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THE DEVELOPMENT OF GRAIN-FEED STORAGE AND HANDLING SYSTEMS FOR LIVESTOCK FARMS

by

Bruce Aldus McKenzie

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Agricultural Engineering

1958

APPROVED: D. E. Kirk

BRUCE ALDUS McKENZIE ABSTRACT

Grain-feed handling on livestock farms is a highly repetitive operation that will justify mechanization. Grain-feed handling methods and facilities on livestock farms are a hetereogeneous lot; scoop shovel methods of handling prevail; coordinated equipment arrangements for complete mechanical handling are difficult to find. Storage structures dating over several generations are still in use; new structures are selected according to tradition, rather than function; both old and new building designs are planned with little consideration of mechanized handling. The locating of structures in relation to grain-feed preparation and distribution appears to be done on a random basis.

Some improvement in grain-feed handling efficiency on livestock farms can be made by modifying existing facilities and practices. But such a study is an attempt to solve problems created by wrong decisions in the past. More significant progress can be made by studying ways of avoiding such mistakes in the future.

The grain-feed handling systems presented in this thesis are a plan for the future. They outline an organization of buildings and equipment into an integrated system for storing, handling, and processing livestock grain-feed. The systems are planned to permit a gradual or immediate transition from existing practices.

BRUCE ALDUS McKENZIE ABSTRACT

A procedure is developed for analyzing grain-feed handling systems for livestock farms. This procedure is supplemented by the development of general design fundamentals. Considerations in design that cannot be summarized into a fundamental are analyzed in terms of their influence under various circumstances.

Grain-feed handling systems are developed that present a maximum practical opportunity for mechanized materials handling. These systems embody current and projected practices in building types and storage and handling methods. Commercially available grain storage structures and handling equipment make up the primary system components.

Investment and use cost schedules are presented for all components featured in the system layouts. Selected storage and handling systems and components are analyzed in detail to demonstrate a procedure for estimating cost. Although systems of processing grain are not analyzed, data sufficient for estimating costs are presented.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Handling grain and processed feed on a livestock farm is virtually an everyday job. Out of the multitude of storage structures must flow the daily ration of grain to the feed lots. By basket or by scoop, in sack or in bulk, on truck or with tractor, this is feed handling. Coordinate the buildings, the equipment, and the work methods with an operating procedure, and the result is a system--a feed handling system.

From an engineering point of view there are three approaches that can be used in considering grain-feed handling[1] systems for livestock farms. The first of these is to consider methods of improving systems existing on specific farms, utilizing buildings and equipment in use. The method would offer immediate results, assuming the analysis was meaningful, but would be somewhat limited in application due to the unique nature of each farmstead considered. The study would concentrate heavily on problems created by past decisions rather than determine ways of avoiding such problems in the future.

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[1]Grain-feed handling as used here means the handling of that grain to be fed to livestock, either in a whole or processed form. Throughout the remaining text, grain handling and feed handling will both be used to describe such grain-feed handling, depending on which most aptly fits the discussion at hand. Feed in this context means only concentrate rations.

A second type of analysis would involve a complete rejection of everything now existent in types of materials handled and methods employed, and would attempt to predict the system of handling grain in the future. The study would seek to outline new methods and components for systems of the future. Results would be of benefit to farmers only to the extent that the predictions became reality.

A third approach would consider equipment and methods successfully used on livestock farms, and develop and analyze ways and means of combining these components and methods into new, more efficient systems. Where necessary (and possible), new components or methods would be designed to complete a particular system.

The latter method is the approach of the following analysis. Its scope lies somewhere between the previous two methods. It seeks to pick up the problem at the stage of solution presently attained on many farms, and to project this into a plan for future development.

The Problem

The grain handling facilities on livestock farms are a heterogeneous lot. Structures for the same grain often differ markedly in design. Units of origin dating over several generations still stand with new units. Old and new buildings show little or no fore-thought of mechanical unloading. Storage facilities appear to have been located

at random. Their only common bond appears to be that they are "on the farmstead."

Out of all of this must flow the daily livestock ration of grain. This we have assembled that we may bring about the simple marriage of material in an animal's stomach. This is the objective.

But what about the efficiency of attaining that objective? A 30 cow dairy herd will require approximately 50 tons of grain per year. If this is handled four times, 200 tons must be moved. A 25 sow, 2 litter swine operation consumes 200 tons of grain per year, or 800 tons to handle on a four-time-repeat basis.

Four re-handlings may be conservative for many farms. At harvest time, a bushel of grain is generally moved from the harvester to a wagon, and then to storage. In preparation for feeding, the grain may be removed from storage, loaded on a vehicle, hauled to mill, unloaded, handled through the mill, reloaded, returned to the farm, and unloaded into storage. If the storage is not a self-feeder, the ration must be re-handled to be fed.

Not all of these steps are involved on all farms, or with all grains. Some grain may be stored at harvest in self-feeders and fed direct from storage. On other operations, grain handling systems will involve added steps attributed to several kinds of grain stored in different buildings or on different farmsteads.

Obviously, some re-handling is unavoidable where grain must be processed prior to feeding. But needless re-handling represents unproductive effort and investment that could be devoted to other tasks or to leisure. With 30 to 40 per cent of the average farmer's time presently spent in routine chores, (2, 19), a highly repetitive operation such as feed handling must operate at top economical efficiency. Kleis (24) in a study of materials handling systems on livestock farms found ground feed to require the most handling time per ton of all materials studied.

The per cent of total time spent in routine chores is not decreasing as fast as field time (19). In the period 1940 to 1956, production per man-hour in meat animals increased only 14 per cent, and in dairy 69 per cent (38). Measured on the same basis, hay and forage production increased 118 per cent and feed grains 305 per cent. This is due in part to the fact that numbers of livestock have increased while numbers of acres of cropland have not changed materially. A larger share of the difference, however, can be attributed to the standardization of field practices as opposed to farmstead practices. With standardized field practices, manufacturers have marketed a multitude of machinery of many sizes and capacities. Both the market and the performance were reasonably predictable.

Farmstead mechanization, on the other hand, must be integrated into existing buildings and the particular management practices in force. This means custom engineering with costly installation. Manufacturers have been reluctant to gamble on such markets and farmers hesitant to buy at the asking prices. The lack of accurate cost and return data has further limited progress.

Farm building manufacturers have done little to help chore mechanization. Since they do not generally manufacture materials handling equipment, they have tended to sell buildings and leave the mechanization up to the farmer. The resulting system often falls far short of what could be attained in a pre-engineered package. The one exception is the grain drying packages offered in many prefabricated structures. Such packages undoubtedly came about because they enhance the sales possibilities.

The long time nature of investments in farm buildings further complicates the problem. At best, one may be able to predict several years into the future. Farm buildings, on the other hand, generally last at least 20 years. Decisions must be reckoned with over considerable time, whether right or wrong. Ideas cast in concrete are difficult and costly to change.

Grain-feed handling systems for livestock farms are needed that embody a more scientific integration of buildings and equipment into a system for preparing livestock grain rations. The systems should permit a gradual transition from old to new, to permit economical use of sound existing structures. Construction should be possible as a completely new unit, or as a step by step project extending over several years.

The systems should present a plan for the future. They should serve as a guide to farmers, extension personnel, power suppliers, and farm building contractors in designing grain handling facilities and systems. The results of the analysis should further serve as a recommendation to manufacturers of buildings and equipment for pre-packaged materials handling systems.

II. OBJECTIVES

The general objective of this study is to develop grain and feed storage and handling systems for livestock farms. More specific objectives are:

1. The design of coordinated grain-feed handling facilities that afford a maximum practical opportunity for efficient materials handling on livestock farms.
2. The selection and design of alternative equipment combinations for mechanizing grain handling through the storage facilities.
3. The development and analysis of the costs associated with combinations of storage facilities and mechanized grain handling under several levels of grain through-put.

III. LITERATURE REVIEW

A search of technical and popular literature on materials handling on the farm finds references to many phases of the problem. Some of these works relate to over-all problems of system design, while others concentrate on a particular component. The literature reviewed on the following pages is not a complete listing of all such references, but is rather a selection of those deemed most pertinent to the problem at hand. Most of the selections are drawn from the more technical works.

The review is presented under six sections including: General Labor Considerations, Farm Buildings, Grain Handling Equipment, Grain Processing Equipment, Ground Feed for Livestock, Materials Handling Analysis, and Cost Analysis.

General Labor Considerations

Routine chores performed in and around farm buildings require 7 billion man-hours per year, according to Ashby (1945). In terms of specific livestock enterprises, he places the amount of total time in chores at 80 per cent for dairy, 80 per cent for poultry and eggs, 40 per cent for swine, 30 per cent for cattle and calves, and 20 per cent for sheep and lambs. He predicts that 1 billion man-hours per year could be saved by better, handier farm buildings.

Hecht (1955) suggests that since World War II, a figure approaching 40 per cent of total time for routine chores is more correct than 30 per cent. He states that the average farm worker is spending an increasing proportion of his total time on routine chores. Hecht attributes the relative increase in routine chores to the fact that the reduction in chore time per head of livestock has been less than the decrease in man-hours per acre for crops. In addition, numbers of most kinds of livestock have increased while acres of crop land has remained relatively constant.

Data presented in the United States Department of Agriculture Agricultural Outlook Charts (1958) substantiate the statements of Hecht. Cropland for the period 1920 to 1956 has remained nearly constant at 100 per cent, using the period 1947 to 1949 as a base. Numbers of livestock breeding units for the same period have demonstrated a generally upward trend. Starting at 90 to 95 per cent in the early twenties, numbers fluctuated around this level until an abrupt climb to a peak of 120 per cent during World War II. Dropping sharply to the 100 per cent level by 1948, the index again began to climb, standing at approximately 105 per cent by 1956.

Production per man-hour for crops and livestock, in contrast show wide differences in gains made in the period

1940 to 1956 (Table I). While meat animal production efficiency has advanced only 14 per cent, feed grain production per man-hour has advanced 305 per cent.

TABLE I

PER CENT INCREASE IN PRODUCTION PER MAN-HOUR FOR SELECTED CROP AND LIVESTOCK ENTERPRISES

Livestock or Feed Crops	1910-1956	1910-1940	1940-1956
	Per Cent	Per Cent	Per Cent
Meat animals	25	11	14
Milk cows	89	20	69
Poultry	106	16	90
Hay and forage	137	19	118
Feed grains	349	44	305

Cooper, _et_ _al_. (1947), writing on the progress of farm mechanization, state that of the 21.2 billion man-hours spent on farms in 1944, 13 billion man-hours or 60 per cent were done by hand or with hand tools such as an axe, pitchfork, shovel, hoe, et cetera. The authors state that 75 per cent of the man-hours spent with livestock is hand labor. They cite feeding, watering, and manure handling operations as problems needing improved systems.

Searching for more specific labor requirements associated with materials handling on livestock farms, Kleis (1957) reported data compiled from 320 Michigan livestock farms. Considering 30 different materials handling operations, Kleis classified the methods of performing these operations as eliminated, manual, semi-mechanized, mechanized, and automatic. The operations on each farm were classified according to the methods employed. The time, tonnage, and equipment involved in each operation were obtained in consultation with the farm operator.

Some conclusions in the study by Kleis most pertinent to the analysis at hand were:

1. Materials consuming the most handling time per ton:
    a. Ground feed--first of three.
2. The most highly mechanized handling is associated with:
    a. Small grains--third of three.
3. General types of operations requiring the greatest handling time:
    a. Feeding or distributing.
    b. Removal from storage.
    c. Moving from storage to area of use.
4. Considering average annual tonnage involved along with the man-hours per ton, the materials requiring the most annual total time were:
    a. Ground feed--first of four.

5. Materials handling operations conspicuous for the time required:
    a. Feeding ground feed--second of seven.
    b. Moving ground feed from storage to feeding area--third.
    c. Removal of ear corn and small grains from storage--sixth.

Kleis suggests that while some operations in handling most feeds are well mechanized, little consideration has been given to their integration into the total handling program. He suggests a need for engineering to bring about such integration. He reports a highly significant correlation co-efficient between the amount of materials handling mechanization and the over-all farm production efficiency.

Farm Buildings

Farm buildings are often the bottleneck in handling materials on the farm. The high investment requirements and relatively long life of farm structures present a static dimension to system planning. Mayer (1947) states that all farm building designs should be studied critically from the standpoint of the best utilization of labor used in the activities in each structure. The location and relationship of each farm structure should be studied with respect to other buildings and the total farmstead.

Carter (1953), writing on challenges in farm building design, makes a plea for a coordination of engineering thought with the science of production and the principles and practices of operation and management. According to Carter, research has demonstrated that engineering of structures, methods, operations, and equipment can double the output per farm worker. The increased output comes about through reduced labor, increased yields, and preservation of quality.

Carter states that changes to tractor power, hybrid seed, commercial fertilizer, et cetera, has placed new pressures on the farmstead physical plant and its design. In his opinion, much of the improvement in farm structures in the past has been in the form of details, additions, attachments, or new versions of traditional structures. He suggests that the greatest current need is that of a new attack to create entirely new facilities. The engineer, according to Carter, is charged with the responsibility of accepting new resources and anticipating new demands, rather than waiting until other pressures compel him to act.

Carter foresees several obstacles that must be overcome by the farm building designer, namely, the relative permanence of farm buildings, and the natural resistance to change. He suggests that buildings should be considered on the same basis as any other production tool. In his opinion, it is unfortunate that farm building improvements are classed as real-estate instead of as operating equipment.

Grain Handling Equipment

Most of the grain handling equipment for farms is designed primarily with in-to-storage conveying in mind. The host of portable units available with carriages are prime examples. Although most of these units can be used for out-of-storage handling, planning their use inside a centralized structure is left primarily to the individual.

For the current analysis, the questions involving such equipment are three-fold. These concern (1) capacities versus speed, size, and angle of incline; (2) horsepower for the same variables; and (3) cost of ownership and operation.

Screw Conveyors

Millier (1957) presented one of the most complete works on screw conveyors designed for farm use. His studies included 4 and 6 inch diameter single-pitch screw conveyors, at angles of inclination from approximately 10^{o} to 90^{o} in 10^{o} increments. Wheat, oats, and ground corn meal were the materials conveyed. Speeds from 300 RPM to 1000 RPM in increments of approximately 50 RPM were studied.

Results of the studies are presented graphically in Appendix I. Millier concluded that auger horsepower varies directly with the length of screw conveyor in use. Maximum capacity for a 6 inch diameter conveyor handling oats and wheat occurred at auger speeds of 750 and 850 RPM. Maximum capacity speeds were slightly lower for 4 inch diameter units. The maximum horsepower was required for both units at a 45° angle of incline for wheat and a 60° angle of incline for oats.

In tests involving corn meal, both the 6 inch and 4 inch units continued to give increasing capacity throughout the 1000 RPM maximum speed studied. Maximum horsepower was required in both units at an approximate 45° angle of incline.

Paine (1955), writing on the design and application of equipment for conveying grain in-to and out-of flat bottom bins, suggests six variables to use in designing grain handling systems. These include (1) initial cost, (2) cost of operation and maintenance, (3) ease of operation, (4) flexibility, (5) adaptability, and (6) capacity.

Paine outlines a system of grain handling for wide, flat storages. Primary features include a 9 inch open top screw conveyor suspended horizontally along the top of the building. A closed tube 6 inch inclined auger is carried on an overhead track such that the intake rests on the floor with the discharge positioned over the top conveyor. The inclined auger can be used for truck unloading, or in removing grain from the building. Outlets at points along the top conveyor permit distribution of the grain at filling time.

McKenzie and Ross (1957) studied a mechanical bin unloader for removing grain from round, ground level, flat-bottom bins. The unit can also be adapted to square or rectangular structures, although 100 per cent removal may not be attained. The unloading system includes a horizontal drag conveyor to withdraw grain from a hopper centered in the bin floor. The intake is below floor level while the discharge is positioned outside the bin above grade level.

In operation, the drag conveyor withdraws all of the grain that will flow by gravity to the floor hopper. When gravity flow ceases, the unloader is placed in the bin, inclined on the remaining grain funnel. When energized, the unit, consisting of a single-pitch helicoid with a shield on one side, conveys grain to the center hopper. Working its way to the floor, the unloader propels itself into the grain pile by means of a friction wheel mounted on the outboard end. The unloader continues to rotate about the center hopper until the grain is removed. A permanent pivot pin installed over the floor hopper keeps the device in position.

McKenzie and Ross point out that the unloader and the drag are both portable units, and can hence be used in

several consecutive bins. The system can be used for unloading a shallow layer drying system consisting of a round metal bin with a false floor. Unloading capacity is comparable to a 6 inch diameter inclined screw conveyor.

Puckett(1957) studied a similar unloader. The unit he designed is intended for permanent installation in a flat-bottom bulk storage bin, for use with such materials as alfalfa meal and soy bean meal. The unloading system consists of a separately powered drag conveyor, installed similar to the previous system. The unloader is powered through a bevel gear assembly by a motor located in a chamber under the bin floor. Both components are permanently installed.

The sweep screw in unshielded, and rotates so that the ascending side of the helicoid acts against the material mass. In operation, the drag carries material from the centered, floor-level intake, while the sweep screw is inoperative. When bridging occurs and the drag hopper flows empty, a pressure sensitive switch actuates the sweep auger. The sweep continues to cycle until the bin is empty. Rotation of the sweep screw is controlled by the torque of the bevel gear drive, with an adjustable brake to add drag. An idler wheel carries the outboard end of the unit.

Chain Conveyors

Horsepower requirement data in relation to size, capacity, and angle of incline is markedly lacking for chain conveyors. Most researchers appear to use an estimate based on manufacturers quotations, tempered by experience and judgment. Henderson and Perry (1955) present a general description of all types of conveyors used in agriculture. Theoretical equations for calculating horsepower requirements and capacity are presented for chain conveyors. However, in the author's judgment, this formula is so specialized in terms of the conditions under which chain conveyors operate on the farm as to render it of little value. Results in applying the method are based on so many assumptions that one may as well use the expedient method of modifying manufacturers' quotations.

Euler (1955) used a measure for chain elevators that combines the width of trough and the tons conveyor per hour. He termed the measure foot-hours of elevator trough width. Based on observations of corn elevating systems on farms, he lists the capacity of chain elevators as 13.62 tons per foot-hour of elevator width.

Kjelgaard and Olver (1957) report on a top conveyor for use in distributing grain in flat-type storage structures. The unit consists of a horizontal single chain flight conveyor suspended horizontally in the peak of the structure. The boot of the conveyor extends outside one end of the building to facilitate loading. Grain can be lifted to the top conveyor with any conventional elevator. Multiple outlets drop grain at points along the top conveyor, thereby distributing grain and foreign material.

Bucket Elevators

The capacity quotations for bucket elevators are generally considered more accurate than those for most other farm elevators. This is due in part to the fact that an angle of incline is not involved, plus the fact that the per bucket capacity is more predictable and constant. Henderson and Perry (1955) present a formula for calculating the capacity of such elevators, along with a general discussion of their characteristics.

Wiant and Sheldon (1953) present detailed plans for building and installing a vertical cup-type belt elevator. The elevator may be built in lengths from 10 to 50 feet, and in capacities from 150 bushels per hour to 400 bushels per hour. Complete instructions for fabrication are given, along with power requirement data. Wiant and Sheldon suggest that a well planned elevator installation should include some provision for delivering grain to the various storage bins and some provision for carrying grain back by gravity from bins to the elevator hopper. Complete recirculation of grain is then possible.

Pneumatic Conveyors

Air conveying of grain and ground feed from the processing area to the feeding area offers a completely mechanized method. Sheet steel pipes supported overhead can place the distribution system completely out of the way.

Kleis (1954) states that air velocities of 4000 feet per minute are necessary for satisfactory performance. He suggests that the optimum pipe diameter for a system is the smallest allowable for the desired conveying rate. The optimum diameter is not affected by the length of the pipe, which may be up to 300 feet. Horsepower and capacity data for pneumatic conveyors is presented in Table II.

TABLE II

HORSEPOWER REQUIREMENTS AND CAPACITY DELIVERED WITH PNEUMATIC CONVEYORS--HORIZONTAL CONVEYING

Pipe Diameter Inches	Horsepower* per 100 ft. of pipe	Maximum Conveying Rate Lbs. per Hr.
6	1-1/2	5500
5	1-1/4	4500
4	1	3500

*Plus 1/3 horsepower for each 1000 lbs. of material conveyed per hour.

Grain Processing Equipment

Most of the recent research works involving feed processing equipment for farms have centered around small, automatic, electrically driven units. Several commercial models have been developed and marketed, ranging in size from 7-1/2 horsepower down to 1 horsepower.

Several variations in tractor driven grinders have also appeared on the market, with special emphasis on power-take-off driven units mounted on wheels. Many of these grinders are of the burr type.

Forth, et al. (1951), report on the Feed-O-Mat system developed at the University of Illinois. This system consists of a 5 horsepower electrically driven hammer-mill, fed by a load-controlled mechanical feeder. A multiple channel web-type conveyor acts as a blending unit for small grains and supplement. The blending rate is controlled by varying the clearance between the traveling web and a calibrated bin outlet tube. A mechanical unloader for a converted section of corn crib is a part of the system, permitting automatic removal of ear corn at a rate controlled by the mill.

The complete system grinds ear or shelled corn with small grain and supplement and blends the ration as it is ground. The unit, since it consists of separate components to handle each part of the ration, can be fitted into numerous combinations according to the circumstance at hand.

