.

Table 18. Reasons for Using Present Harvest System

Reason	Number	%
Low labor requirements	263	22
No problems with present system	393	33
Adequate rate of harvest	227	19
Changing to another system requires large investments	238	20
Other	72	6
Total	1193	100

Source: 1193 responses from survey data on 1275 dairy farms.

When dairy farmers were asked (Appendix I, question 7) if they planned to change harvest systems, 84% indicated they planned to maintain present harvest systems. In Table 19, the remaining 16% signified that slow rate of harvest and obsolescence were the primary reasons to change systems.

Table 19. Reasons to Change Harvest System

Reason	Number	%
Plan to keep present system	958	84
Slow rate of harvest	57	5
Present harvest system is worn out or obsolete	57	5
High repair costs	12	1
Other	57	5
Total	1141	100

Source: 1141 responses from survey data on 1275 dairy farms.

It was impossible to perform chi-square analysis on questions 10 and 11, Appendix I, due to inconsistencies in the response rate. Farmers were requested to list the three most important advantages and disadvantages for the corn storage systems being used on their farms. Cross checks revealed that for several storage systems there were responses in question 10 and 11, Appendix I, than the number of storage systems reported in question 8,

Appendix I.

The statistical analysis of questions 10 and 11 (Appendix I) was hampered by several problems. Eleven advantages and disadvantages were listed for each system. With a maximum of three responses being marked for each system, eight responses were left unanswered. Thus, the author did not know how the dairymen felt about the remaining responses.

The design of questions 10 and 11 should be modified in future surveys. A maximum of four factors should be listed for each question, consequently it would be easier to determine which factors statistically influenced selection of a storage system. By presenting a large array of responses in questions 10 and 11, it was possible some dairymen marked responses they had not previously considered. Thus, some of the responses may not have been true indicators of a dairyman's concept of the advantages and disadvantages for the storage systems being used on his farm.

Dairymen were requested to indicate (question 12, Appendix I) improvements desired for present storage systems. As shown in Table 20, farmers intend to expand dry and high moisture corn facilities at nearly equal rates.

Table 20. Farmers Planning to Expand Present Storage Systems

System	Number	%
Concrete silo	147	19
Bunker silo	62	8
Sealed storage	163	21
Steel grain bin	132	17
Wooden grain bin	15	2
Corn crib	178	23
Other	77	10
Total	774	100

Source: 774 responses from survey data on 1275 dairy farms.

Reasons for changing storage systems are shown in Table 21. The responses to Appendix I, question 14 were summarized in Table 21 into two categories. Group A included all responses to question 14 while Group B included only the responses to question 14 who had indicated in question 8 the type of storage system used on their farms.

Over 40% of the farmers reported they would switch storage systems if the new storage system would increase

Table 21. Reasons Farmers Change Corn Storage Systems

Reason	Percent of Responses Group A	Group B
Harvest more acres per day	10	3
Present system has limited capacity	16	9
Present system worn out and/or obsolete	6	3
High drying costs	7	1
Anticipate rising energy costs in the future	6	3
Reduction in handling after harvest	14	7
Lower storage costs	5	5
Greater mechanization of storage system	10	6
Mechanized unloading	10	14
Expect to increase milk production	14	41
Other	2	8

Source: Survey data on 1275 dairy farms.

Note: Group A = 951 responses
Group B = 415 responses from farms with the storage system known.

milk production. By raising milk production the dairymen expected increased profits. This was contradictory to the responses: high drying costs and anticipated rising energy costs in the future. Decreasing variable costs in the operation of a storage system will also increase profits. Thus it appears energy costs will not have a large impact on selection of corn storage systems.

Mechanization of handling and unloading were the most important reasons to change storage systems. Thus a reduction in labor inputs rather than costs were the primary reasons to change systems. The author could not justify the differences in responses between Groups A and B in Table 21.

Dairymen were asked if they planned to change corn grain storage systems in question 13, Appendix I. The popularity of concrete silos, sealed storages and steel grain bins in Table 22 indicated that farmers were planning to implement storage systems which could be easily mechanized.

Table 22. Farmers Planning to Change Storage Systems. New System Listed by Percentage

System	Number	%
Plan to keep present system	780	81
Concrete silo	56	6
Bunker silo	20	2
Sealed storage	40	4
Steel grain bin	40	4
Wooden grain bin	0	0
Corn crib	10	1
Other	20	2
Total	966	100

Source: 966 responses from survey data on 1275 dairy farms.