In my judgment, the Illinois Feed-O-Mat system has served primarily to focus attention and ideas on feed handling problems. Efforts to merchandise the unit to farmers were apparently unsuccessful. This appears to be due to the initial cost plus installation cost associated with each sale. Modification of the storage structure to receive the unit is extensive. Without on-the-site planning and subsequent installation by experienced personnel, results are unpredictable. Sales organizations are not prevalent in the farm field that can undertake such a complex merchandising program.

Butt (1955) reports the results of performance tests on a 2 horsepower grinder-mixer. The unit consists of a 2 horsepower hammermill, to which is attached a 4 channel blending device for metering ration components. The blender is driven from the mill, and the feed rate of each channel is adjustable. Automatic shut-off in case material should fail to feed to one channel is possible with the use of series connected pressure switches located in each channel. A timer to shut the mill off at the end of a selected time period is built into the unit, thereby making it fully automatic.

It was determined that the mill would grind and mix a satisfactory ration for either swine or poultry when the meters were set for a suitable proportion. Proportioning is by volume, and was found accurate within 1 per cent by weight, the volume to weight ratio having been established for the materials processed.

Electric power consumption ranged from 0.151 to 0.663 kw-hrs. per 100 pounds of feed, depending on the dial setting and the amount of grinding required. Capacity ranged from 419 to 2086 pounds per hour.

It should be pointed out that the 2 horsepower grinder-mixer outlined above will not grind ear corn, unless it is first pre-crushed. Too, the mill generally requires over-head hopper bins to deliver grain by gravity, although a mechanical feeding system is available for use with ground level storage.

Ground Feed for Livestock

Several questions invariably arise when one discusses the value of grinding feed for livestock. The question is usually two-fold. First, "Does it pay to grind?" and secondly, "What type of mill is best?".

The answer to the first question appears to depend on the class and age of livestock involved. Wilbur (1933) studying milk production of dairy animals fed ground and unground grain concluded that grinding did pay. The greatest quantity of milk per hundred pounds of feed was produced with what Wilbur termed a medium-finely ground material.

Gerlaugh (1929), studying the value of ground feed for 250 pound calves, found that the calves fed shelled corn consumed a greater quantity and gained more rapidly than calves fed ground shelled corn. The calves fed shelled corn did not pass whole kernels of corn until after they had reached 500 pounds in weight.

Snapp (1948) reported a study of ear corn, shelled corn, crushed ear corn, corn and cob meal, and ground shelled corn fed to beef cattle followed by hogs. Average daily beef cattle gains were 2.52, 2.71, 2.59, 2.61, and 3.08 pounds, respectively. Feed per pound of gain (on a shelled corn basis) was 6.80, 6.57, 6.58, 6.48, and 5.95 for the five rations. Based on an estimate of 5 pounds of corn per pound of pork, the whole corn produced more total meat (beef and pork combined) than did the processed rations. Snapp concluded that unless the price of fat cattle is considerably higher than the price of hogs, grinding of corn is not ordinarily justified where hogs are available to follow cattle. In the absence of hogs, corn should be ground, as the larger gains made by the cattle will more than offset the cost of grinding.

Evvard, et al. (1927), studying corn preparation for yearling brood sows, concluded that ear corn and shelled corn were more efficient than ground ear corn or corn meal for wintering brood sows. All lots received salt plus 3/5 of a pound of supplement mix daily, plus the corn ration. Differences in gain on various rations were not great. Sows on the corn and cob meal made the least gain. There was little difference in the pigs farrowed from sows fed various rations.

Garrigus and Mitchell (1935) reported a 3.5 per cent gain in corn as a source of energy when fed to five pigs weighing from 135 to 196 pounds.

Morrison (1951) states that numerous experiments of ground versus whole corn for swine indicate that grinding will not generally pay, up to the usual market weights produced. He cites a series of studies that indicate little gain for ground feed fed to pigs weighing up to 150 pounds. Thereafter, a saving of 6 or 7 per cent by feeding ground feed was attained, but this short feeding period will usually not justify grinding.

Foster, et al. (1955), reported on the value of high moisture shelled corn stored in a hermetically sealed storage as a feed for hogs. Results indicated that corn stored at 27 per cent moisture content maintained its feeding value as a feed for swine.

Isaacs, et al. (1958), found that high moisture shelled corn stored in a hermetic storage gave an 8 per cent greater daily gain than did 13 per cent moisture content dry corn when fed to two lots of 15 hogs each. The high moisture corn was stored in a conventional corrugated metal grain bin, with a sealed plastic liner. The initial moisture content of the corn was 25 per cent. The hogs fed the high moisture corn ate 9.2 per cent more corn on a 13 per cent moisture basis, but ate 19.7 per cent less protein supplement. All feeds were fed free choice. The feeding value of the high moisture corn was concluded to be at least as good as that of dry corn.

In the author's experience in talking with swine farmers throughout Indiana, some of the results of feeding trials on swine fed dry corn may not be representative of situations currently existent on some farms. With the advent of heated air dryers for drying shelled corn, the farmer has 13 per cent moisture content corn on a year around basis. This moisture content is necessary for safe storage.

Several farmers feeding 13 per cent corn to hogs have remarked that although they can detect little gain in feed efficiency by grinding the grain, intake is increased. Some suggest that they can double intake, and hence rate of gain. Other farmers remark that the pigs may eat too much supplement when fed free choice with the hard corn. Thus the economical balance of the ration is uncontrollable.

Studying the difference in grain ground by different types of mills as a feed for beef cattle, Kleis and Neuman (1956) concluded that there was no significant difference in gains of steers on 3 different 56 day feeding tests. The amounts of feed consumed were not significantly different between lots fed grain processed by various mills.

Materials Handling Analysis

Numerous studies that relate to some aspect of materials handling on the farm have been reported by agricultural and industrial scientists. The techniques outlined under such captions as plant layout, motion and time study, materials handling, activity analysis, process analysis, and operations research all contribute suggestions relative to the problem at hand.

System Design

Curry (1955) writing on the development of co-ordinated feed handling systems for farms, states that the design of feed preparation and handling systems involves the development or selection and the coordination or integration of a number of separate pieces of equipment into an operating unit.

Kelly, et al. (1953), writing on the design of a livestock physical plant suggest that the analysis must consider the flow of animals, feed, water, products, manure, and men. They state that the procedure in designing such facilities should be:

1. Determine the problem.
2. Construct materials flow charts.
3. Make a preliminary layout.
4. Select equipment and machinery.
5. Evaluate the design.
6. Make the final selection of equipment and layout.
7. Design buildings for the proper environment for products, animals, materials, and men.

Kelly, et al., estimate that 84 per cent of the grain and nearly 100 per cent of the hay is fed in and around the farmsteads. They point out that while the industrial production plant is a somewhat static thing within a given production period, the farm livestock enterprise is continually changing in terms of livestock numbers and size, feed volume, et cetera. While the industrial factory can reduce production and curtail costs to meet the market, the farmer must perform one feeding operation, whether he has 1 cow or 1000 cows. He in a sense still may have a full time job.

Euler (1955), studying work methods for handling grain on Indiana farms, suggests that the entire process of grain

handling can be broken down into basic operations. These include:

1. Separation of grain from parent plants.
2. Conveying of whole or processed grain.
3. Storing grain.
4. Processing grain.
5. Holding feed.

He concluded that Indiana farmers in handling over 10 million tons of grain per year could reduce costs from 9 to 11 per cent, mainly by organizing and mechanizing for greater work efficiency. The analysis provides rates of man and machine accomplishments for all operations in handling grain.

McKenzie (1956) suggested a method of analyzing grain handling and processing systems. Grain handling from the storage to the feed lot was broken into four steps: storage, assembly, processing, and distribution. Two intermediate storage functions following the assembly and processing steps were listed as optional. By considering different equipment and methods at each step in the preparation of grain for feeding, alternative systems characterized as manual, semi-automatic, and automatic were developed. The analysis also presented some suggestions on combining different types of conveyors into a continuous power train. Suggestions for mechanizing storage unloading were also presented.

DeForest (1955) presents four principles of materials handling on the farm. These include:

1. Don't move it, or move materials as little as possible.
2. Handle large amounts.
3. Make flow continuous. Use machines and gravity.
4. Condense it. Reduce bulk and weight.

DeForest suggests two reasons why farmers are reluctant to mechanize farmstead operations. First, other investments offer more immediate benefits, and second, materials flow problems on the farmstead are more difficult to solve than mechanization of field operations. Materials flow is characterized as basically a problem in farm structures.

DeForest states that farmers need suggestions and methods to help plan the use of equipment and buildings into an integrated, engineered system. Buildings now on farms lack flexibility for conversion to alternative uses. There is also a lack of equipment designed for materials handling uses.

Ross (1957), writing on the analysis of materials handling systems, suggests that very little effort has been made to integrate equipment and methods into a complete system. He states that systems engineering starts with an appreciation of the fact that any action or reaction in any part of an over-all system induces a reaction in other system components.

Ross states that any materials handling system which is successful must:

1. Contribute to a maximum financial return and/or decrease the work involved in operating the farm.
2. Conform to the existing conditions imposed by topography, building layout, and seasonal variation in work.
3. Be psychologically acceptable to the personnel involved in the work.
4. Be simple and safe to operate.
5. Be functional.

The study conducted by Ross considered materials handling on a 280 acre Indiana grain-hog farm. Data were first collected on existing farm practices. Process charts were developed for the existing layout and for several modified programs. Each program was then equated in terms of time, human energy requirements, and capital investment.

Ross concluded that process charts were a satisfactory method of analyzing farm materials handling problems. He suggests this method as particularly useful in evaluating human energy requirements.

Efficiency Analysis

Winter (1956) discussing how to make an efficiency analysis, suggests that the first step should be to establish an objective. This may be cost or labor reduction, or improved service or quality. The areas outlined as most profitable for study include those with high labor requirements, costly operations, expensive processes, critical quality preservation characteristics, excessive in process storage, excessive materials handling, and/or an unsatisfactory flow of materials.

Winter suggests that any study should first attempt to increase efficiency without the addition of new equipment. The second step should consider the substitution of new equipment, coupled with the proper work methods layout, and materials handling. The final step involves the development of totally new equipment and techniques.

In using process and flow charts in an analysis, Winter suggests that the questions of why, what, who, where, when, and how, be asked of every detail. Can transportation be eliminated, distances shortened, sequences changed, or back-tracking eliminated? Further, can storages be eliminated, reduced, or relocated?

Winter outlines a number of principles to keep in mind in materials handling. These include:

1. Materials flow.--Speed is increased and costs reduced when material is moved directly and through the shortest possible distance. The ultimate is continuous flow.
2. Mechanical equipment.--Use horsepower instead of man-power. The total cost of equipment must equal the cost of the man-power before substitution is economical.
3. Unit load.--The larger the load, the more efficient the materials handling.
4. Flexibility.--Use one unit for as many jobs as possible.
5. Equipment in use.--Reduce idle time to a minimum.
6. Performance.--Select the most economical and practical unit available.
7. Equipment replacement.--Replace present equipment with more efficient devices provided the increased productivity will more than offset the cost of the charge.
8. Safety.--Safe work means increased productivity.
9. Facility layout.--Layout has a direct influence on efficiency. It is an integration of equipment, materials, work centers, materials handling, and labor utilization. A poor layout presents the use of modern equipment because of unadaptability.

Vaughn and Hardin (1949) in their book on Farm Work Simplification state that the basic consumers of labor in farming are (1) movement of the hands and body while the worker stays in one place, (2) movement of the worker from place to place, and (3) the movement of materials and equipment from place to place.

A summary of the most important principles concerning work that involves the movement of the worker from place to place includes:

1. Have buildings and work areas close together.
2. Provide for circular travel routes.
3. Use gravity to move materials.
4. Provide wide smooth alleys and doorways.
5. Locate tools and supplies near work.
6. Combine and rearrange jobs.
7. Plan to end one job where the next starts.
8. Haul maximum loads.
9. Work at a reasonable speed.

Plant Layout

Immer (1950) suggests that good plant layout means placing the right equipment with the correct method. These should then be located so that a product unit can be processed in the most effective manner in the shortest possible time.

Hall (1958) presents several methods that may be used in determining the location of grain handling facilities on a farm. One approach is called the center of moments or center of gravity method. Given two quantities of feed to be fed at two separate locations, the method seeks to locate a point on a line between the two feed lot locations such that the weight of the ration times the distance moved is equal for both feed lots.

Hall points out that the center of moments method gives an erroneous answer. A ton-mile figure lower than the value for the center of moments analysis can be attained if the storage facility is moved to one feed lot. The facility should be moved to the feed lot using the most total ration. Such a layout gives a minimum ton-mile value.

Hall presents a general analysis for minimizing ton-mile relationships with three feeding locations. A general equation is developed which can be solved by trial and error.

Cost Analysis

A comparison of costs is one of the most realistic measures of farm practices. Although a cost analysis generally presents a very static view of a problem, the cost estimates so obtained are valuable guides in decision making.

Bradford and Johnson (1953), writing on farm machinery costs, state that the underlying economic principles with respect to the profitable use of a machine are no different than that of other production factors. This means that the marginal cost of using the machine must be equated to its marginal value product. Marginal returns include the labor saved, the marginal physical product, timeliness, and the increased product quality.

Heady and Jensen (1954) writing on the nature of machine costs in farming express their thoughts in terms of total costs and variable and fixed costs. Variable costs are those which vary with machine use, such as fuel and labor. Fixed costs, on the other hand, are those that occur irrespective of use, such as interest, insurance, most depreciation, taxes, et cetera.

Heady and Jensen present a discussion of the costs that must be considered in evaluating the purchase of a given machine. They state that only the additional cost resulting from a given purchase should be considered. This is, then, really a marginal cost which is computed from the additional cost associated with the use of an additional input unit. A detailed discussion of costs that should and should not be considered in estimating the costs of a new machine is presented.

IV. METHOD OF PROCEDURE

The scope of the grain-feed handling problem considered in this analysis includes the system from the in-take of the in-to-storage elevator to the common output point of the out-of-storage conveyors. The problem definition permitted consideration of a maximum number of factors exerting influence on the make-up of handling facilities without consideration of unrelated fringe factors.

The step by step method of procedure was:

1. A review of previous investigations of materials handling systems for livestock farms was made to locate usable data and workable procedures.
2. Manufacturers of prefabricated farm grain storage structures were contacted for information on units available, storage capacity, and cost. Visits were made to two manufacturers in Michigan, one in Illinois, and one in Indiana. Three representatives came to the campus.

   A survey was also made of grain storage plans available in the Agricultural Engineering Plan Service. Cost estimates for selected structures were formulated. A summary cost schedule was then prepared for all structures.

3. Visits were made to three manufacturers of grain handling equipment located in Illinois, and to one in Michigan. In addition, two representatives in the Lansing area were visited, along with contact by mail to an Indiana manufacturer. The manufacturers selected were considered representative of grain handling equipment designed for farm service factors. Data collected included units available, estimated capacity and horsepower requirements, and retail costs. The equipment included chain drags and elevators, chain and belt bucket elevators, and screw conveyors. Manufacturers of grain processing, mixing, and bulk storage equipment were contacted by mail. Data similar to that for handling equipment were obtained. Summary cost schedules were prepared for all equipment.
4. Agricultural Extension Service and Experiment Station personnel were contacted for information on recommended livestock rations and management procedures; also, information was obtained concerning livestock-grain enterprise combinations representative of Michigan farms. The data were used in the preparation of theoretical system requirements.

5. A criteria for the design of grain-feed handling facilities was formulated employing the writings of researchers and feed handling authorities as a guide.
6. Using the design criteria, available buildings and equipment, and livestock-grain enterprise combinations, grain storage layouts were developed. Each layout included a corn, small grain, supplement, and ground-feed storage area, along with space for on-the-farm processing of grain. Where new equipment or building components were needed and unavailable, preliminary designs sufficient for cost estimates were prepared.
7. Total cost relationships for storage-processing layouts and alternative equipment complements were prepared for several levels of grain volume and ration requirements.
8. Results were analyzed and summarized.

V. DEVELOPMENT OF SYSTEM LAYOUTS

A Conceptual Framework

Assumptions

The first step in outlining a conceptual framework for consideration of a problem is to define the basic assumptions upon which the analysis is based. In the development of the grain-feed handling systems covered in this analysis, the following assumptions are made:

1. The handling systems must be designed such that they can be built component by component, over a period of years.
2. Each system must provide space for on-the-farm grinding.
3. The maximum practical degree of mechanized grain handling must be possible in all systems.
4. Only those grains destined for consumption by livestock need be considered in the system design. This includes purchased livestock feed supplies.

Construction by components. This assumption is necessary to instill realism in the systems developed. Most

farmers who use the results of this analysis will have some sound grain storage structures and grain handling equipment on hand. This assumption insures that the systems designed will present an opportunity for economical use of such components.

On-the-farm processing. This assumption is necessary because such processing is always an alternative to commercial service. Some operators may not desire to grind, either on or off the farm, and others may not find it economical. On the other hand, if the size of livestock enterprises continues to grow, such processing may be feasible within the life of the facilities. Too, commercial service is a variable factor. What is satisfactory today may be undesirable tomorrow.

There is another line of reasoning behind the one-the-farm processing assumption. In the author's opinion, the long time trend in livestock feeding is to a complete, prepared ration. Several reasons are offered in support of this opinion. First, most animals utilize a processed ration more efficiently (14, 32, 36, 42). Second, by pelleting processed feed, utilization by the animal appears to be increased, while wastage is reduced. Third, with the trend toward drylot feeding, the complete, prepared ration offers one material to handle at feeding, instead of two or three. Hence, mechanical feeding is simplified.

Finally, a free choice system of feeding, from an economic point of view, offers little opportunity to adjust the ration to cost and price situations. A complete prepared ration, in contrast, presents an opportunity for week by week modifications in feeding. This permits the operator some adjustments in the ration and growth rate to meet varying feed prices or market situations. By giving more control over growth rate, a complete ration offers a more exact utilization schedule of livestock facilities, a problem of increasing importance in the more intensified enterprise of tomorrow.[1]

Maximum practical mechanization. This assumption is a hedge against the decreased labor supply and increased mechanization foreseeable in the future. The possibility of complete mechanical handling at some future date is thus assured. This assumption also permits an estimate of the maximum mechanization considered practical at the present time.

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[1]Although this discussion of complete prepared rations does not preclude the possibility of incorporating forages with grain in a ration for ruminate animals, it is not within the scope of this analysis to consider such systems. It appears to the writer that such consideration would place an entirely new and as yet relatively unknown dimension on feed handling system design. This is all the more reason that such practice should be followed closely in the future.

Grain for livestock. Limiting the system design to grain for livestock is necessary to allow freedom in the design of facilities. It is the day by day unloading of grain structures in the preparation of livestock feed that is the heart of this analysis. Cash grain storage tends to be unloaded once per year. Consequently, the need for mechanical handling is substantially different. In addition, there is merit from a grain sanitation standpoint to have each grain storage totally separate from other grains.

Functional Classification of the Problem

In a previous paper (28) on the subject of grain handling for livestock farms, the writer outlined a functional classification of the problem. The classification consisted of dividing the grain-feed handling problem into functions of storage, assembly, processing, and distribution.

Such a division offers several advantages. First, it breaks the problem down into components that are more easily analyzed. Secondly, mechanization opportunity exists within a given function that can be approached quite independent of other aspects of the total problem. Indeed, it was just such an independent component approach that has created the problem with which this analysis is concerned. Suffice it to say that independent does not mean unrelated.

Thirdly, such a functional division is not unlike an actual investment program in a grain-feed handling system on a livestock farm. It is a "jig-saw puzzle" approach, and can be used in planning and building a system step by step, with each investment a part of a future whole.

System Design Fundamentals

An analysis of grain-feed handling facilities under the functions outlined above serves to focus attention on some general design fundamentals. For instance, consider the effect of distance on the operation and performance of a system.

Effect of distance. There are two alternatives in the layout of storage and processing facilities. One is to separate some or all component structures, and the other is to integrate buildings into a combined facility. Consider the problem of assembling a batch of feed for processing under each layout.

With the scattered layout, a transport vehicle would generally be used to travel from storage to storage and collect the ration components. If accurate weights are desired, a return to a common scale location is necessary between each load-out. Once the batch is loaded, it may be transported to a commercial mill, or to the on-the-farm processing area. It should be noted that the method of processing is not influenced in any significant way by the system of storage unloading or batch assembly.

In contrast, with the storage facilities as an integrated unit, the vehicle is pulled into a central drive-way, and all ration components assembled from this one location. Scales for weighing can be located in the drive. The storage unloading system can be the same as before, but the grain is unloaded directly into the processing area. It may be scooped onto the vehicle, or discharged into the processing conveyor system. The latter may consist of the same elevator used in loading from the scattered storages.

The conclusion is that distance between storage units in a grain-feed handling system simply adds to the cost of operation.[1] The first fundamental in the design of grain-feed storage and processing facilities is: MINIMIZE DISTANCE.

Distance is a factor in the development of other fundamentals. The scattered layout involves the use of storage unloading devices, conveyors, and/or elevators at each location. These units must either be moved or multiple units or methods employed. The former involves considerable set-up, knock-down, and transport time, in addition to the lugging and lifting involved. Multiple units or methods mean increased costs and/or varying efficiency.

In the centralized layout, distance between structures approaches a minimum. Movement of conveying and elevating

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[1]The increased fire risk and grain sanitation hazard of centralized facilities are considered of minor importance.

devices is reduced, along with set-up and knock-down time. The fact that permanent devices may be installed to facilitate expedient set-up of multiple use units further complements the central layout. The second fundamental is: MINIMIZE SET-UP AND KNOCK-DOWN TIME.

Equipment use. The previous discussion in formulating the second fundamental developed most of the thoughts for the third. One grain handling device can be used for a number of different handling operations, provided it is less work (and cost) to so use it than to employ a second method or device. The centralized storage system places all operations within a radius serviceable by one unit. The third fundamental is: DESIGN FOR MULTIPLE USE OF EQUIPMENT.

Man-power use. The fourth fundamental involves the use of man-power. A man is a complicated device. To build into a machine all of the things he can do has to date been impossible. But as a producer of horsepower, he is next to nothing.

The average man can develop approximately one-tenth horsepower. Working ten hours, he can perform one horsepower-hour of work. A one horsepower electric motor in one hour will perform the same work, and consume approximately one kilowatt-hour of electricity. A kilowatt-hour costs approximately 2¢ on an average Michigan livestock farm. This

means that a man is worth 2¢ a day as a producer of horsepower! All that he is worth above 2¢ per day must come from above the ears. This should be a sobering thought to any thinking farmer.

Man should always be used first as a thinking device. This he can do as nothing else can. In terms of grain-feed handling system design, he should be used first to think, second as a floating control device, third as an expediter, fourth as an agitator, and last as a producer of horsepower.[1] The fundamental to keep in mind can be stated as: USE MAN-TIME FIRST TO THINK AND LAST FOR POWER.

Processing system. A fifth fundamental involves the design of the processing system for on-the-farm grinding. Many authors have expounded on the merits of continuous flow in processing. Although this is a fundamental principle of materials handling, it appears unrealistic to the writer in terms of reality on the farm.

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[1]This sequence in the use of man-time can be turned around and used as a guide in the mechanization of any operation. The mechanization would proceed as follows:

1. Remove the drudgery.
2. Mechanize all handling.
3. Apply simple on-off control.
4. Integrate the control system.
5. Introduce automatic programming.

In the first place, continuous flow implies flow over time. Yet the per hour feed requirements on a livestock farm are, relatively, very low. This means either of two alternatives: Use a very small unit many hours per day, or a larger unit a few hours per week. The former represents a difficult concept to sell to farmers, because it is contrary to most mechanization decisions on field crops. The unavailability of successful continuous systems at a reasonable price does not enhance the selling task.

To set up a continuous system of processing for relatively short time operation amounts to inefficient use of a large device. The system must be the same for 10 minutes or 10 hours of automatic operation.

A preferable approach to grain processing on the farm, in this writer's opinion, is to process in batches. A batch system of processing offers several advantages. In the first place, it is adaptable to any type of mill, manually supervised or automatic, small or large. In addition, batch processing avoids much of the automatic control necessary for continuous flow assembly. Each batch gives an automatic check on ration formulation, an important consideration in formulating high potency feeds with any so-called automatic device. Further, high cost accurate measuring devices can be concentrated into one unit for batch processing

permitting purchase of a higher quality, more reliable design. Where weight by volume gives sufficient accuracy, measurement is greatly simplified.

Finally, most farm processing centers must have a central conveyor system for handling in-to-storage of grain, as well as out-of-storage load-out or processing. This conveyor system can usually be fitted into a batch make-up arrangement with little additional cost.

In practice, a batch system of processing should be designed for manually supervised, speedy, batch assembly. This is the operation that requires the thinking, planning, and scheduling. This is good use of man-time. Processing may then be completed with a mill of sufficient capacity to justify supervision, or with a small automatic unit. The design fundamental is: PROCESS IN BATCHES. EMPLOY HIGH CAPACITY, MANUALLY SUPERVISED BATCH ASSEMBLY.

Long-range planning. The last fundamental simply accounts for the long life of farm structures. Mechanization today will be sub-standard tomorrow. Competitive volume today will be too small tomorrow. Methods today will be outmoded tomorrow. The fundamental is very general and can be applied to any materials handling system: PLAN IN AN OPEN-END MANNER FOR FUTURE GROWTH AND ALTERNATIVE ACTION.

Summary of Design Fundamentals

1. Minimize distance.
2. Minimize set-up and knock-down time.
3. Design for multiple use of equipment.
4. Use man-time first to think and last for power.
5. Process in batches. Employ high capacity, manually supervised batch assembly.
6. Plan in an open-end manner for future growth and alternative action.

Other Considerations

The method of materials handling, the method of feed mixing, and the frequency of feed grinding and distribution are of importance in the design of feed-grain handling facilities. The question of handling methods involves gravity versus mechanical systems. Although this question cannot be sufficiently answered at present to permit summary into a design fundamental, some general guides in the use of gravity and mechanical handling methods can be stated. The method of feed mixing, and the frequency of feed grinding and distribution each involve options that may be equally sound, depending on circumstances.

Gravity and mechanical handling. Handling by gravity flow is often recommended in the design of materials handling systems for farms (9, 39). The implication appears to be that since gravity handling involves a natural phenomena, it is thereby a preferred method. However, gravity flow is generally not attained free of cost. A structure must be elevated and/or hoppered to attain such flow. The cost of these features must be charged to storage unloading. The indiscriminate use of gravity bins in a grain-feed handling system may prove costly.

Elevating a bin and hoppering a bin should be considered as two different but complementary methods of storage unloading. An elevated bin normally is designed to discharge above grade level, usually at a height sufficient for grain-feed load-out without rehandling. By elevating the structure, all material is discharged that will flow by gravity to the outlet. A hopper bottom, in contrast, is designed to prevent any repose of material in the bin, thereby bringing about complete removal. Elevating a bin thus avoids the use of grain-feed elevating equipment. Hoppering, on the other hand, is an alternative to the use of a mechanical, flat-bottom bin unloader.

Elevated versus ground level bins. A ground level, flat-bottom bin unloaded with a mechanical grain-feed elevating device is an alternative to an elevated flat-bottom structure unloaded by gravity. To be strictly comparable, the grain-feed elevator should deliver the same quantity of material at the same rate and height as the elevated bin. Assuming both bins are of the same dimensions, the quantity of material that will flow to the grain outlet is equal. To attain maximum gravity flow from one discharge point, the grain outlet with either bin should be located in the center of the bin floor.

Several considerations are important when comparing gravity handling from an elevated bin with mechanical handling from a ground level bin. First, to attain gravity flow, every bin must be elevated, thereby involving duplicate investment. The mechanical system, in contrast, can be portable for use on any number of ground level units. Secondly, elevating a bin increases the height of the bin inlet, by an amount roughly equal to the support height. Equipment length necessary to fill the bin must be correspondingly increased. In selecting grain elevators for use for both in-to and out-of storage grain handling, the greater height of in-to-storage operations generally determines the length of the elevator. The over-all lower inlet height of the ground level structure reduces the elevator length, and hence cost.

<u>Flat versus hopper floors</u>. The use of a mechanical unloader in a flat-bottom bin to remove material that reposes on the bin floor is an alternative to the construction of a hopper-bottom for complete gravity removal. Some adjustment must be made in the comparison of the two bins to compensate for the loss of storage associated with

the hopper system. The mechanical unloader may be either a permanent fixture in one bin, or a portable device for use in a number of similar structures. The hopper is a permanent installation.

Selecting the handling method. The question of whether to use mechanical unloading from ground level bins or gravity unloading from elevated structures is primarily one of cost. Whether to use a hopper-bottom bin or a mechanical unloader in a flat-bottom bin is also a question of cost. Unfortunately, data on the cost of elevating and hoppering bins are markedly lacking. Similarly, mechanical bin unloaders for flat-bottom structures are not manufactured to any great extent. Consequently, a detailed cost analysis is not possible at the present time.

This does not mean that some general guides concerning the use of these materials handling methods cannot be formulated. The factors that influence decision making can be stated. A rigorous evaluation of most cost aspects of each method, however, must be left unanswered.

The cost of grain storage unloading is a function of the type and amount of material handled and the handling frequency. If one bin is unloaded once per year, the cost of the handling method must be charged to that one quantity of material. In contrast, if one bin is unloaded and refilled many times throughout a year, the cost of storage unloading can be charged to the total quantity handled. Cost per unit is proportionately reduced. Similarly, if one bin is completely unloaded in one operation per year, a single equipment set-up is involved. If, in contrast, some withdrawal of material is made every day, a complicated set-up[1] of equipment may involve more time than the actual operation.

The handling cycle affects the choice of method in another way. If similar storages each contain the same kind of grain, only one storage need be opened at a time. When unloading is completed in one structure, a portable mechanical system may be moved to a second storage. In contrast, if material must be withdrawn from several bins in the same time period, moving the unloader tends to be impractical. Too, if both bins are not emptied at each withdrawal, moving a bottom unloading mechanical device is impractical.

Handling system design guides. In planning feed-grain handling facilities, some general recommendations

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[1]Set-up as used throughout this text means the necessary arrangement, assembly, and servicing of equipment prior to operation, rather than the equipment itself. The latter is sometimes described as an equipment set-up, but the author does not use this context.

concerning the use of gravity and mechanical systems of handling can be formulated. These recommendations are:

1. Limit the use of elevated structures to small working bins in the processing area. The more times a bin is refilled, the less is the cost per unit of material handled. Since elevating equipment is necessary no matter what type of storage is used, build small elevated bins and invest in high capacity refilling equipment. Consider free standing, small elevated bins that can be rearranged in the future.

2. Limit hopper bottom structures to working bins in the processing area. Since material and labor are major items in the cost of such facilities, keep bin size small.

3. Use simple one-way and two-way slope hoppers instead of more costly four-way designs. Cost is materially reduced. Flow characteristics may be improved.

4. Consider the use of hopper floors of gentle slope, rather than the steep 60 to 75 degree slopes required by most ground feed materials. The latter bins occasionally bridge, requiring agitation. Thus, supervision is required. The gentle slope requires more agitation, but uses supervision man-power already at hand. Invest some of the reduced construction cost of the gentle slope unit in methods of easier agitation. One-way and two-way slope bins place the "bottleneck" at the side of the bin, making hand agitation more practical.

5. For 100 per cent unloading of bulk grain storage, consider the use of mechanical devices that remove material from a flat floor. Plan a portable installation of the unloading system, so that the unit can be used in all storages. Recognize the advantage of center draw-off as opposed to a side outlet, both from a maximum gravity flow and balanced structure side-wall load view-point. Determine the quantity of grain that will not flow by gravity to the storage outlet. The handling of this quantity of grain is all that can be accomplished with a hopper or mechanical device.

Feed Mixing

A general criteria on mix requirements. The question concerning how complete a mix is necessary for each class of livestock is important in considering mixing methods. Little specific information on this question is available.

A general criteria can be reasoned in terms of animal intake. The greater the intake, the greater the chance that the animal will consume a random mixture of blended and unblended material. This means that the smaller the animal, either in terms of age or type, the more important is a thorough mix. Thus, baby animals and animals such as chickens require a more accurate mix than adult swine or cattle.

The use of feed as a carrier for growth stimulants and medication has placed more rigorous measurement and blending requirements on livestock ration formulation. In addition to questions of possible toxicity resulting from an incomplete mix, the cost and returns of the additive when not properly distributed throughout the herd must be considered.

Wagon mixers. The advent of self-unloading feed wagons has introduced a new dimension in feed mixing methods. Although these wagons are commonly advertised as transit mixers, few models exhibit design features characteristic of horizontal mixers. With the exception of a few models, the mixing accomplished in a self-unloading wagon generally consists of withdrawing material from the bottom of the load, and discharging the material back into the wagon. Only one-half load can be so mixed on many feed wagons, because the discharge spout will not permit loading to the far end of the box.

Standpoint of this thesis. The systems outlined in this analysis are planned for either wagon mixing or the use of a stationary verticle mixer. In my opinion in working with farmer's, rations for swine, beef, and dairy cattle can be acceptably mixed in a self-unloading wagon. Poultry and baby animal rations should be blended in a conventional mixer. The mixing requirements for adding growth stimulants and medication to feed may change as new formulas are developed, and should be considered in terms of specific standards for each material.

Grinding Cycle

There are two alternatives in planning the grinding cycle. One involves frequent, small batch operation, and the other weekly or semi-monthly large batch grinding. The question of which cycle to use is primarily one of set-up cost.

If a grinding system is always "ready to go," frequent small batch processing is a good alternative to a large batch system. Automatic operation is especially well suited to small batch operation. If set-up time is virtually eliminated, short time processing approaches the longer cycle systems in the efficient use of labor.

Tractor grinding systems, which generally are not automatic in operation, involve more set-up time than electrical powered systems. Consequently, the grinding cycle generally will be longer for a manually supervised tractor powered system than for an automatic system. Some farms have a sufficient number of tractors to permit permanent location of one power unit at the grinding site throughout much of the year. The set-up efficiency of such a system can be high. However, this may not be efficient use of tractor power, and may add to operation costs.

Feed Distribution Cycle

Processed feed storage may be planned in several ways. The storages may be located at the processing site, with the feed distributed as needed. Or, the feed may be stored at each livestock area, either in an intermediate storage or in a self-feeder. The feed processing cycle and distribution cycle each influence the amount and location of processed feed storage. A short, frequent schedule of both tends to minimize the amount of the storage space necessary. The greater the cycle length of either operation, the greater the storage requirement.

In the author's experience in consulting with farmers, a few individuals have organized a feed processing and distribution cycle to match the size of their self-unloading feed wagon. Feed is processed and discharged directly into the self unloading wagon. The cycle is planned on a day by day schedule, according to livestock needs. Each batch is stored on wheels, from which it is delivered directly to the feed area. One swine farmer delivers feed to hogs on pasture as he goes to and from field work. His only serious problem with such daily distribution occurs during an extended rainy period.

Presentation and Discussion of System Layouts

The Basic Plan

The grain-feed handling system layouts consist of three basic components. These include:

1. A corn storage component.
2. A small grain storage component.
3. A feed processing and storage component.

Figure 1 is a schematic drawing of the basic layout. Each unit is made up of ground level structures. This

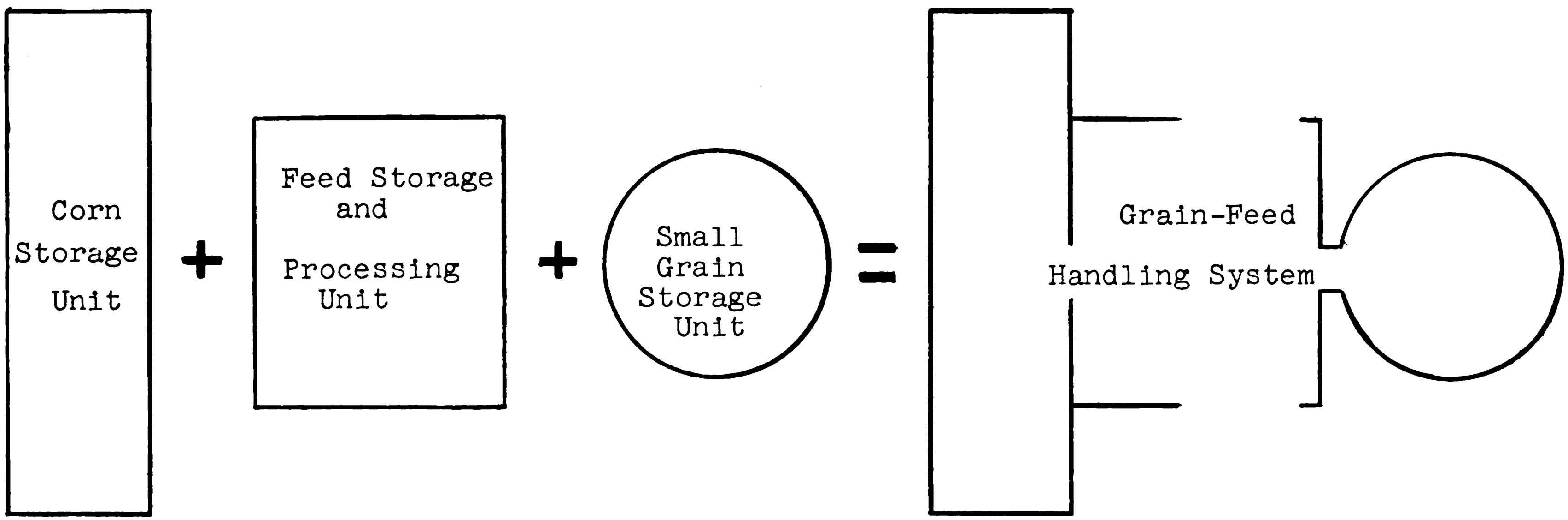

Figure 1. A schematic drawing of the basic grain-feed handling system layout. Each layout is made up of ground level components combined into a unitized facility.

permits construction of any component at any time, independent of the remaining units. The only requirement in construction by components is an over-all plan outlining the final system. Construction need not be spread over a period of time, if a complete facility is desired immediately.

Many options exist in the type of structures that may be used in building any component. Figure 2 is a schematic diagram of the component structures that are considered in this analysis. In the author's opinion, the structures listed in Figure 2 and outlined subsequently in more detail indicate building types and grain handling methods most representative of the needs of today's and tomorrow's agriculture. Some of the structures listed are not typically found on Michigan farms. This should not be interpreted to mean they do not represent sound investments. It should rather be interpreted as a question concerning whether traditional designs are meeting the needs of today. New building designs offer features in storage methods and handling practices not even considered in the planning of more traditional plans.

The mechanization of materials handling is an important consideration in the selection of any building. A structure planned in a period when a day's labor was

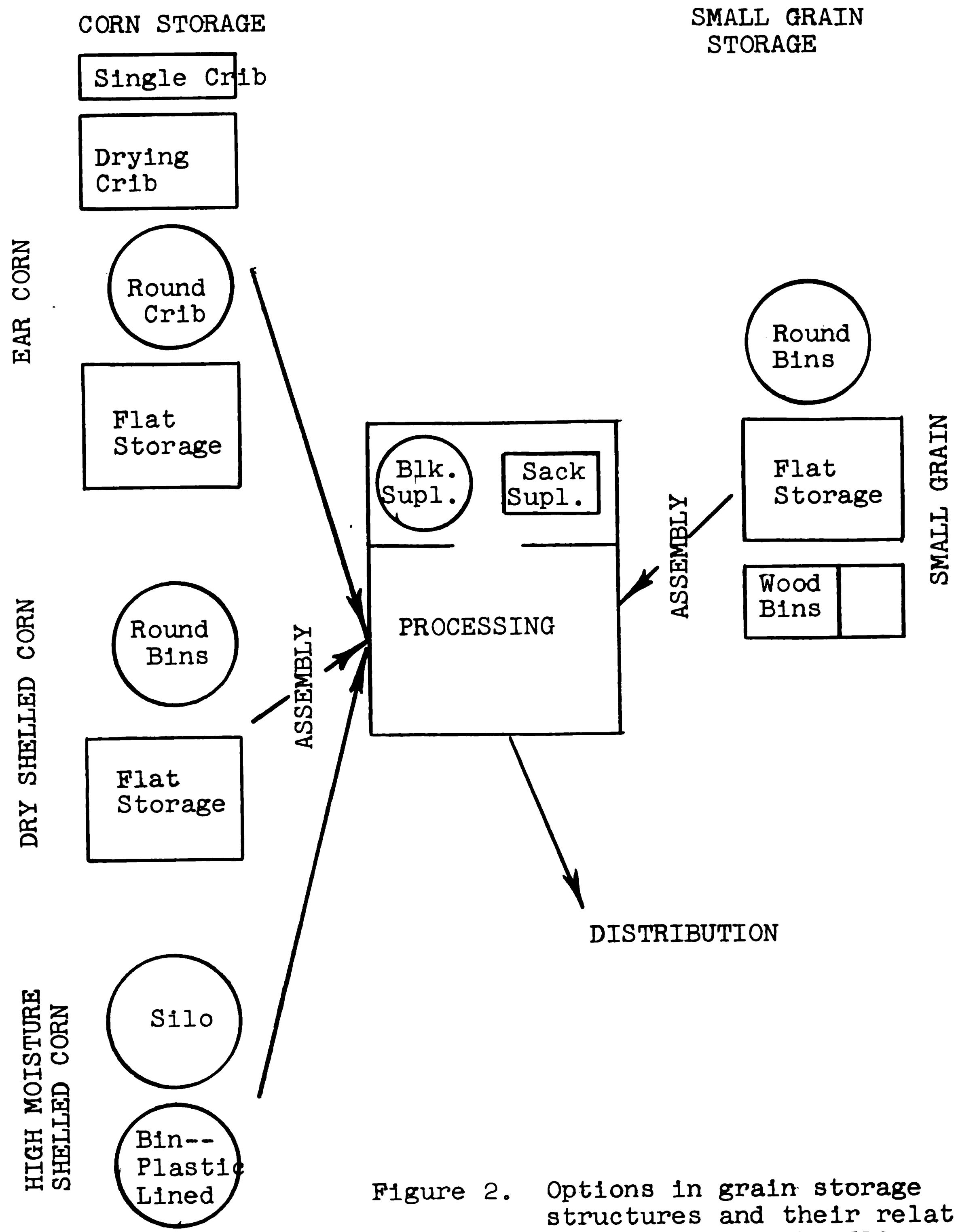

Figure 2. Options in grain storage structures and their relation to a grain-feed handling system.

worth 50¢ to $1.00 is a liability in light of mechanical handling possibilities today. Figure 3 lists in schematic form some of the mechanical handling methods that are available for storage-unloading, grain assembly and processing, and feed distribution. As with the storage components, the handling equipment may be installed as a complete assembly, or purchased unit by unit over a period of years. However, the necessity for a complete plan prior to the construction or purchase of any component is apparent.