The selection of these systems reaffirmed the findings of Table 21. Table 21 stated that mechanization of unloading and reduction in handling after harvest were important reasons to change storage systems.

The response rate from the owners of sealed storage systems may be biased. The A. O. Smith Company encouraged Harvestore owners to reply to the survey. A. O. Smith supplied photo copies of the surveys to Harvestore owners. Several photo copied surveys were received and included in the survey data. A higher proportion of Harvestore owners may have replied to this survey compared to the owners of alternative storage systems. Consequently, the findings of Tables 16 and 22 may have been biased.

Dum et al. (1978) recommended grinding before ensiling in concrete and bunk silos to reduce storage losses. Table 23 showed that not all farmers utilizing these systems followed this recommendation.

The manufacturers of sealed storages systems do not recommend grinding before ensiling because the systems are airtight. Eleven percent of sealed storage system owners reported grinding before ensiling. Perhaps these farmers had storage losses from the sealed silo in previous years. Thus, grinding has resulted in a reduction in storage losses on these farms. The manufacturers of sealed storage systems encourage rolling HMC prior to feeding. This was reflected in the high percentage of sealed systems

Table 23. High Moisture Corn Processing Practices By Storage Systems

Practices	Concrete silo No.	Concrete silo %	Bunk silo No.	Bunk silo %	Sealed storage No.	Sealed storage %
Ground before ensiling	127	78	15	71	23	11
No grinding before ensiling but processing before feeding					7	3
Hammer mill	6	4				86
Roller mill	29	18	6	29	175	
Total	162		21		205	

Source: 388 responses from survey data on 1275 dairy farms.

utilizing roller mills.

Table 24 showed 53 percent of the farms utilize group feeding. Thirty-six percent of the farms reported HMC being fed as a complete ration. It appears that dairymen are feeding HMC on the basis of production so that over conditioning problems may be avoided in the later stages of lactation. The other category of HMC feeding included feeding HMC in magnetic feeders and as a top dress to high producing cows in stanchion barns.

Table 25 summarized the changes encountered by dairymen when they switched from dry corn to HMC systems. The reduction in fat cows and displaced abomasums could be attributed to the higher level of nutritional expertise

Table 24. High Moisture Corn Feeding Practices

Practice		Number	%
Group feeding			
Yes		211	53
No		187	47
		398	100
Place of feeding			
Parlor		99	22
Complete ration		165	36
Other		191	42
		455	100
Average pounds fed per day	19.9		
Average number of feedings per day	2.1		

Source: Survey data on 1275 dairy farms.

held by dairymen feeding HMC.

Dairy farmers were asked (question 16, Appendix I) to list where HMC was used on the farm besides feeding the milking herd. The number of dairy farms reporting HMC being fed to calves, heifers, dry cows and "other animals" are as follows: 305, 205, 146, 43. Survey responses in the "other animals" category included goats, swine, dairy beef and pet Black Angus steers.

Tabulation of survey responses was handicapped by several problems. Due to an error in survey design, it was not possible to determine the number of farms which had multiples of a system (e.g. cribs). The response rates to survey questions 6 through 19, Appendix I, was low. Thus it was difficult to summarize the results due to missing data.

Table 25. Change in Disorders After Changing to High Moisture Corn

Disorders	Increase		Decrease		No Change		Total	
	No.	%	No.	%	No.	%	No.	%
Mastitis	34	11	7	2	270	87	311	100
Ketosis	32	11	16	5	253	84	301	100
Metritis	15	5	29	10	249	85	293	100
Fat Cows	19	6	97	30	209	64	325	100
Displaced abomasums	17	6	60	21	205	73	282	100
Other	2	5	7	18	31	75	40	100
	119							

Source: Survey data on 1275 dairy farms.

Survey Response

A 14.16% response rate (1,275 surveys) was generated from the 9,000 surveys sent to Michigan dairy farmers. Personal interviews revealed a feeling of frustration among many dairymen for the increasing volume of forms they are being requested to answer from state and federal government agencies. Consequently, many dairymen answered only those forms that were required for the operation of their farms.

Dairymen did not return the survey for several reasons. Some dairymen did not complete the survey because they felt they had little to gain from the survey. It appeared to them that the survey information would not benefit the operation of their farms. Other dairymen returned uncompleted survey forms because they felt it was an invasion of their privacy. Several dairymen noted in personal interviews that the survey appeared complicated and time consuming. Thus, many dairymen were reluctant to complete the entire survey or only answered the first four or five questions because it took more than ten minutes to complete.