As the reader reviews the feed-grain handling system layouts presented on the following pages, he will recognize a level of materials handling mechanization considerably above that commonly found on livestock farms. It should be remembered that this is one of the objectives of this analysis--to present systems that embody a maximum opportunity for mechanical handling. It should also be recognized that there are many degrees of mechanical handling. Virtually all of these degrees are possible in the following layouts, from scoop shovel methods to maximum mechanical methods. In the author's opinion, no matter what level of mechanization is used, the layouts present an efficiency opportunity at least comparable to more traditional methods.

STORAGE		ASSEMBLY	PROCESSING	DISTRIBUTION
Loading	Unloading		On Farm	
Scoop shovel	Scoop shovel	Scoop shovel	Tractor	Basket or sack
Elevator	Chain drag	Sack or basket	Burr Mill	Flat bed vehicle
	Tractor scoop	Vehicle	Hammermill	Self-unloading vehicle
	Screw conveyor	Conveyor	Electric	Pneumatic conveyor
	Bin unloader		Grinder-mixer	Mechanical conveyor
	Web-type conveyor		Custom	
	Hopper bin			
			Off Farm	
			Commerical	

Figure 3. Materials handling possibilities for each function of a grain-feed handling problem.

Special Equipment Designs

Two devices should be outlined before proceeding to the actual layouts presented in the grain-feed handling systems on the following pages. These include an overhead carrier device for easing the movement of an inclined conveyor within the processing area, and one-way slope wood hopper bins for ground feed and supplement storage.

Figure 4 presents a schematic drawing of the overhead carrier device. It consists of a swinging cantilevered boom, supported from the top of the processing structure. The boom is of truss construction, with the bottom chord an angle iron carrier track. Stop plates are installed at each end of the track. The boom is hinged at one end, so that it can swing in a horizontal plane but is rigid in the vertical plane. A cable support is attached to the middle of the boom. The entire assembly can swing in a 180° arc.

In practice, a 4 or 6 inch screw conveyor is attached to the carrier dolly. The suspension point on the screw conveyor is selected so that the weight to be lifted at the boot end will not exceed 50 pounds. With this light conveyor weight, plus the possibility of moving the suspension point of the conveyor along the boom length and within the entire 180° arc, maneuvering the conveyor is

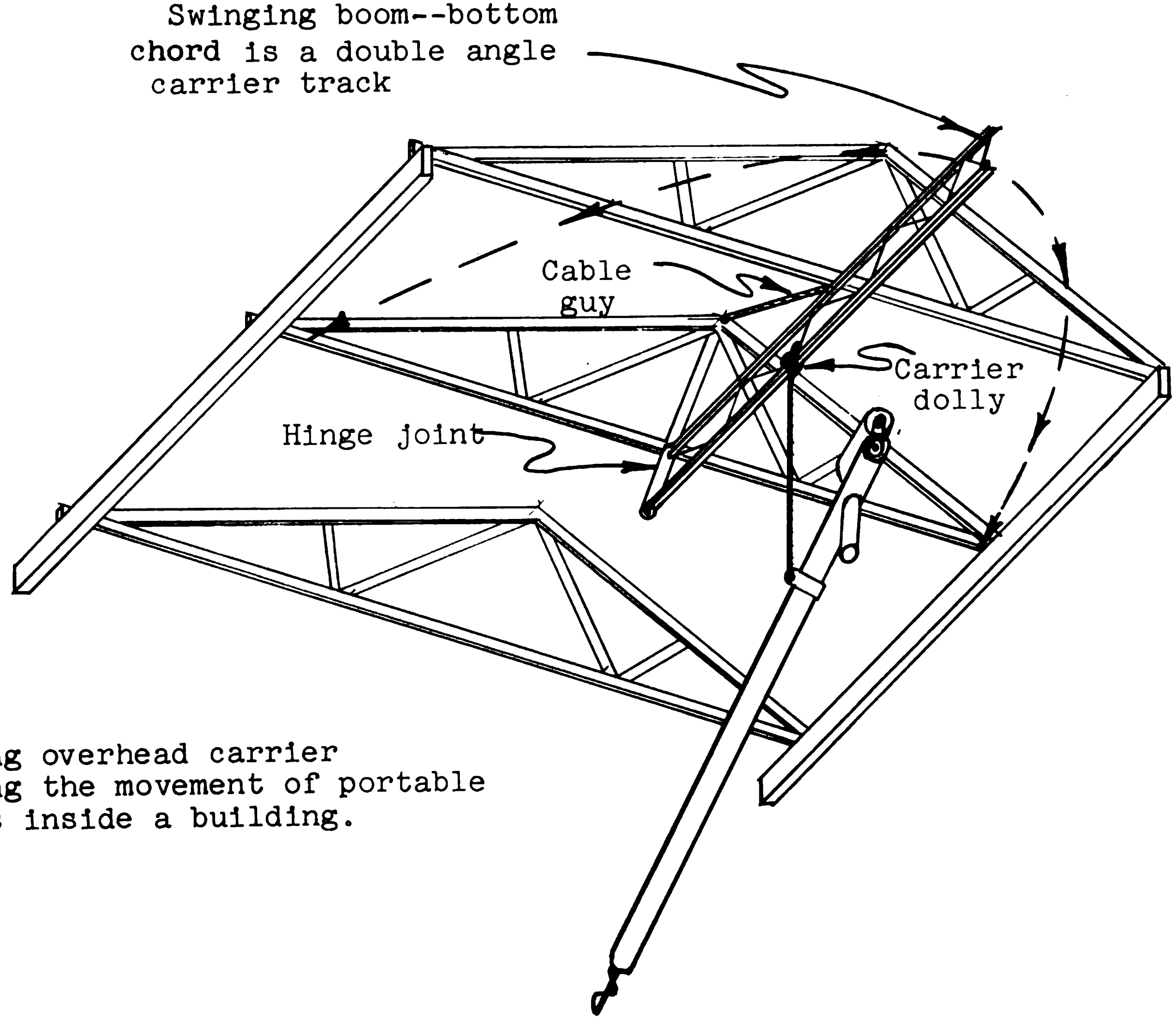

Figure 4. A swinging overhead carrier for easing the movement of portable elevators inside a building.

greatly simplified. The use of the conveyor in servicing a number of structures arranged around an enclosed area can be fast and efficient.

Figure 5 is a schematic drawing of a one-way slope, wood hopper bin. The bin is rectangular in shape, with all floor stringers, flooring, studs, and sidewall essentially rectangular components. Fabrication of a hopper bin is thereby simplified.

The bin is not designed to be entirely free-flowing. It is rather designed to operate with hand agitation, but with agitation that does not require much effort. The bin can be divided into any number of sections, each discharging through a flow control at the lower end of the sloping floor. The sections may be of any size corresponding to needs. Partitions could be made removable, within structural limits, to permit adjustment of bin size to seasonal and yearly changes. An access door at waist to shoulder height is provided in each section for agitation of the final material reposing on the floor.

Several options exist in mechanizing the material movement from the one-way slope hopper bin. The bin may be elevated to discharge above feed cart height. Or, the discharge may be placed near the floor, with the material elevated with a mechanical device. The latter method

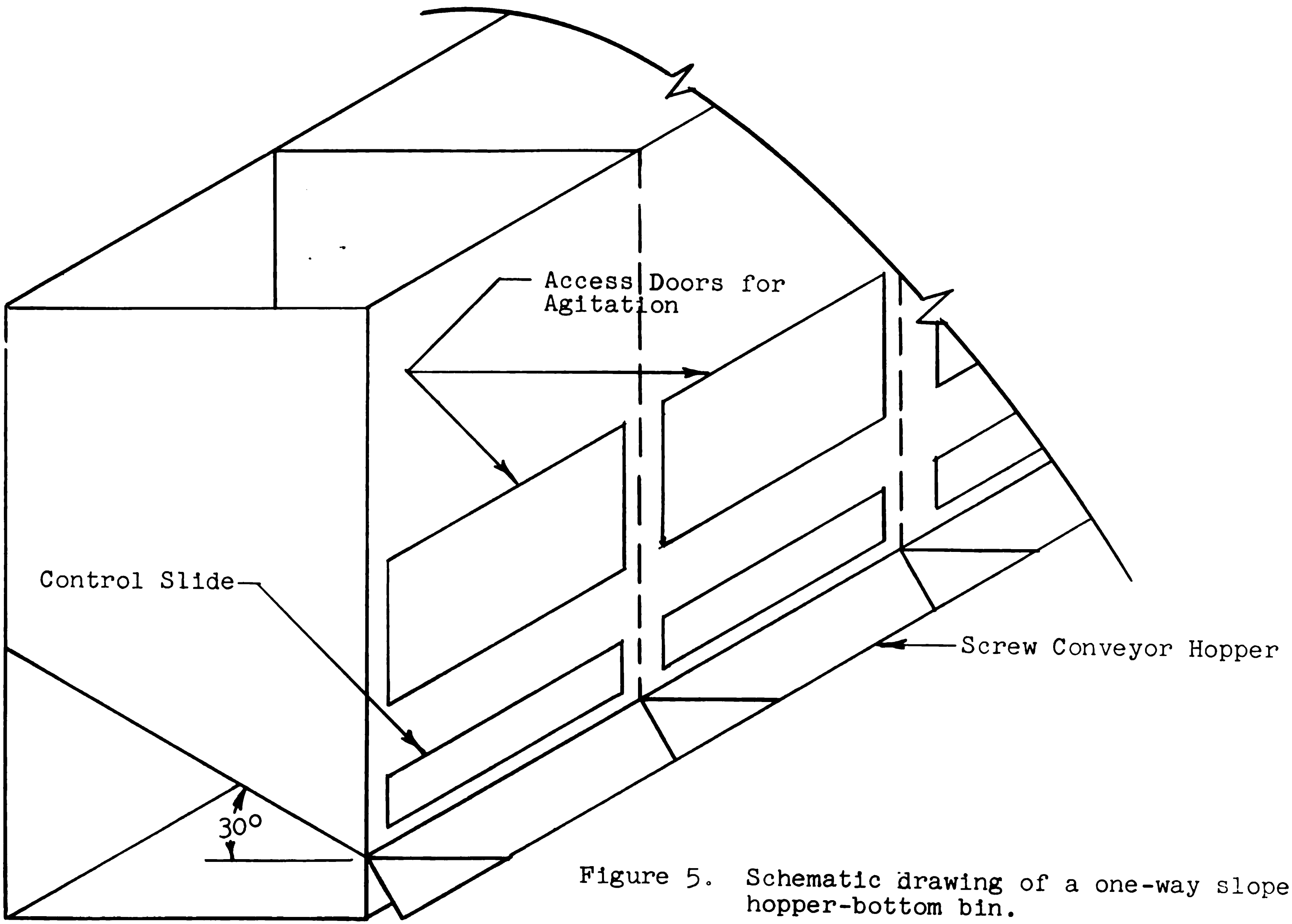

Figure 5. Schematic drawing of a one-way slope hopper-bottom bin.

requires a continuous hopper along the bin discharge. The use of a suspended screw conveyor system such as outlined in Figure 4 would permit servicing a long bin with one conveyor.

A horizontal screw conveyor may be installed along the entire bin front. The use of left and right hand helicoids on one shaft will bring material to a central point. A permanent or portable inclined conveyor is used to lift the material to the desired height.

Some caution must be used in the selection of the continuous horizontal conveyor system. Feed materials cannot be stored in adjacent bins on one conveyor train if any residual material remaining in the conveyor is objectionable in the other feeds. Too, if accurate weights out of storage are a part of the operation, it should be recognized that considerable material may be in transit when the final weight is reached. Provision for returning any overrun to the proper bin must be considered.

Ear Corn-Shelled[1] Grain Layouts

Single crib with circular metal shelled grain. Figure 6 is a feed-grain handling system plan for a small

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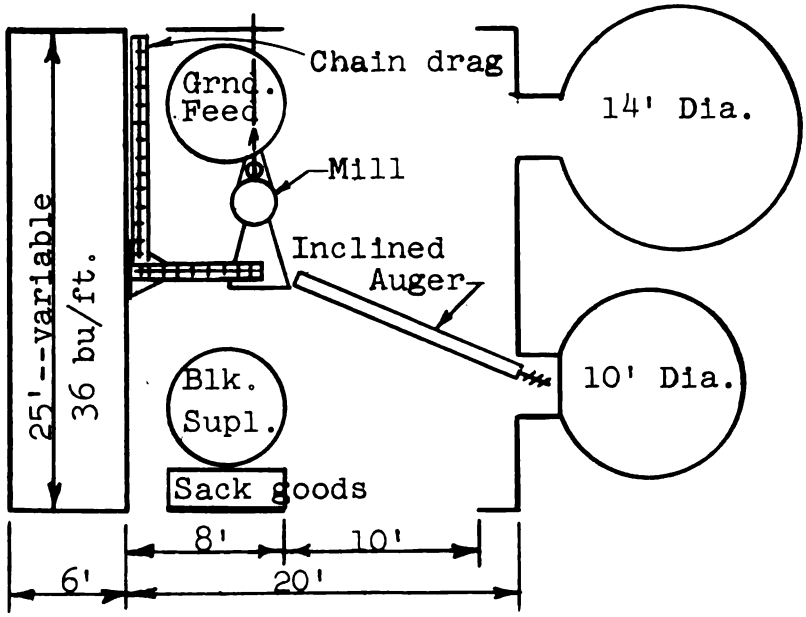
[1]Shelled grain includes both shelled corn and small grain. Many farms store some shelled corn. Since the storage structures for shelled corn and small grain may be the same, they are grouped under shelled grain storage bins.



Layout 6a

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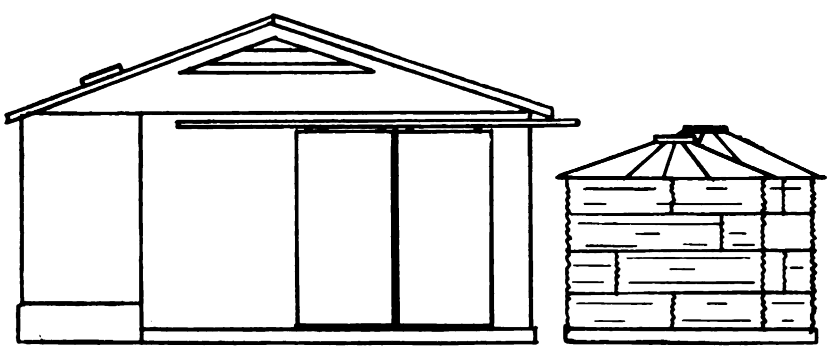
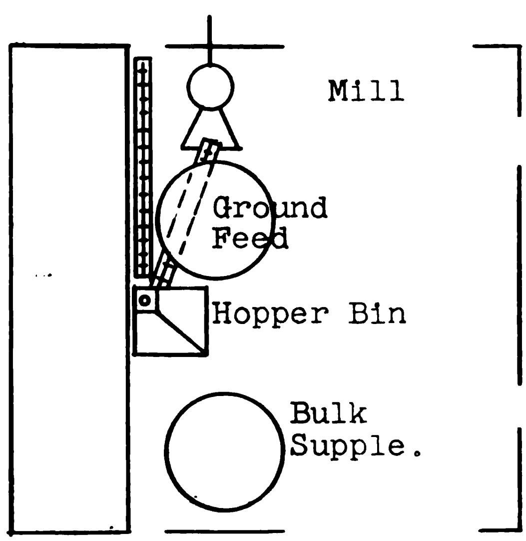
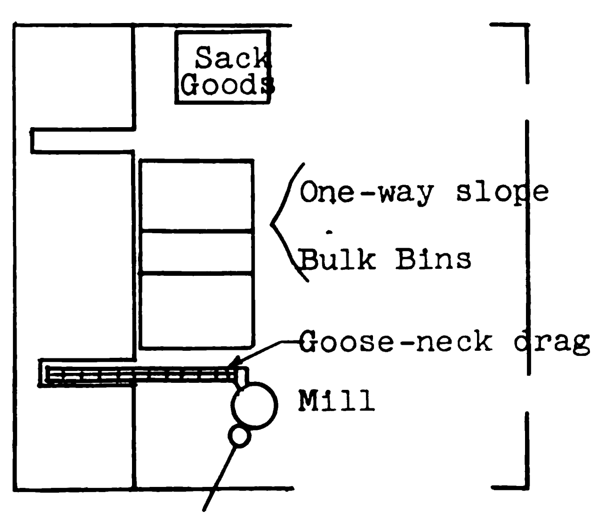


Elevation 6



Layout 6b



Layout 6c

Figure 6. Grain-feed handling system with a six foot wide single crib, two shelled grain bins, and a 20' x 24' processing area.

livestock farm. The plan features a 6 foot conventional or pole single crib for ear corn storage, coupled with round metal bins for shelled grain storage. One or both of the round bins may be equipped for in-storage drying.

The primary difference in the three layouts of Figure 6 involves the location of the grinder. Layouts 6a and 6b use a stationary mill location, while Layout 6c requires moving the mill. In Layouts 6a and 6b, the ear corn conveyor system consists of a horizontal chain conveyor placed along the side of the crib, and an inclined chain conveyor that feeds the mill. Both units are independently powered, although the inclined unit may be driven from the mill. The horizontal conveyor can be shifted to service either end of the crib.

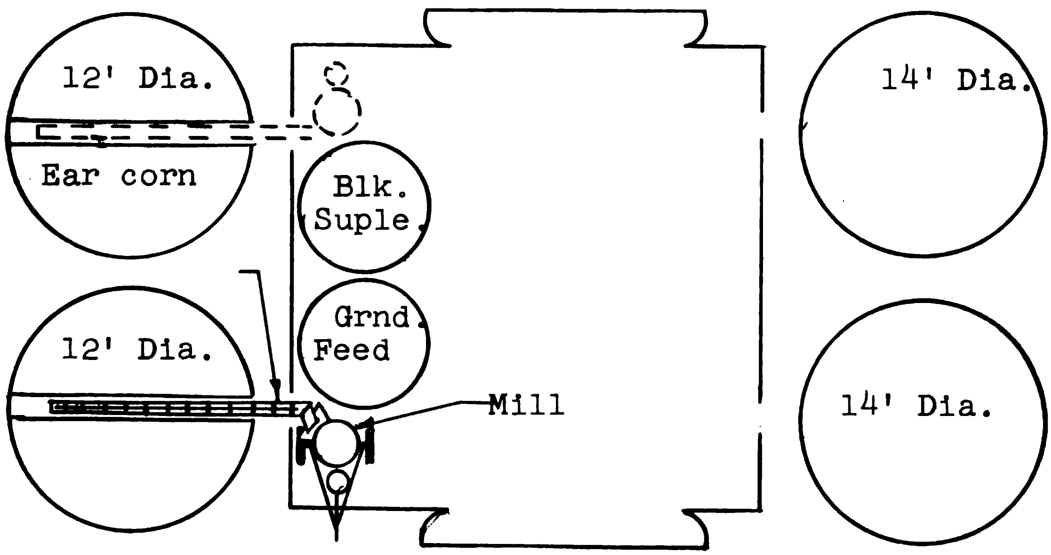
Layout 6b indicates a small hopper storage bin for small grain located over the grinder conveyor intake. This bin has a 2-way slope hopper, and discharges approximately 2 feet above floor level. This permits maximum capacity with the least height. The bin would be sized for one batch of feed.

Layout 6c presents an interesting variation in ear corn handling mechanization. By running the drag tunnels across the crib rather than along the side, the amount of conveyor necessary is reduced. In the particular crib shown, running the tunnel across the crib will remove the same amount of material by gravity as will a lengthwise installation running along the side of the crib, as in 6a or 6b. Since one conveyor with an inclined section at the discharge end is used instead of two tandom units, the cost of drive equipment is reduced. The cross tunnel method on a wood floored crib is also more easily installed than a lengthwise tunnel centered in the floor, because the cross tunnel can be boxed in between floor stringers.

The use of shallow hoppers formed in the concrete floor is recommended at the intake of the grinder conveyor and in front of each round bin. Cast-in-place hoppers are out of the way, and in addition give the necessary height differential needed for tandem operation of two conveyors.

The author considers the layouts illustrated in Figure 6 to be a minimum in space and capacity. The processing area is crowded. The driveway clearance is critical. The processing area can be expanded to 24 feet for additional space.

Circular crib and circular shelled grain. The layout in Figure 7 is very similar to that of Figure 6, except in the type of ear corn storage. Four additional feet have been added to the width of the processing area



Layout 7a. 24' x 24' Processing Area, Circular Wire Crib.

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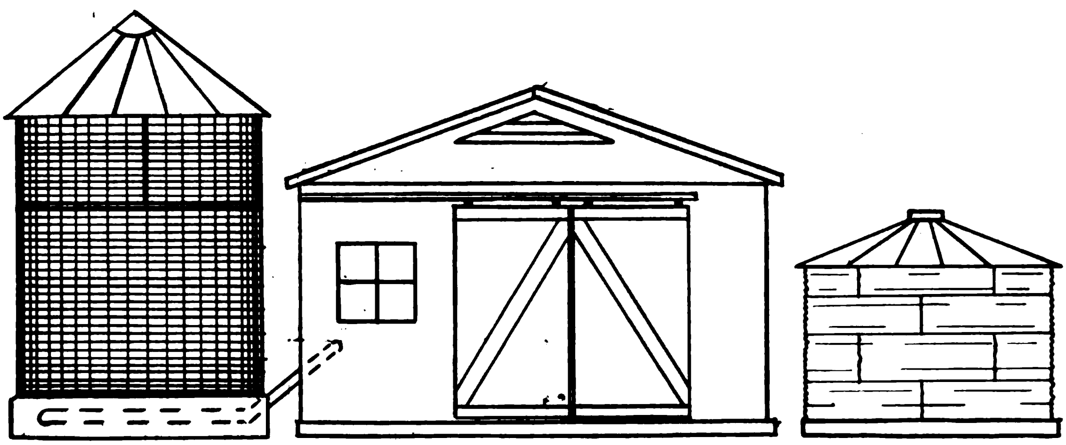


Elevation 7a

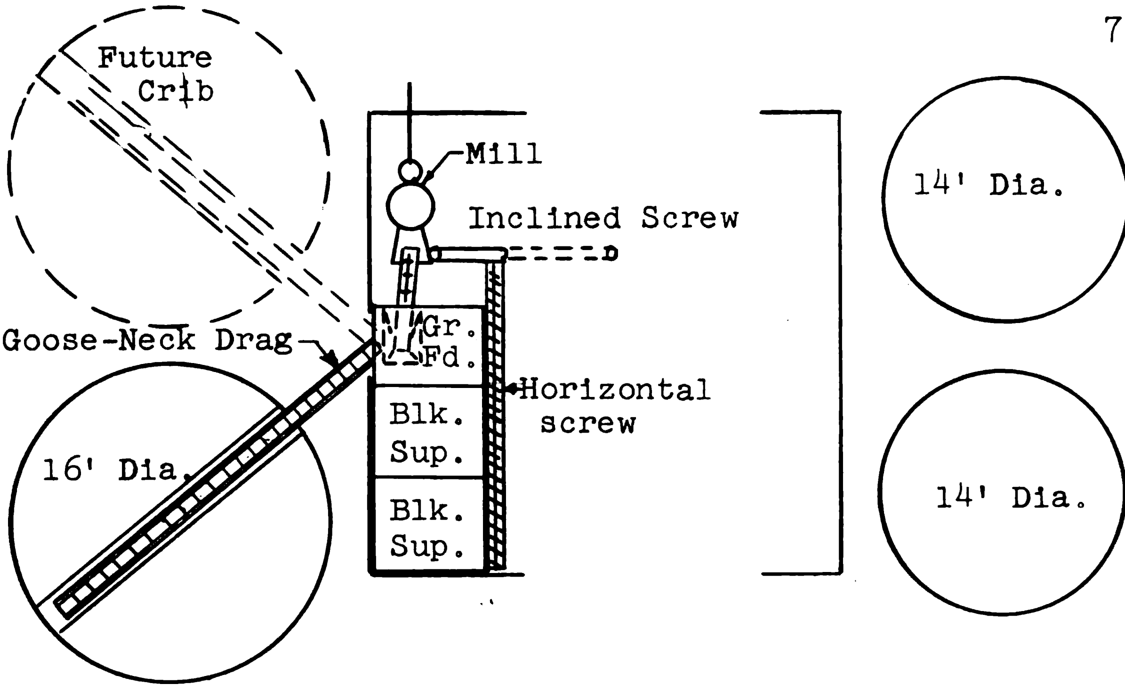
Figure 7. Grain-feed handling system using circular ear corn storage with circular small grain storage.

to permit a wider door and driveway clearance. The round grain storage bins are shown as equal size. Actually, they may be made up of any combination of two bins that will fit the space and still give access from the processing area. The reader will note this latter feature is a part of all layouts. In the author's opinion, a good grain-feed processing system permits batch assembly totally within an enclosed area. A layout that involves going outside in cold weather is poor design.

In the layouts in Figure 7 (and all layouts in this thesis) the round structures are placed within 2 feet of adjacent buildings. This appears to the author to be a minimum distance to permit working between two buildings for construction or maintenance. If neither structure is round, this distance must be increased.

The two round cribs in Layout 7a might be moved apart to bring the drag discharge nearer the corner. The power-take-off shaft length would be reduced, and some space gained for supplement and feed storage. The sack goods dock shown in Layout 7a is moved when the mill is moved. Assuming the corn storage is ample for a year's grinding needs, this involves one move per year.

Layout 7b features a chain drag conveyor of the same type (a goose-neck drag--a horizontal drag with



Layout 7b. 24' x 24' Processing Area, Circular Sheet Metal Crib.

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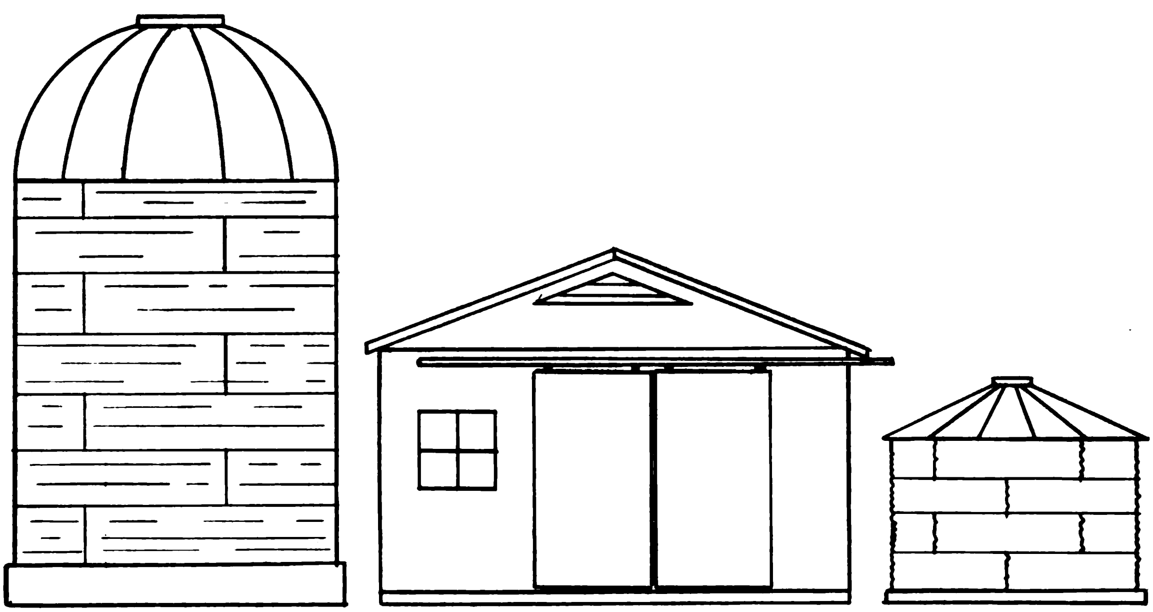


Elevation 7b

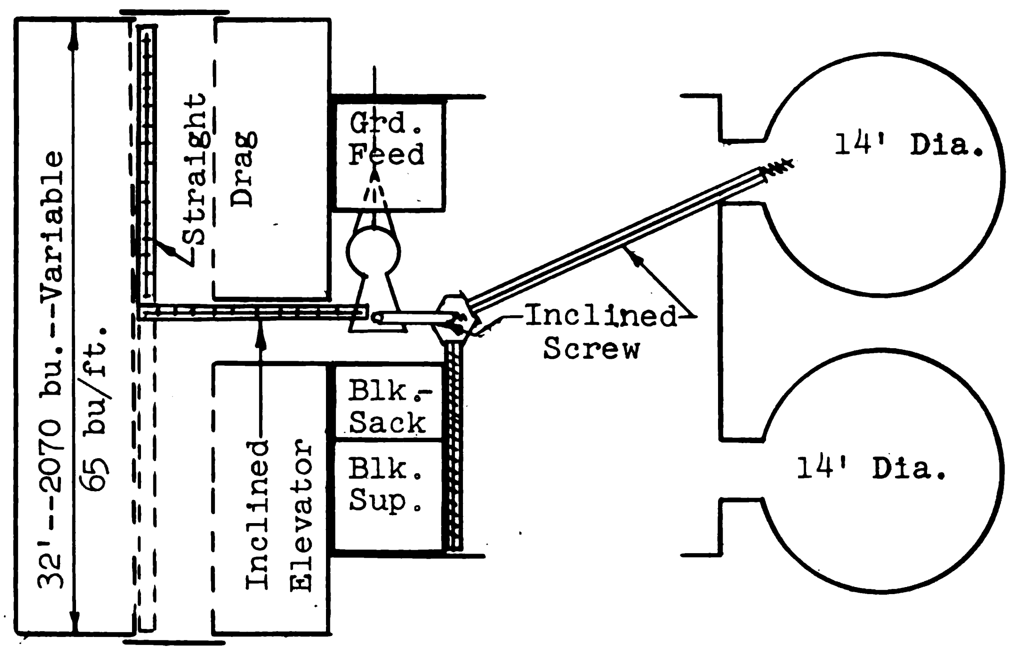
Figure 7. (Continued)

an inclined discharge section) as in 7a, but with a longer horizontal section. Layout 7b offers the advantage of a stationary mill location, along with the possibility of a hopper bin for feeding small grain into the mill.

Although tractor power-take-off driven mills have been shown in Figures 6 and 7, the use of belt driven mills for tractor or electric power is possible in all layouts. The reason for illustrating the power-take-off mill is to consider the location of the tractor. Since a tractor driving a power-take-off mill must be close to the grinder but clear of the driveway, this grinding method presents the greatest problem in planning.

The use of round metal bins with a small crawl-type service hatch rather than a large walk-through door should be considered in each layout. When complete mechanical unloading is used, the need to get inside the bin may occur only two or three times per year. The saving in bin cost when the walk-through door is eliminated can be used to partially off-set the cost of mechanical unloading.

<u>Drying crib with circular shelled grain</u>. The layouts in Figure 8 present some additional variations from previous plans. The primary difference again is the type



Layout 8a. 24' x 24' Processing Area, 16' Wide Drying Crib.

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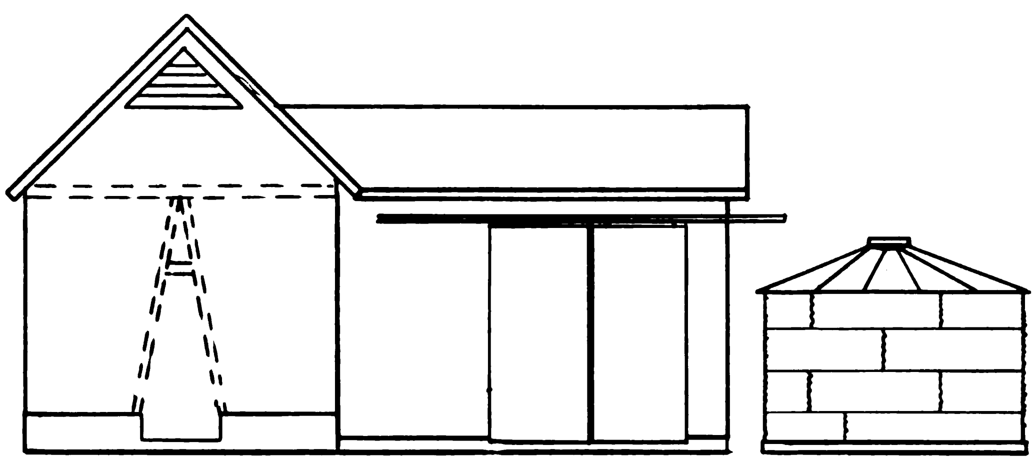


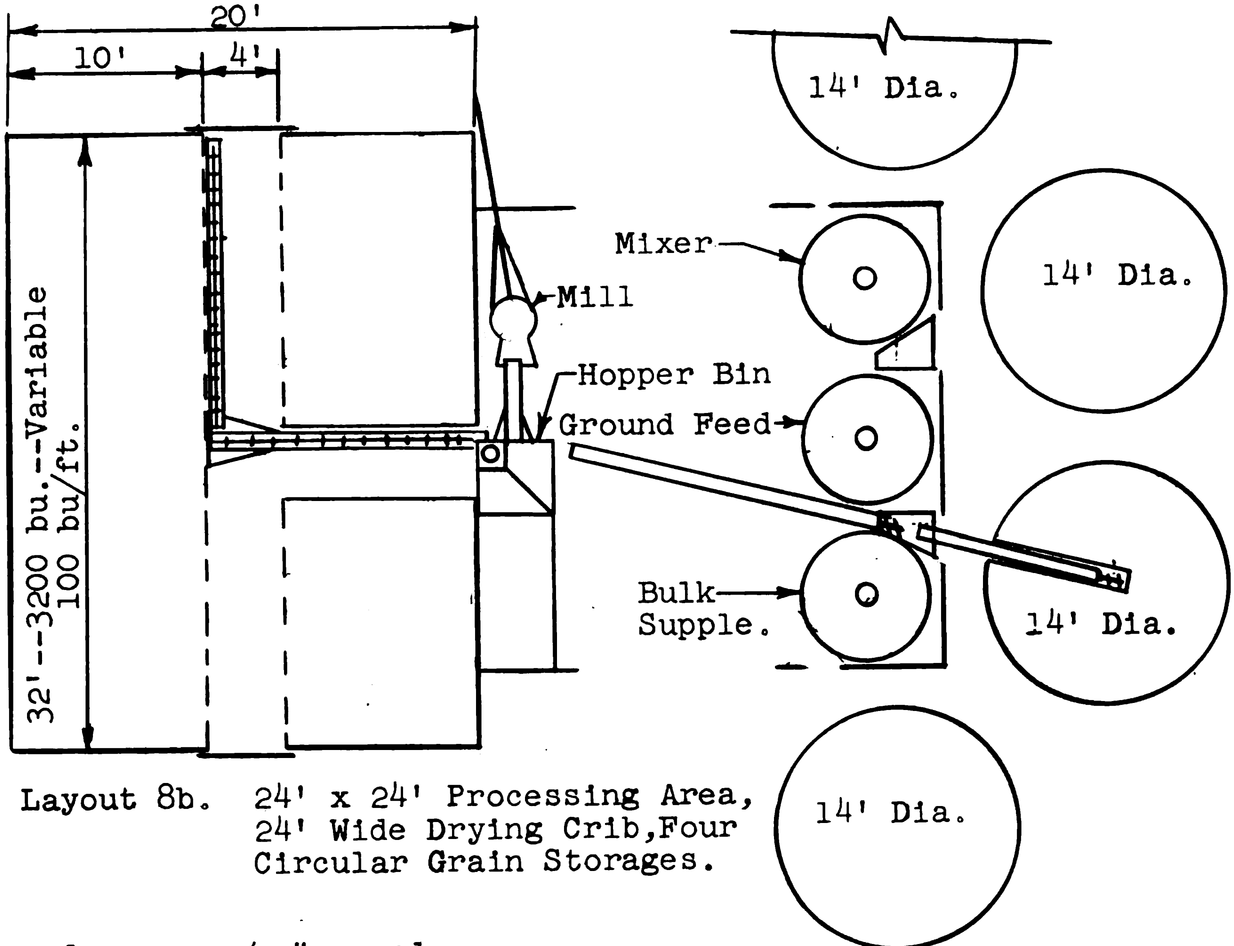
Elevation 8a

Figure 8. Grain-feed handling system using a 16' drying crib with circular shelled grain.

of corn crib used. The crib in Layouts 8a and 8b has a permanent drying tunnel running lengthwise through the center of the structure. This tunnel serves for drying, inspecting, and removing the corn. Whereas the crib in Layout 8a can be used with or without forced air drying, the additional width of the plan in Layout 8b must be equipped with a drying fan to satisfactory store corn in Michigan. The crib may be built in any length.

The ear corn conveyor system in the layouts in Figure 8 consists of two separate units. One conveyor is inclined from the drying tunnel to the processing area. This unit is permanently installed, and may discharge at heights from floor level to the grinder hopper height. The second chain conveyor is a horizontal unit that may be shifted to either side of the drying tunnel, and to either end of the crib. Hence, the horizontal drag, which is one-half the crib length, can be used in four positions.

Layout 8b indicates a small grain storage unit different than shown previously. A four bin layout of round metal structures doubles the shelled grain storage capacity of previous systems. Any or all of the bins may be equipped for in-storage drying with either heated or unheated air. One flat-bottom bin unloader can service all



Layout 8b. 24' x 24' Processing Area, 24' Wide Drying Crib, Four Circular Grain Storages.

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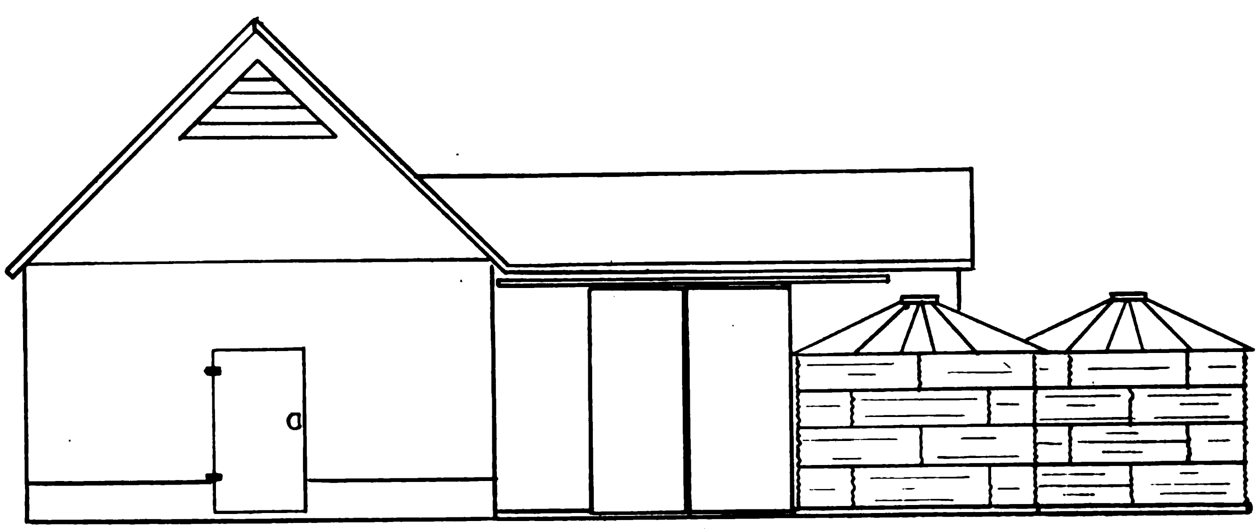


Elevation 8b

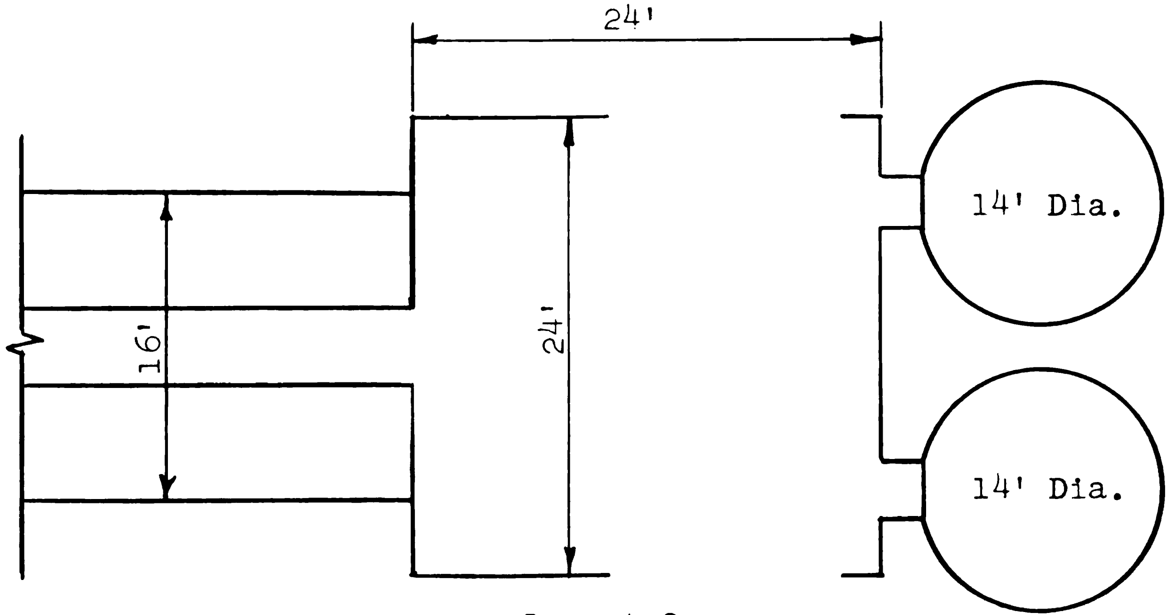
Figure 8 (Continued)

bins. The under-floor conveyor channels in the two bins opposite the corn crib in Layout 8b have been skewed inward toward the center of the processing layout. This places the discharge of the under-floor conveyor between the bulk bins. Cast-in-place hoppers are indicated between the bulk bins. The main service conveyor in the processing area is a 4 or 6 inch inclined screw conveyor, track-mounted as shown in Figure 4.

Figure 9 outlines a plan that orients the crib used in Figure 8 in a different manner with respect to the processing area. Although the crib drag length is increased for this layout, the over-all plan is narrower than that of Figure 8. It may thus be adaptable where erection space permits only a long, narrow facility.