It was difficult to quantify verbal responses into specific categories. Personal interviews would be a more effective method of determining the dairymen's opinions towards the harvest and storage systems being used on dairy farms. Although this method is more time consuming, it would be more efficient since the interviewer would be exposed to a larger variety of opinions, some of which would never be written as responses to the survey. Then the researcher would be able to categorize responses into groups. Thus the researcher and not the dairymen decides the grouping of responses for each question.

Communication is the cornerstone of an effective extension program between the land grant university and production agriculture. Personal interviews indicated a widespread lack of communication between dairymen and university researchers. Many dairymen felt the university staff was not aware of their concerns and problems. They mentioned there was a lack of applied research to the problems they were facing daily in the field. When the author explained the purpose of this survey and how it could benefit them, nearly all the dairymen were eager to complete the survey. Many dairymen expressed an interest to participate in future university research projects, however their participation had never been solicited in the past. Michigan dairymen are an untapped source of research data. More personal contact between dairymen and university staff will develop a strong constituency at the local level for increased funding of educational, research and extension programs sponsored by the land grant university.

SUMMARY

The primary objective of this study was to determine at what point farmers will switch from artificially drying corn to either high moisture corn or ear corn systems. An economic framework was developed in which a dairyman will be able to determine the total annual costs on a per bushel basis in constant dollars for potential harvesting and storage systems that are under consideration for implementation on his farm. A survey on corn harvesting and storage systems was sent to 9,000 Michigan dairy farmers. Survey results were summarized to determine when dairy farmers will change storage and harvest systems.

Total annual cost per bushel for harvesting and storage systems were calculated at volumes of 1,000, 5,000, 10,000, 15,000, and 20,000 bushels. Harvesting and storage systems considered in this project are as follows:

Harvesting	Storage
1 row corn picker	low moisture ear corn
2 row corn picker	automatic batch dryer
2 row picker sheller	portable batch dryer
1 row snapper head	steel grain bin
2 row snapper head	concrete silo for HMC
4 row combine	sealed silo for HMC, full bin dryer with stirrators

Total annual cost per bushel was calculated on a constant dollar basis using the capital investment model, Teleplan III. Cost data incorporated into the analysis are as follows: 10 year planning period, 20% tax bracket, 10% salvage value on harvesting equipment, 30% salvage value on storage systems, 7% inflation rate, 9% electricity and gasoline inflation rate, 11% propane inflation rate.

Cribs were the least cost storage system due to their low investment cost. Full bin dryers provided the second least cost storage system followed by concrete silos, automatic and portable batch dryers and sealed storage units. Full bin dryers were competitive in price because they could be used for both drying and storage. The full bin dryer had an advantage of $.05 and $.07 per bushel over concrete silos for 5,000 and 10,000 bushels. Full bin dryers were more efficient in propane utilization than batch drying systems. Full bin systems had lower costs of $.20 and $.13 per bushel over automatic batch systems for 5,000 and 10,000 bushels, respectively. Sealed storage was the most expensive storage system due to the high initial investment. Sealed storage systems had higher annual costs of approximately $.34 and $.30 per bushel for volumes of 5,000 and 10,000 bushels compared to full bin drying systems.

Two row snapper heads and two row picker-shellers were the lowest cost harvesting systems due to longer harvest seasons and lower investments. Pickers had higher costs at volumes greater than 10,000 bushels due to a delayed harvest season. A one row picker was the lowest cost harvesting system for volumes less than 5,000 bushels. The four cow combine had the highest annual costs due to the large initial investment.

Annual energy inflation rates were allowed to vary from 10% to 80% within the capital investment model to determine the more economical harvest and storage system with rising energy costs. At volumes ranging from 5,000 to 20,000 bushels annual energy inflation rates greater than approximately 20 percent economically justify changing from drying systems to high moisture corn systems. When compared to drying systems, sealed storages and concrete silos had lower annual costs per bushel at higher inflation rates because minimal amounts of energy are required to operate these systems. In sealed and concrete silos, energy useage is limited exclusively to mechanical loading and unloading. Due to greater investment costs, sealed storage systems had higher annual costs per bushel than concrete silos.

Eighty-four percent of the farms did not plan to change harvest systems. Low labor requirements and no problems with present harvest system were the major reasons for not changing harvest systems.

In the tabulation of survey data, counties were classified according to region. The average acreages of corn grain and cash crops were the highest in the southern regions of the state.

Cribs were the most prevalent type of storage systems. Concrete silos, sealed storage and steel grain bins were the next most popular systems.

Combines were the most popular harvesting system. Picker-shellers and pickers were the second and third most popular harvesting systems.

Expectations of higher milk production and increased mechanization of the storage system were the primary reasons to change storage systems regardless of present storage system. Eighty-one percent of the dairymen reported they did not plan to change storage systems. Lower storage costs and rising energy costs were not considered as important reasons to change storage systems.

Fifty-three percent of the farms feeding HMC utilized group feeding. Thirty-six percent of the HMC was fed in complete rations. It appeared dairymen feeding HMC had a greater understanding of the cow's nutritional requirements and the role of HMC in the diet. This was shown by the reduced incidence of fat cows and displaced abomasums when changing from dry corn to HMC rations.

The objectives of the study were not completely met. Expectations of higher milk production and increased mechanization of the storage system were the major reasons for changing storage systems. Consequently, it cannot be predicted when farmers will switch from artificially drying corn to low moisture ear corn or high moisture corn storage under the spectrum of rising energy costs. Eighty-four percent of the dairymen indicated they did not plan to change harvest systems. One percent of the responses reported high repair costs as a reason to change harvest systems. The survey did not contain questions regarding harvest systems dairymen were planning to implement on their farms. As a result, projections for changes in harvest systems being implemented on dairy farms could not be made.

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APPENDICES

APPENDIX I

Mail Survey

1. Farm location

   a. County ________________ b. Township ______________

2. Number of milking cows last month _______ Number of

   dry cows last month ________

3. Pounds of milk sold last month ____________

4. Acreages for the following crops (1977 seasons - owned and rented)

   a. Total tillable acreage _________________

   b. Corn for grain __________________

   c. Corn silage __________________

   d. Hay __________________

   e. Oats and new seeding ___________________

   f. All other cash crops ___________________

   g. Pasture ____________________

5. How do you harvest your corn for grain? Number of rows

   a. Combine _____________

   b. Picker-sheller _____________

   c. Snapper-header (chopper) _____________

   d. Harvested by a custom operator _____________

6. What are the reasons for using present harvest system? (Circle those which apply)

   a. Low labor requirements.

   b. No problems with present system.

   c. Adequate rate of harvest.

   d. Changing to another system requires large investments.

   e. Other, please specify____

   ____

   ____

7. Do you plan to change the harvest system?

   a. No.

   b. Yes. If yes, what are your reasons for changing? (Circle those which apply)

      1. Slow rate of harvest

      2. Present harvesting equipment is wornout or obsolete.

      3. High repair costs.

      4. Other, please specify____

      ____

      ____

8. What kind of corn for grain storage facilities (exclude corn silage and haylage) do you now have on your farm? What is the approximate capacity of each kind? (Circle those which apply)

Kind	Approximate dimensions and/or capacity		
	Tons	Bushels	Dimensions
a. concrete silo	______	______	______
b. bunker silo	______	______	______
c. sealed storage (Harvestore) or similar structure	______	______	______
d. steel grain bin	______	______	______
e. wooden grain bin	______	______	______
f. corn crib	______	______	______
g. other, please specify	______	______	______

9. Do you plan to continue using your present storage facilities? (Circle one)

   a. Yes

   b. No

10. Now we want your opinion about the major advantages for each of the kinds of corn for grain storage facilities on your farm. Circle the systems used on your farm. Rank the three most important factors for each system by writing:

1. most important 2. second most important 3. third most important

Systems	Don't have to take corn to the elevator for grinding	Harvest at moisture levels greater than 30 percent	Mechanical unloading of storage facilities	Inexpensive storage facilities	Harvest more acres per day	Plant full season variety	Mechanized feeding system	Mechanical handling	Lower drying costs	Limited spoilage	Other, specify
a. concrete silo											
b. bunker silo											
c. gas tight silo											
d. steel grain bin											
e. wooden grain bin											
f. corn crib											
g. other, please specify											

11. Now we want your opinion about the major disadvantages for each of the kinds of corn storage facilities on your farm. Circle the systems used on your farm for each system by writing:

1. most important 2. second most important 3. third most important

	Large investments required in storage facilities	Slower rate of harvest	Decreased palatability of stored material	Cannot harvest until corn is below 30 percent	Mold	Drying costs	Limited market for stored material	Butterfat depression	Low moisture 21-23% unpalatable to cows	Considerable labor needed to unload the system	Other, specify
a. concrete silo											
b. bunker silo											
c. gas tight silo											
d. steel grain bin											
e. wooden grain bin											
f. corn crib											
g. other, please specify											

12. What improvements would you like to make on your present storage system? Circle all responses which apply.

    a. Go to larger harvesting equipment

    b. Increased storage capacity

        1. concrete silo
        2. bunker silo
        3. Harvestore
        4. steel grain bin
        5. wooden grain bin
        6. corn crib
        7. other, specify________________

13. Do you plan to switch to a different type of corn storage system?

    a. No   b. Yes, please circle one

        1. concrete silo
        2. bunker silo
        3. Harvestore
        4. steel grain bin
        5. wooden grain bin
        6. corn crib
        7. other, specify________________

14. If you plan on switching systems, what reasons would cause you to change corn corn storage systems? Circle all reasons which apply.

    a. Harvest more acres per day
    b. Present systems has limited capacity
    c. Present system is worn our and/or obsolete
    d. High drying costs
    e. Anticipate rising energy costs in the future
    f. Reduction in handling after harvest
    g. Lower storage costs
    h. Greater mechanization of storage system
    i. Mechanized unloading
    j. Expect to increase milk production
    k. Other, specify________________

15. For those farmers using high moisture corn, we want to know some things about your use of high moisture corn as feed for milking cows.

    a. Dimensions of silo used for storage________________________

    b. Is the high moisture corn processed before ensiling?

        1. No   2. Yes. Please circle one ---ground or other, specify________

        3. Processed before feeding. If Yes, specify____________________

            a. hammer mill   b. roller mill

        4. Group feeding

            a. No   b. Yes

        5. Approximate pounds fed per cow per day____________

        6. Number of feedings per day____________

        7. How is the H.M.C. fed? Circle one

            a. parlor   b. complete ration

            c. other, specify____________________________

16. Besides feeding the milking herd, where is H.M.C. used on the farm? Circle all that apply.

a. calves (1-12 months

b. heifers (13 months-freshening)

c. dry cows

d. other

17. Amount of corn sold each of the past two years:

	1977 Crop		1976 Crop	
	Bu.	Tons	Bu.	Tons
a. ear corn	____	____	____	____
b. dry shelled corn	____	____	____	____
c. high moisture shelled corn	____	____	____	____
d. high moisture ear corn	____	____	____	____
e. snapped ear corn	____	____	____	____

18. Do you buy corn? (Circle one)

a. No b. Yes c. If yes, please specify the type and amount purchased since October 1, 1977 and that you plan to purchase before the harvest 1978.

	Tons (as is basis)	Bushels
1. high moisture ear corn	____	____
2. high moisture shelled corn	____	____
3. ear corn	____	____
4. dry shelled corn	____	____
5. snapped ear corn	____	____

19. Since switching to H.M.C. has there been a change in the following disorders in the herd?

	Decrease	Increase	No Change
a. mastitis	____	____	____
b. ketosis	____	____	____
c. metritis	____	____	____
d. fat cows	____	____	____
e. displaced abomasums	____	____	____
f. please specify below			

Please state any additional comments below.

Please return this questionnaire in the enclosed envelope. We thank you for taking the necessary time to complete the questionnaire.

APPENDIX II

Average Total Field Losses of Corn as Influenced by Length of the Harvest and Moisture Content at the Beginning of Harvest. Cool, Humid Season, Picker with Spiraled, Lugged Snapping Rolls.