Any of the grinder and feed storage layouts that are planned for a stationary mill location, and one ear corn input, are adaptable to Layout 9. Thus, any of the processing area arrangements shown in Layouts 6a, 6b, 7b, or 8a, are possible. In addition, the 4 bin shelled grain component of Layout 8b, along with the corresponding grain processing area arrangement, is an option in Layout 9.

The layouts shown in Figures 10 and 11 feature a tractor storage area as a part of the plan. The cribs shown are the same as those used in Figures 8 and 9. A



Layout 9

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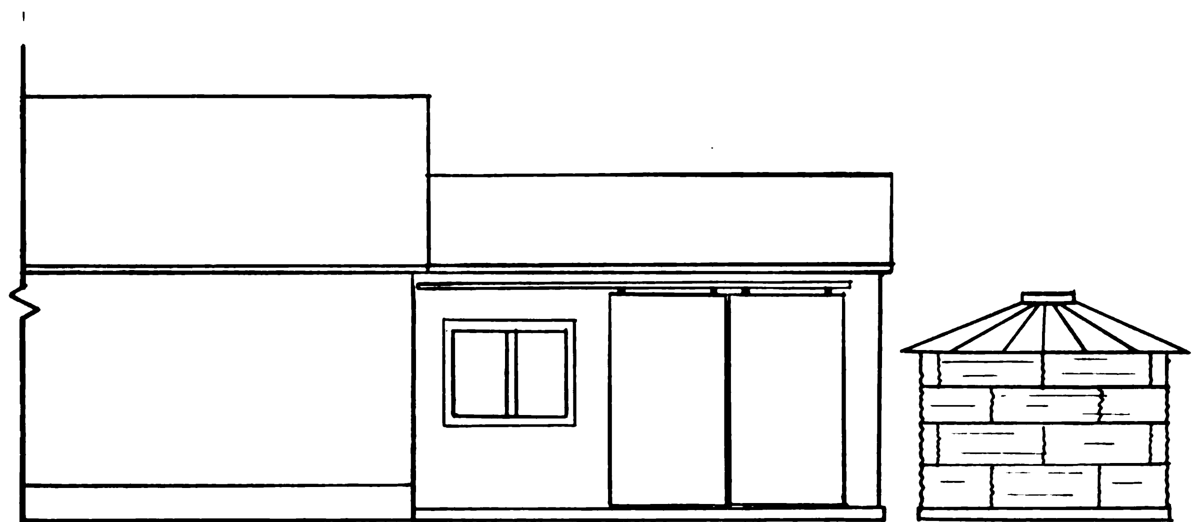


Elevation 9

Figure 9. Grain-feed handling system with 16' drying crib and circular shelled grain storage. Crib unloaded from one end.

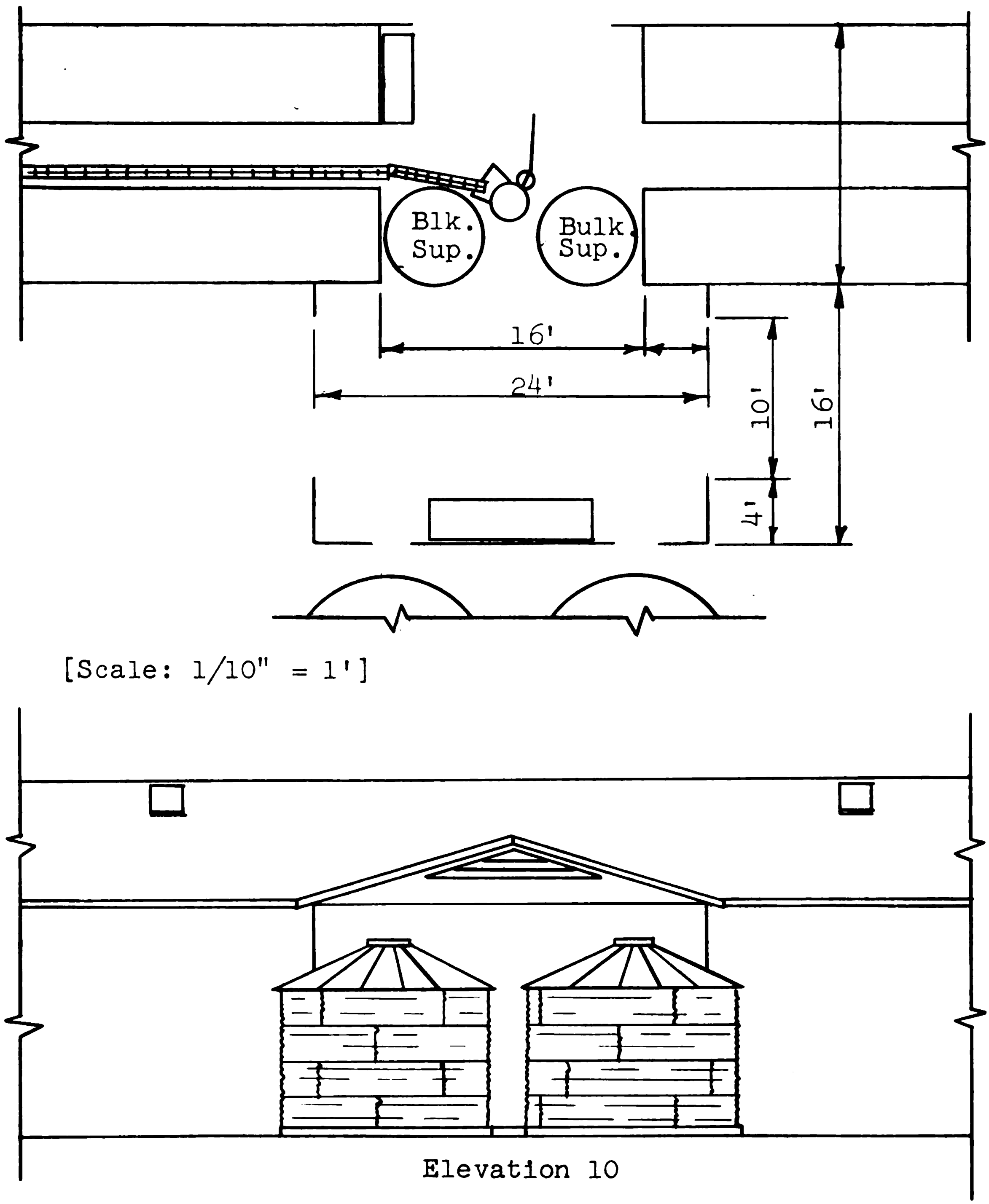
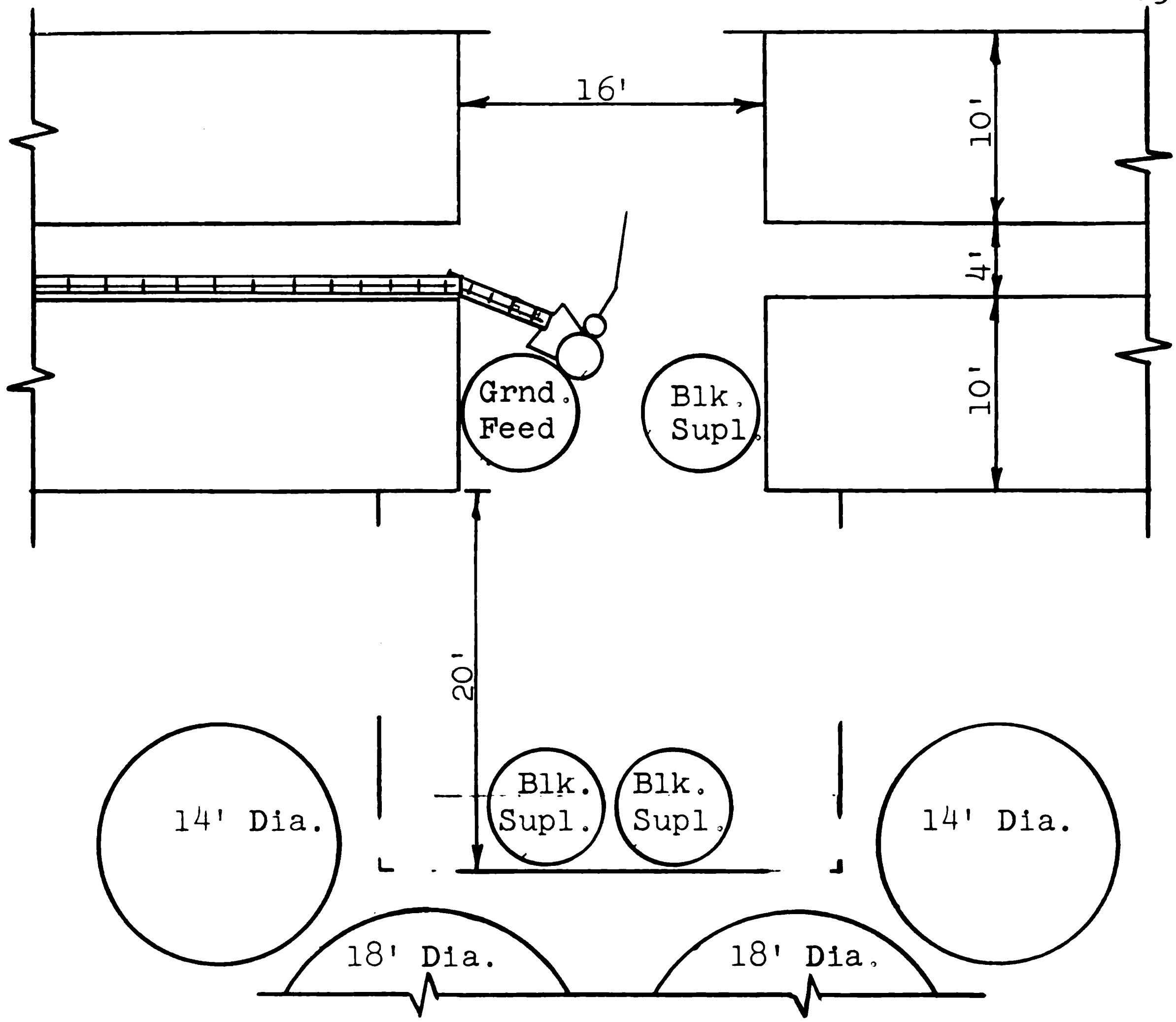
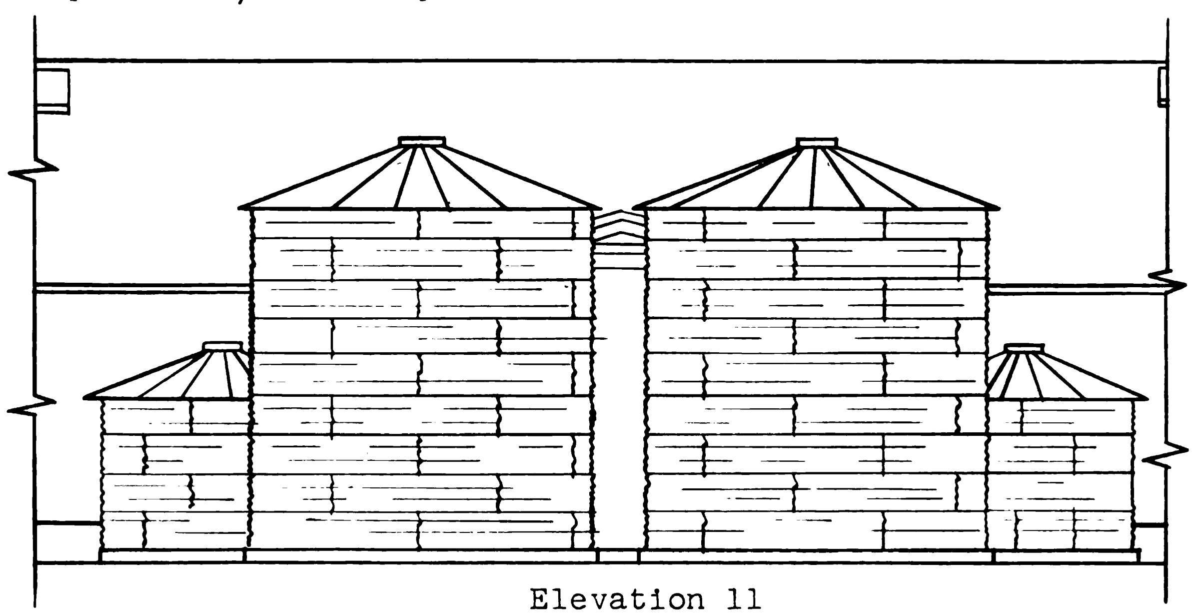


Figure 10. Grain-feed handling system using two 16' wide drying cribs with circular shelled grain storage.



[Scale: 1/10" = 1'] Layout 11



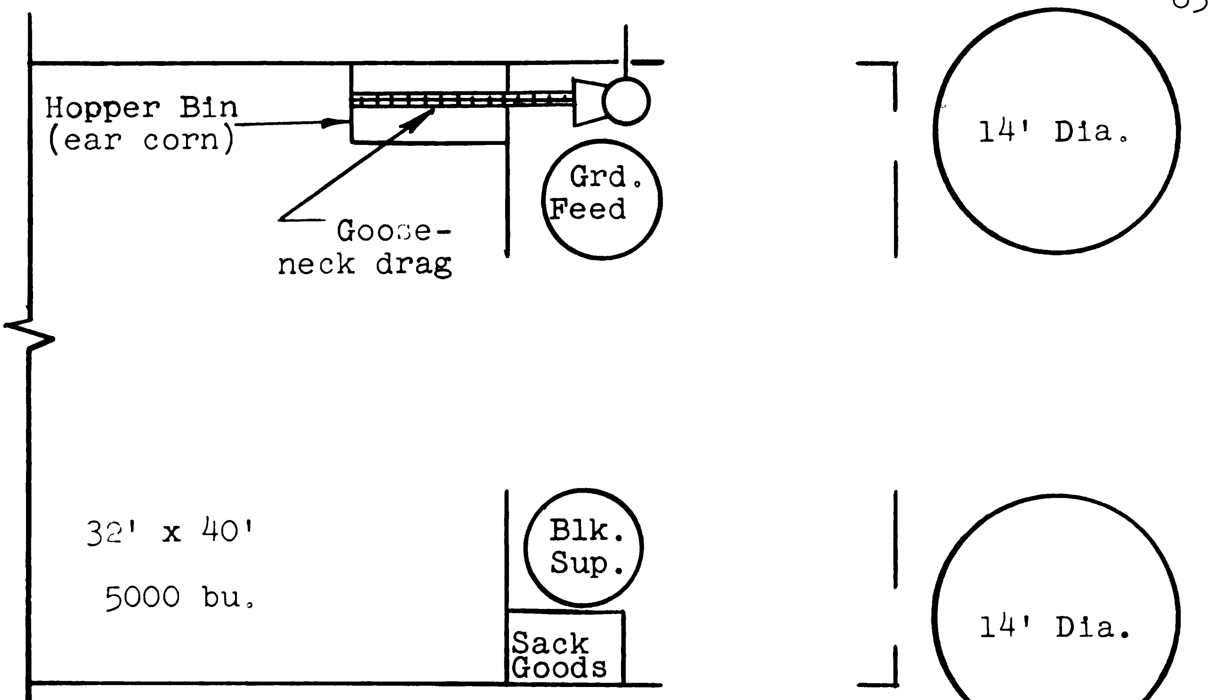
Elevation 11

Figure 11. Grain-feed handling system using two 24' wide drying crib with four circular shelled grain storages.

comparison of Layouts 8a and 10 shows that the processing building in Layout 10 has been reduced in width. This is compensated by the space between the two crib storages.

Figure 11 is a plan for a 4 bin shelled grain storage unit in conjunction with two drying cribs.

Clear-span crib with circular small grain. Figure 12 presents a grain-feed handling system using a flat storage structure for ear corn. Layout 12a is designed for storage unloading with a tractor manure loader equipped with a snow scoop. The plan features two options in ear corn grinding. In one method (shown on the plan) a small hopper bin located in one corner of the ear corn storage holds sufficient ear corn for one batch. The bin is filled prior to grinding. A second option (not illustrated), would involve the use of a short goose-neck drag, with the horizontal section recessed into the crib floor. A 10 foot to 16 foot unit would suffice. The drag would be located at the same point as the hopper bin. In operation, the tractor scoop would be used to pile a mass of ear corn over the drag. The quantity of ear corn that would flow from this pile by gravity and agitation would constitute a batch. The tractor scoop may be used to shove the remaining corn into the drag.



Layout 12a. 20' x 32' Processing Area, Designed for Unloading With Tractor Scoop

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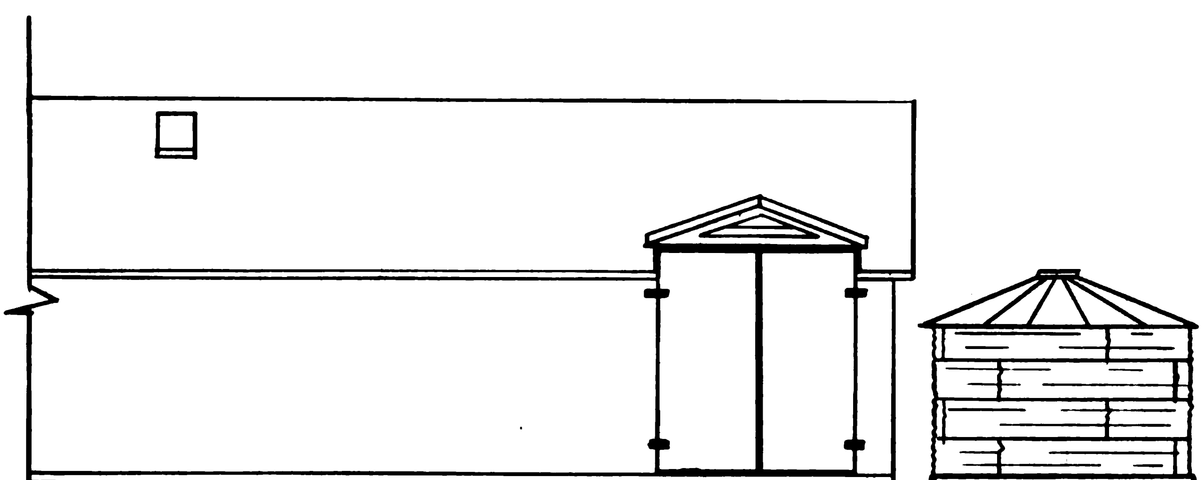


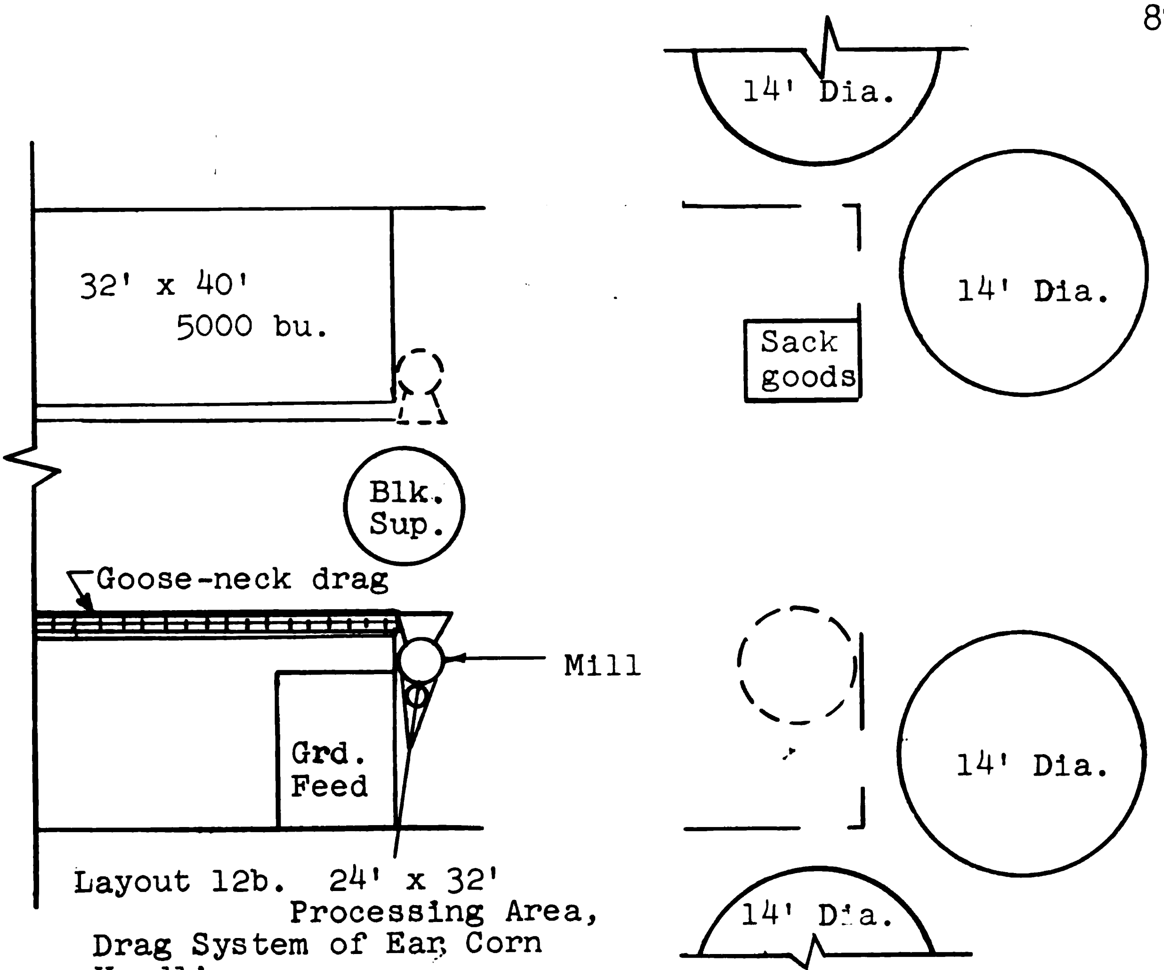
Elevation 12a

Figure 12. Grain-feed handling system using a clear span ear corn crib and circular shelled grain storage.