Length of Harvest, Calendar Days	Moisture Content Beginning of Harvest, % Kernel Moisture						
	35	33	30.2	27.5	25.1	22.9	20.8
	(Average total field losses, % of total yield)						
	2 mi/hr						
9	3.2	3.2	3.9	5.2	7.1	9.4	11.8
13	3.3	3.4	4.0	5.7	7.7	10.0	12.4
17	3.4	3.6	4.6	6.2	8.3	10.6	13.1
21	3.5	3.8	5.0	6.7	8.9	11.2	13.8
25	3.8	4.1	5.4	7.3	9.4	11.9	14.5
29	4.1	4.5	5.9	7.8	10.0	12.5	15.3
33	4.4	4.9	6.5	8.4	10.7	13.3	16.2
37	4.8	5.4	7.0	9.0	11.3	14.0	17.1
41	5.2	5.8	7.5	9.6	12.0	14.8	18.1
45	5.6	6.3	8.1	10.2	12.8	15.7	-
	5 mi/hr						
9	4.8	4.7	5.6	7.6	10.3	13.5	16.9
13	4.9	4.9	6.1	8.3	11.1	14.4	17.8
17	5.0	5.2	6.6	9.0	11.9	15.2	18.6
21	5.2	5.6	7.2	9.7	12.8	16.1	19.6
25	5.6	6.1	7.9	10.5	13.6	16.9	20.5
29	6.0	6.6	8.6	11.3	14.4	17.9	21.5
33	6.4	7.2	9.3	12.1	15.9	18.8	22.4
37	7.0	7.8	10.1	12.9	16.2	19.7	23.4
41	7.6	8.5	11.0	13.8	17.1	20.7	24.4
45	8.2	9.2	11.8	14.7	18.0	21.6	-

Source: Johnson and Lamp, 1966.

APPENDIX III

INVESTMENT COST DATA

Harvesting systems		Total Cost
1 row corn picker		$ 4,500
2 row corn picker		8,800
2 row picker-sheller		8,900
1 row snapper head	.5(5000)+2500	5,000
2 row snapper head	.5(8400)+4200	8,400
4 row combine	.5(36,000)+7000	25,000

The costs for the 1 row snapper header, 2 row snapper header, and 4 row combine were allocated as follows: one-half cost of base unit + 100% cost of header attachment.

Storage systems	Dimensions	Bushels	Total Cost
corn crib		960	$ 900
wet holding bin		2,000	2,750
sealed storage	20'x28'	4,943	18,087
sealed storage	20'x36'	6,662	22,815
sealed storage	20'x50'	9,671	27,185
sealed storage	20'x59'	11,605	30,254
sealed storage	20'x80'	16,119	40,127
sealed storage unloader	20'		8,579
sealed storage unloader	20'		10,000
concrete silo	12'x25'	1,768	3,582
concrete silo	16'x45'	5,031	8,172
concrete silo	20'x60'	10,810	13,914
concrete silo	20'x80'	15,722	16,000
concrete silo unloader	12'		3,300
concrete silo unloader	16'		3,500
concrete silo unloader	20'		3,700

Storage system prices include foundation and erection costs.

Silo unloader prices include a 5 HP electric motor, labor, and supplies necessary for installation of the unloader.

Concrete silo capacities were calculated using 28 percent HMSC while sealed storage capacities were calculated using 25 percent HMSC.

A heavy duty silo unloader that cost $10,000 was used in sealed storage systems which had heights greater than 60'.

APPENDIX III

(cont'd)

INVESTMENT COST DATA

Storage systems (cont'd)

Grain bin with aeration system components

diameter	18'	21'	27'	33'	33'
capacity	2,415bu	4,910bu	9,676bu	16,783bu	20,580bu
bin	$1,937	$2,826	$4,836	$6,459	$7,892
drying flues	174	180	458	557	557
aeration fan	775	775	775	1,395	1,395
fan motor	195	195	195	295	295
unloading auger	93.50	138.50	183	147	147
sweep auger	103.50	104.50	123	176	176
erection	250	500	1,000	1,500	2,000
concrete	224	248	353	510	510
grain baffle	21	21	21	21	21
2 (1) HP motors	226	226	226	226	226
TOTAL COST	$3,999	$5,214	$8,170	$11,286	$13,219

Aeration fans equipped with 5 HP electric motors for 18', 21' and 27' diameter bins, while 7.5 HP electric motors were used on 33' diameter bins.

1 HP motors were used to power unloading and sweep augers.

APPENDIX III

(cont'd)

INVESTMENT COST DATA

Storage systems (cont'd)

Grain with stirrator drying system components			
diameter	18'	24'	30'
capacity	3,000bu	5,000bu	9,200bu
bin	$3,400	$4,167	$6,315
drying floor	1,415	2,262	3,108
crop dryer	1,911	2,029	2,180
dryer controls	69	69	69
stirrator	1,478	2,064	2,180
grain spreader	299	299	299
sweep auger	93.50	121	150
unloading auger	103.50	115	126
concrete	224	300	450
2 (1) HP motors	226	226	226
erection	300	500	920
TOTAL COST	$9,519	$12,152	$16,164

Crop dryers were equipped with 7.5, 9.0 and 12.0 HP electric motors for 18', 24' and 30' diameter bins. 1 HP electric motors were used to operate stirrator and unloading and sweep augers.

APPENDIX IV

INPUT COSTS (DOLLARS) PER 100 BUSHELS

	Labor	Propane	Electricity	Gasoline
Harvesting systems				
1 row picker	$4.17	-	-	$3.28
2 row picker	2.18	-	-	1.71
2 row picker-sheller	2.18	-	-	1.71
1 row snapper-header	4.17	-	-	3.28
2 row snapper-header	2.18	-	-	1.71
4 row combine	.83	-	-	.94
Storage systems				
corn crib	$3.33	-	$ .05	$ .54
portable batch dryer	1.60	$13.25	-	4.03
automatic batch dryer	.53	13.25	-	.84
wet holding bin	.80	-	.04	-
sealed silo	.80	-	-	.88
sealed silo unloader	1.75	-	.12	-
concrete silo	.80	-	-	.88
concrete silo unloader	2.63	-	.12	-
2415 bu grain bin with aeration	1.68	-	.19	-
4910 bu grain bin with aeration	1.68	-	.12	-
9676 bu grain bin with aeration	1.68	-	.10	-
16783 bu grain bin with aeration	1.68	-	.09	-
20580 bu grain bin with aeration	1.68	-	.09	-
full bin dryer with stirrators	1.68	8.52	1.93	.25

APPENDIX IV

(cont'd)

Assumptions for calculations of input costs:

1. gasoline/hr = .06 x horsepower of engine

2. KHR/hr = .9 x horsepower of electric motor

3. 500 bushel per hour loading and unloading rates from wet holding bin, automatic batch dryer and steel grain using 3 HP electric motor

4. 300 bushel per hour loading and unloading rate for corn crib using 2 HP electric motor

5. 500 bushel per hour filling rate for concrete silo and sealed storage

6. concrete silo unloading rate 150 bushels per hour using 5 HP electric motor

7. sealed storage unloading rate 228 bushels per hour using 7.5 HP electric motor

8. 70 HP tractor required for filling concrete silo and sealed storage

9. Labor costs per bushel = handling rate/$4.00 per hour

10. Labor for unloading sealed storage and concrete storage was charged to the operation of the unloader

11. 1.5 hours to load and unload each 500 bushel batch from portable batch dryer

12. portable batch dryer automatically shuts off when grain reaches desired moisture level

13. grain is automatically unloaded from wet holding bin into automatic batch dryer

14. $.08/100 bushel labor cost to supervise operation and management of automatic batch, full bin drying system and grain bins aeration systems

15. 13 HP electric motor and 2 (1) HP electric motors were required to operate an automatic batch dryer

16. 2 (1) HP electric motors were required to operate unloading and sweep augers in grain bins

APPENDIX IV

(cont'd)

17. Gasoline costs of \$.25/100 bushels were charged for hauling wet corn to sealed storage, concrete silo, full bin dryer, automatic batch and portable batch dryers

18. a 70 HP tractor was used to haul low moisture ear corn and consumed 2.1 gallons per hour or bushels fuel cost

APPENDIX V

Unusual Survey Responses

Eighty-five percent of the surveys were not returned and completed. The following responses are a sample of the surveys that were returned but not completed due to a variety of reasons:

On strike!

Sounds like a typical example of bureaucratic waste of time and money.

We have no cows and raise no corn, Amen.

I refuse to fill out your questionnaire. Mrs. Dairy Farmer.

I am a smaller farmer and farm like they did 50 years ago. It would be impossible to answer these questions. I think it would be better if all farmers would go back 50 years. Then there would be no surpluses.

When a man has "know how" he should be able to keep it to himself. General Motors does not tell all their secrets to everyone, why should I tell all mine.

I am a small time dairy farmer with a full time job. I do not have time to fill out surveys.

I am on Social Security, so I do not farm much.

#$%¢&* and I'm not just a windy.

MSU is a giant country club. Why don't the professors come out and talk to the farmers while they are working. It would do them some good to get some manure on their shoes.

We sold our dairy last fall and are now making money with beef cows.

I do not believe in mechanization. I pick all my corn and milk my cows by hand.

Farmers will use a post paid return envelope for most anything.

Although surveys were not included, I received the following items in the survey return envelope:

- contract for frozen semen tank
- tractor survey from Agricultural Engineering at Michigan State
- a land contract.