The use of a tractor scoop for storage unloading requires a double door into the corn storage area. Layout 12a is planned with a double door in the end of the corn storage, and a corresponding entrance on the opposite side of the processing area driveway. This may be unnecessary and uneconomical. It is planned as an option because a flat-storage structure may be used for various purposes. Hence, when the storage in Layout 12a is partially or completely unloaded, it may be used for machinery or fertilizer storage, provided access is possible. The door arrangement shown would accomplish this, as would an entrance in the side of crib structure.

The 4 bin shelled grain storage component in conjunction with a flat-type ear corn storage is shown in Layout 12b. A drag system of ear corn handling consisting of two drag tunnels and one drag is illustrated. Depending on the height of the flat storage structure, one or two drying ducts may be used. With two drying ducts, the ducts would be placed over the drag trenches.

Figure 13 shows two flat-storage structures set end to end, with the processing storage in between. This plan has some disadvantages. One criticism is the limited space available for processing equipment and feed storage. The plan also gives little room for shelled grain storage



Layout 12b. 24' x 32' Processing Area, Drag System of Ear Corn Handling

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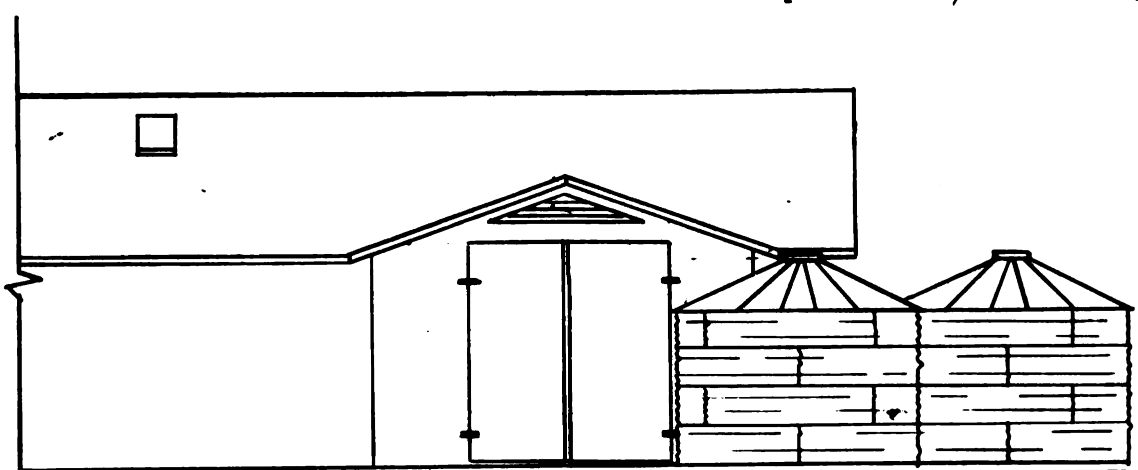
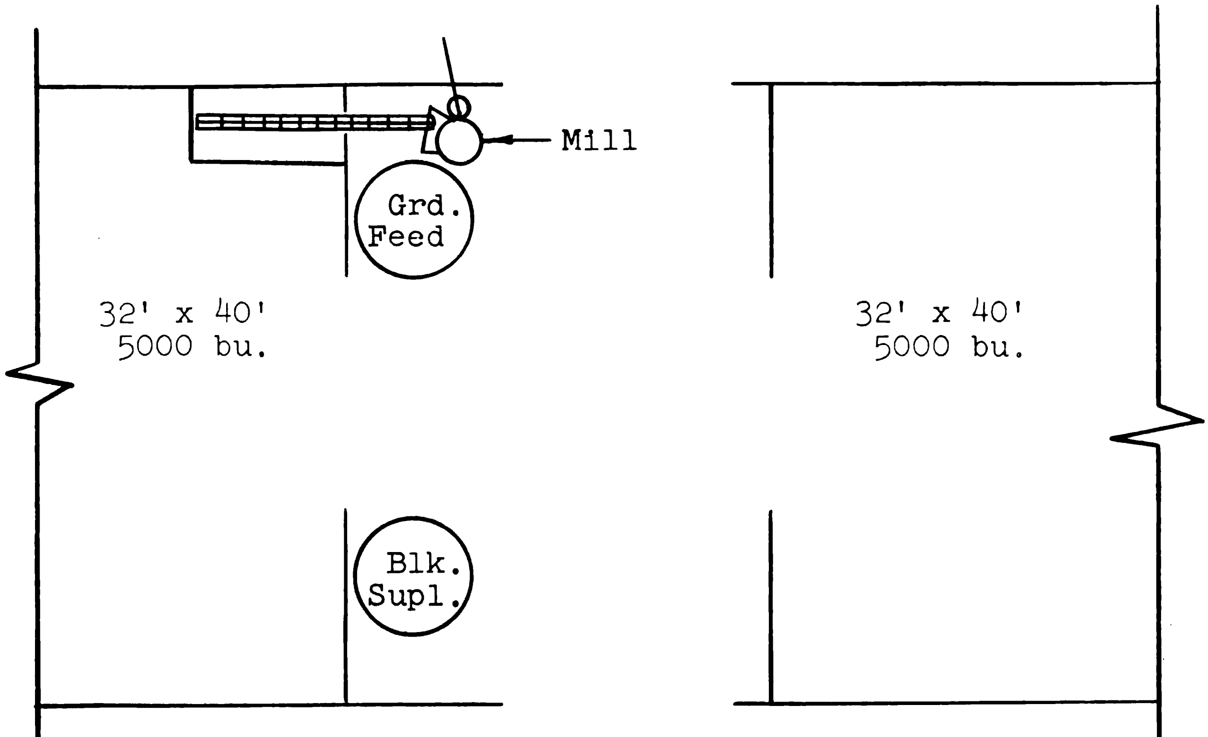


Elevation 12b

Figure 12 (Continued)



Layout 13. 22' x 32' Processing Area

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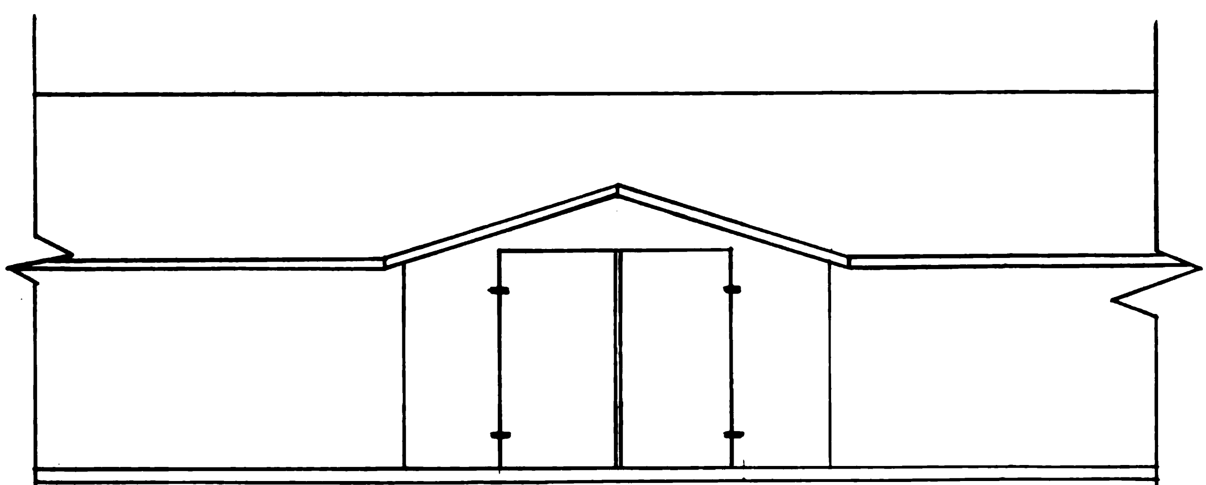


Elevation 13

Figure 13. Grain-feed handling system using two clear span cribs designed for tractor scoop handling.

location. The latter storage might be incorporated into a section of one of the flat storage structures.

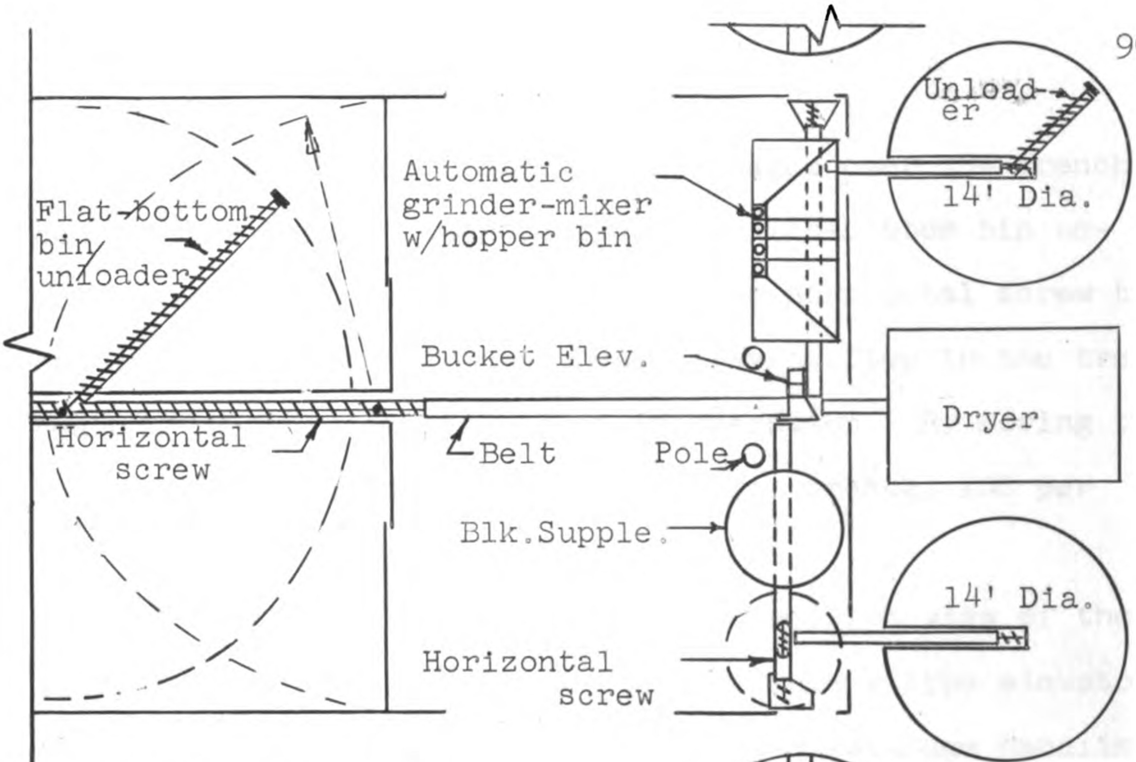
Layout 13 has one advantage over all other layouts presented to this point. Assuming all of the ear corn will be fed out in a year, one of the storages should be empty by late winter. This unit can then be utilized for other purposes until harvest time. Considering the possible need for fertilizer storage and machinery repair during the spring planting season, this may be a strong asset.

Dry Shelled Corn-Small Grain Layouts

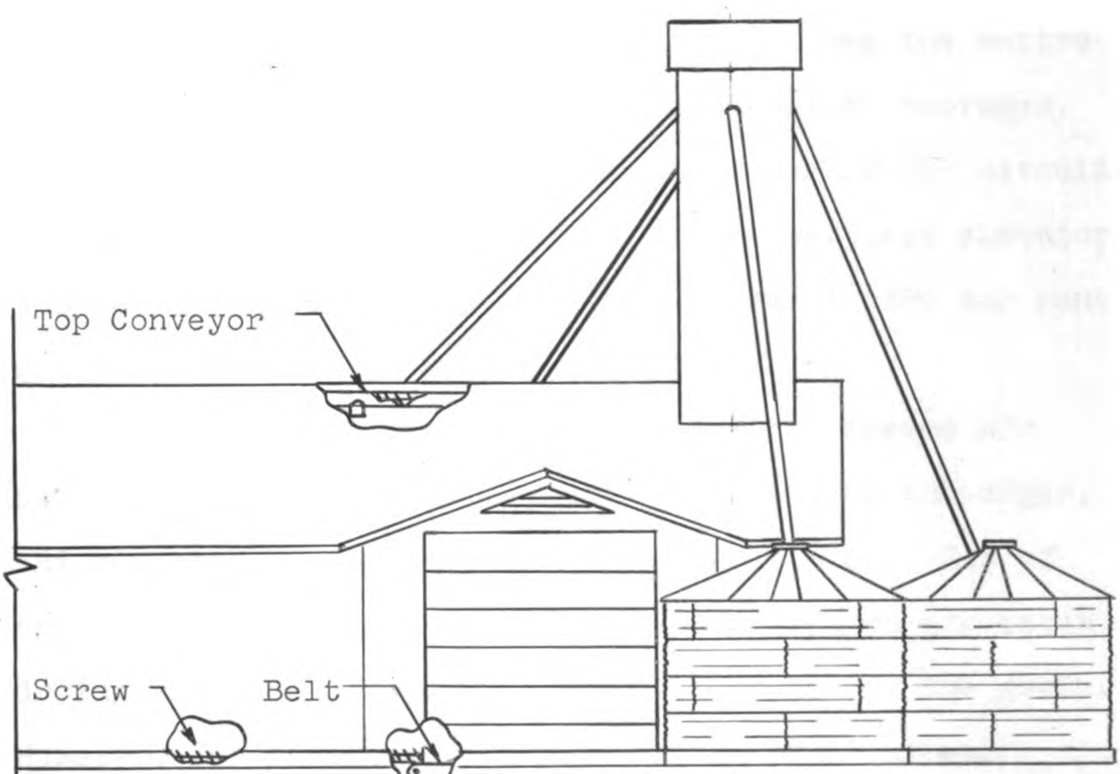
Clear span shelled corn with circular small grain. The layouts using flat shelled grain storage are essentially the same as those for flat ear corn storage. In fact, this is one of the advantages of such construction--the facilities can readily be converted from ear corn to shelled corn. The primary difference in a flat storage layout for shelled grain as opposed to ear corn is the handling system.

Figure 14 presents a flat storage and round bin layout for dry shelled corn and small grain. A comparison of this plan with Layout 12a will demonstrate the similarity in design.

The unloading system for the flat grain storage consists of a horizontal screw conveyor (open top) recessed



Layout 16. 24' x 28'
Processing Area [Scale: 1/10" = 1']



Elevation 14

Figure 14. Grain-feed handling system for shelled corn and small grain designed for complete mechanical handling

in the center of the floor. Cover boards over the trench control the load on the conveyor. A flat-bottom bin unloader is used in conjunction with the horizontal screw to convey grain to the trench. When gravity flow to the trench ceases, the unloader is placed in operation. By moving the unloader pivot point along the conveyor trench, 100 per cent grain removal is possible.

Elevation 14 is a partial cross section view of the complete conveyor system. A vertical bucket type elevator is used both for in-to-storage and out-of-storage handling. A belt-type horizontal conveyor is recessed into the driveway floor. A 6 inch screw conveyor mounted along the peak of the flat structure distributes grain along the entire length. Spouts are run to the circular grain storages. The horizontal screw conveyor in the floor of the circular storage brings grain to the boot of the vertical elevator. A flat bottom bin unloader is used to attain 100 per cent grain removal from the round structures.

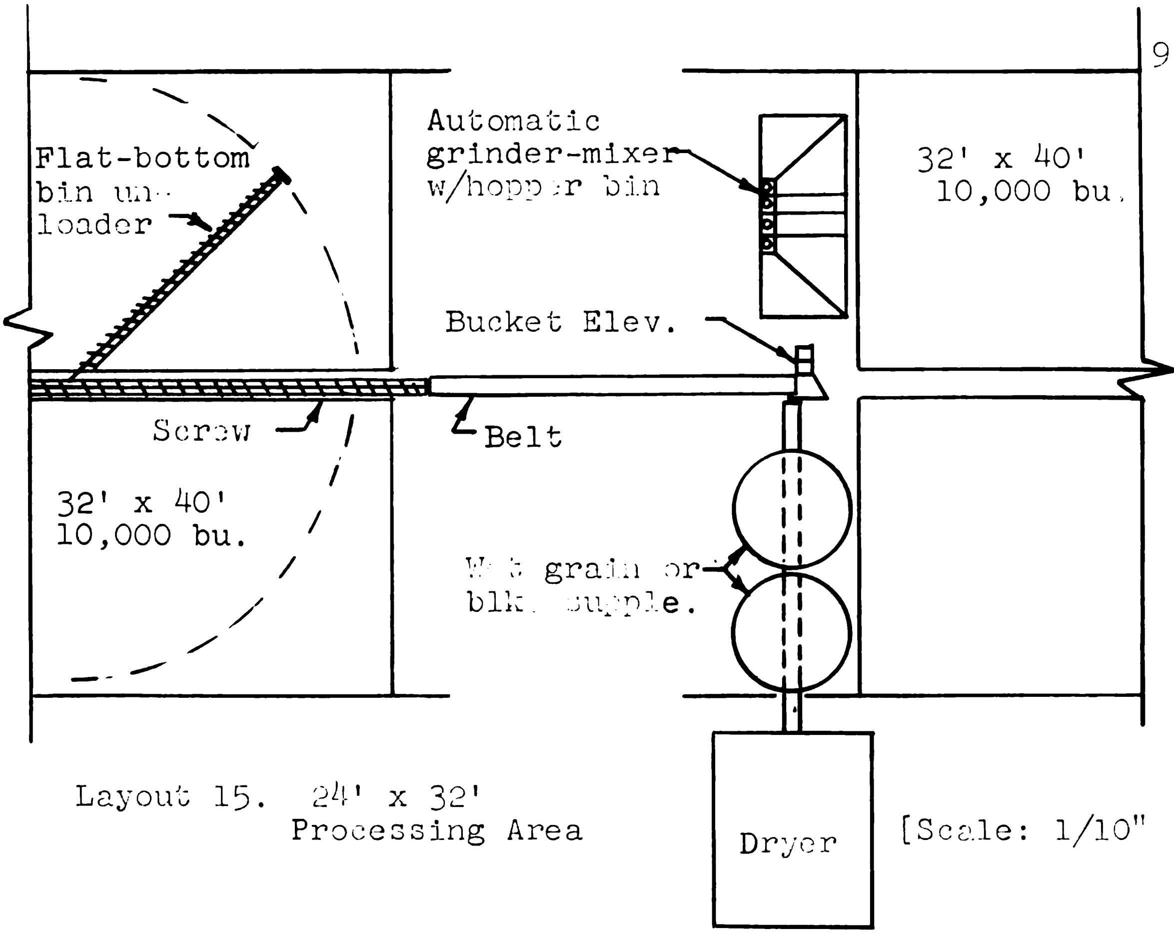
Space is allotted in Layout 14 for a heated air batch drying system. Grain can be spouted to the dryer, and returned by conveyor to the elevator boot. One of the circular storages could be used for heated air batch drying with the flat-bottom unloader to remove the grain. However, the capacity of such a system would appear unsatisfactory for the volume of grain considered in this layout.

The rather unorthodox appearance of the headhouse of the vertical elevator in Elevation 14 is necessary to attain spout height to the side structures. The use of a horizontal conveyor to carry grain to the side structures might be considered an alternative method.

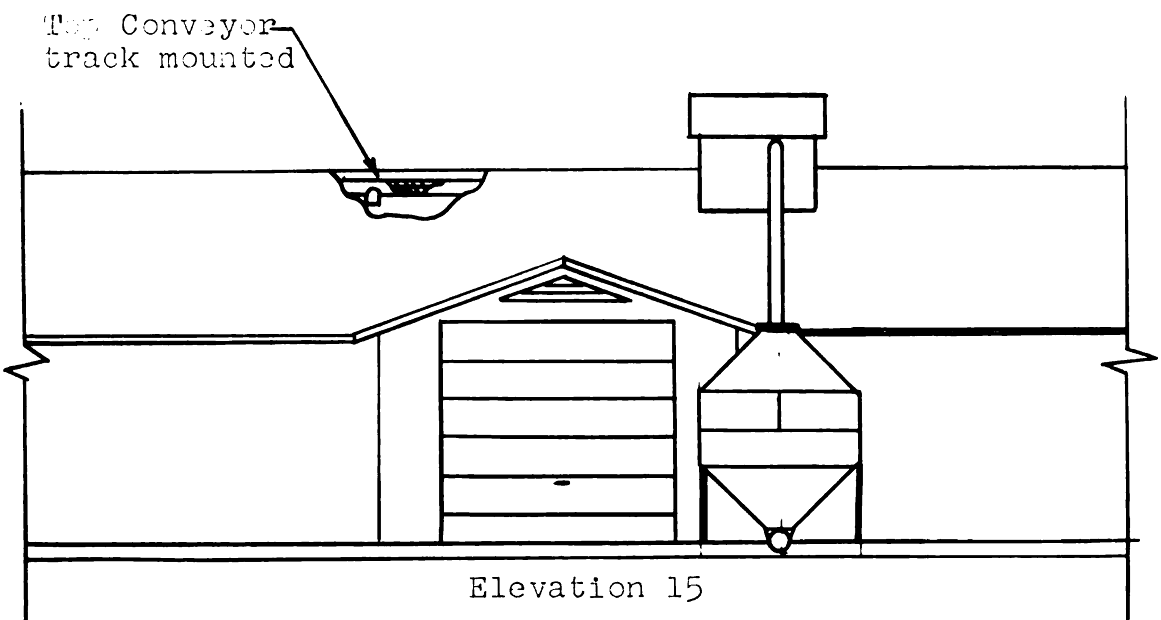
Figure 15 presents a double flat storage layout and elevation. The processing area is centered between the two structures. The advantage of two flat storage units, one of which is unloaded by mid-winter, was discussed previously. It applies equally well in this layout.

The handling system in Layout 15 differs from 14 in several respects. First, the absence of the round structures at the side reduces the need for the high headhouse. However, the batch drying bin has been moved to the side, and requires filling from the central elevator. A horizontal conveyor is substituted for the high headhouse. This conveyor conceivably can be the same unit used for storage unloading. Since both operations are not carried on at the same time, dual use is possible.

The use of free-standing low outlet height hopper bins for wet grain storage is a part of the plan. They can be filled with either the vertical elevator or directly



Layout 15. 24' x 32'
Processing Area



Elevation 15

Figure 15. Feed-grain handling system featuring two clear span storages, drying, automatic grinding, and complete mechanical handling

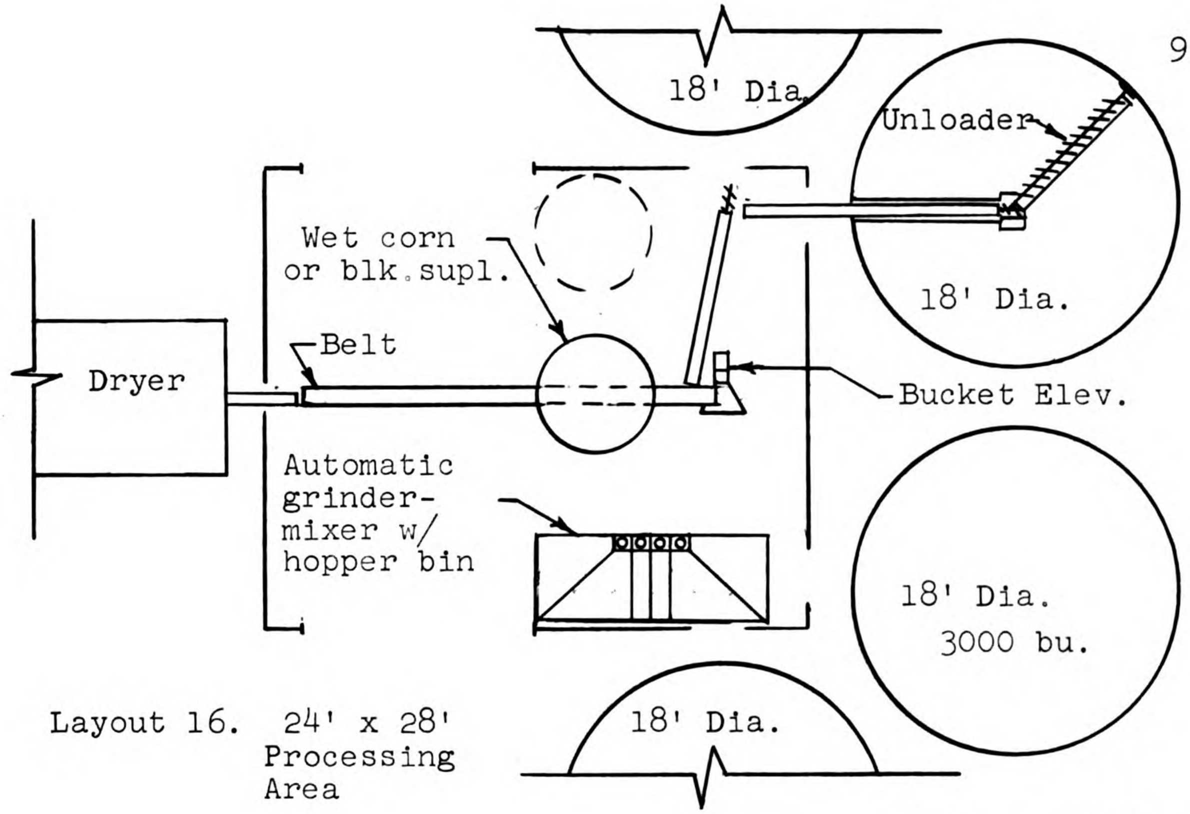
from a self-unloading grain-feed wagon. The hopper storages are positioned to discharge directly over the return conveyor from the drying bin. Hence, wet grain (and throughout the year, ground feed and supplement) can be returned to the vertical elevator boot for handling.

The absence of bins for small grain storage is a criticism of Layout 15. These bins can be added in the flat storage adjacent to the elevator.

The storage Layouts in either Figure 14 or 15 may be filled with portable outside elevators. However, the addition of drying to the handling requirements should suggest the use of a vertical bucket elevator.

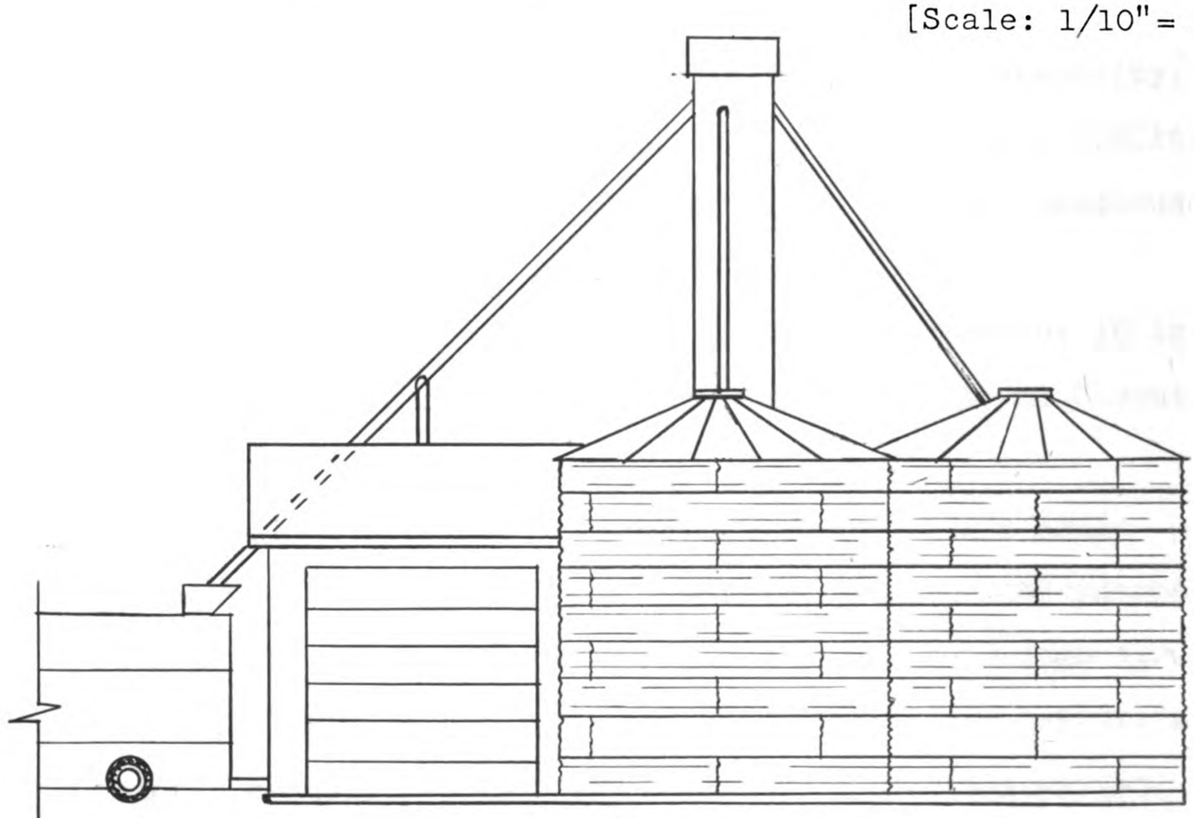
An automatic electrically powered grinder-mixer is featured in the Layouts of both Figures 14 and 15. The grinding systems consists of a four compartment hopper-bottom bin, the four channel grinder-mixer, and a 4 inch screw conveyor to deliver ground feed to a self-unloading feed wagon or a bulk storage bin.

Circular shelled corn with circular small grain. Figure 16 presents a shelled corn and small grain layout consisting entirely of round storage structures. A vertical elevator serves as the central conveyor, and is fed with a horizontal belt conveyor recessed in the drive-way floor. With the elevator located in the center of the



Layout 16. 24' x 28' Processing Area

[Scale: 1/10" = 1']



Elevation 16

Figure 16. Grain-feed handling system with circular shelled corn storage, drying, automatic grinding, and complete mechanical handling.

bin circle, the horizontal drive-way drag must be longer than in Figures 14 and 15.

The unorthodox headhouse appears again in Layout 16. The height is necessary to maintain slope on the spout tubes. Grain is also spouted to the drying system, although a mechanical conveyor in the top of the processing structure may be substituted for gravity spouts.

A weather-proof vertical elevator installed outside the processing building is an alternative to the tall headhouse. However, with so many spout lines involved, the author prefers the shelter of the enclosed headhouse to keep moisture out of the distributor head and vertical leg. The outside elevator would require support for stability. This can be done by cable guys, or by installing a utility pole on each side of the vertical leg. The tall headhouse would be framed around two utility poles.

The out-of-storage handling system for Layout 16 is the same as that for the circular storage units in Layout 14.

The use of grain aeration equipment in dry grain storages of over 2000 bushels capacity must be considered in storage layout. The round metal and flat storage structures outlined in the previous dry shelled corn layouts are adaptable to either a floor-level or top mounted system.

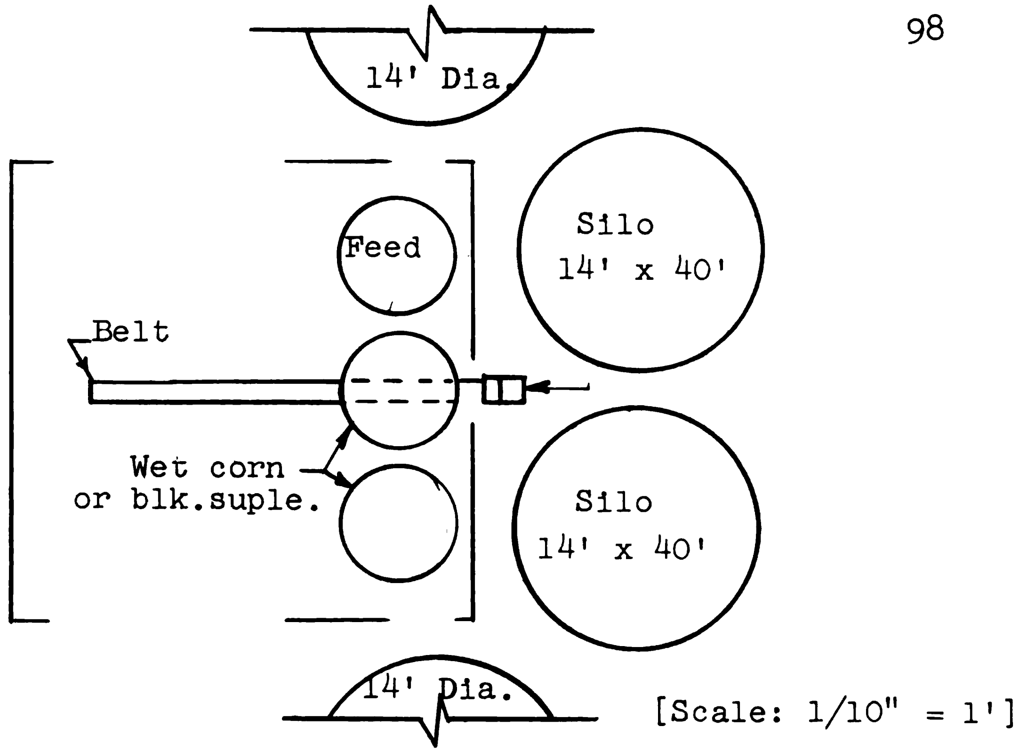
The top mounted system offers the advantage of no obstructions in storage unloading. Although common in circular storages, the use of an overhead suspended aeration system in flat storage would be considered experimental.

High Moisture Corn-Shelled Grain Layouts

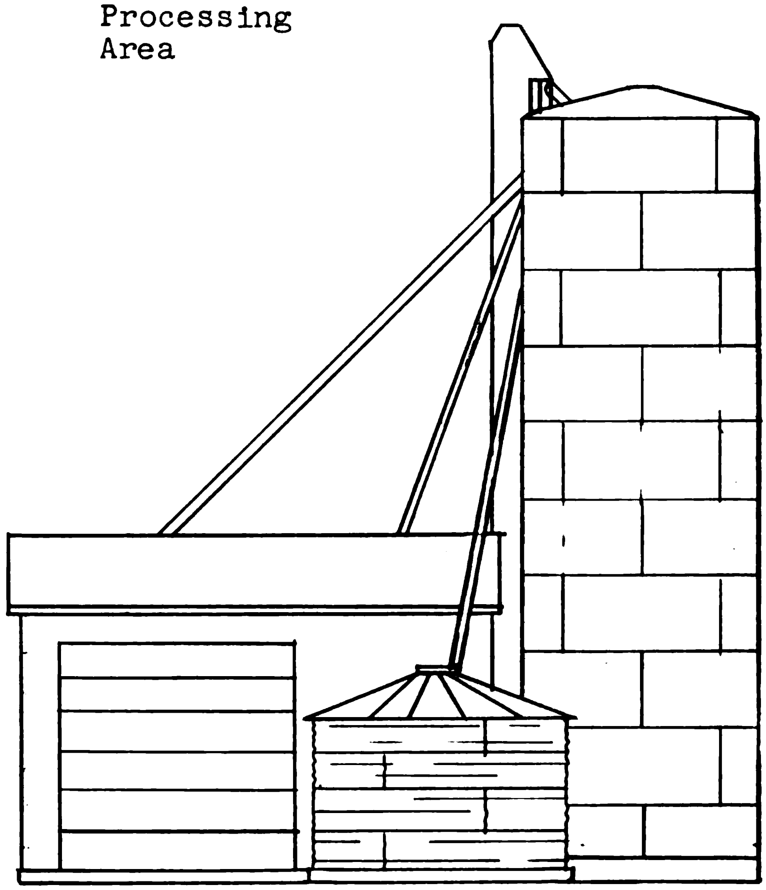
The layouts for high moisture corn storage are almost identical in plan view to those for circular dry corn storage. Two alternatives in structure choice exist. These include silos and metal storages with plastic bag liners.

Silo corn storage with circular shelled grain. A silo layout is shown in Figure 17. An outside weatherproof vertical elevator is illustrated, although a forage blower should be considered an alternative. Placing the elevator outside the processing area adds to the length requirements of the cross-driveway drag. The out-of-storage handling system is not materially affected by the shift in elevator location.

The bulk of high moisture corn to date has been stored in hermetic (gas tight) storages. However, research underway indicates that non-hermetic storages may give satisfactory preservation. Consequently, non-hermetic storages can be considered as an alternative to gas-tight structures.



Layout 17. 24' x 24'
Processing
Area



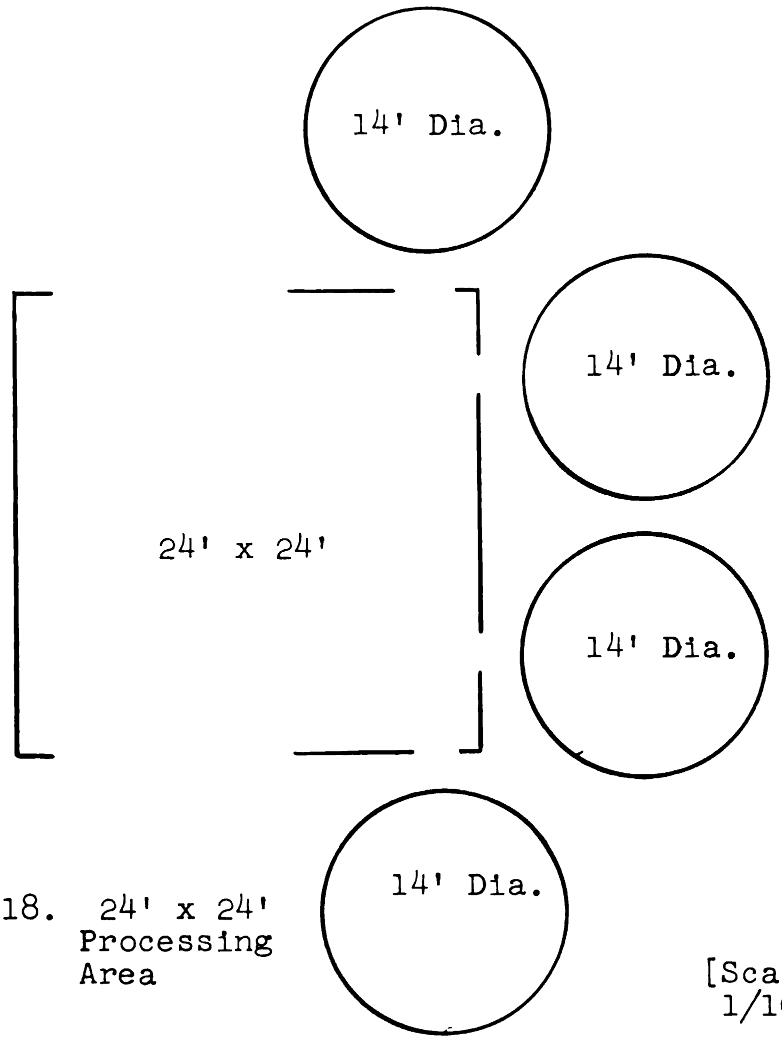
Elevation 17

Figure 17. Grain-feed handling system using high moisture corn storage and a vertical elevator.

Plastic-lined circular corn storage with circular small grain. Figure 18 presents a storage layout essentially the same view in plan view to that of Figures 16 and 17. The storage structures in Layout 18 are round metal bins with plastic bag liners. This storage method, developed by Isaacs (21), is hermetic. The handling equipment system in Layout 18 is the same as the 4 bin layouts without a vertical elevator for in-to-storage handling. A vertical elevator system can be used, if desired.

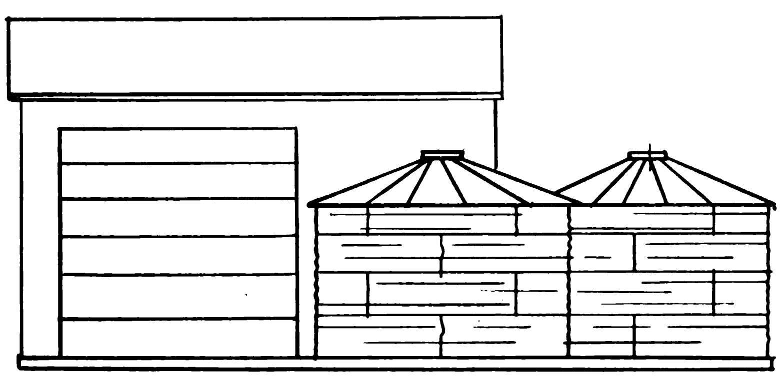
Unloading high moisture corn from flat-bottom bins is a problem with few answers. The glass lined hermetic storages are commonly sold with a horizontal screw conveyor recessed in the floor. The intake of the conveyor is centered in the floor. This method of unloading cannot be safely applied to tall structures not designed for non-uniform sidewall loading. With one-point withdrawal, the grain may not feed uniformly to the conveyor. An unbalanced sidewall load may cause the structure to fail.

The shallow depth metal bins of capacities less than 1000 bushels studied by Isaacs have been unloaded satisfactorily with a horizontal screw conveyor injected into the side of the grain mass. Farmers in Indiana have used plastic liners on bins over 1000 bushels in capacity. The use of top-mounted silo unloaders for high moisture corn unloading has not been investigated to any appreciable extent.



Layout 18. 24' x 24' Processing Area

[Scale: 1/10" = 1']



Elevation 18

Figure 18. Grain-feed handling system using plastic-lined round metal bins.

VI. PRESENTATION AND DISCUSSION OF COST AND CAPACITY DATA

Cost As A Measure

A measuring criteria of some dimension is needed as a foundation for the analysis and discussion of the grain-feed handling systems presented in the previous chapter. There are a number of system characteristics that might be measured, including total horsepower required, labor required, the feet of conveyor used, the amount of buildings and building space used, et cetera. However, any one of these characteristics would give very little information about the total system. Each is a somewhat specialized measure that may or may not have any significant bearing on the over-all performance of the system.

Each of the above system characteristics have at least one common denominator, namely cost. A cost analysis can simultaneously consider the floor space, horsepower, feet of conveyor, and labor. A cost analysis represents a total measure, to the extent that costs are indicative of the inter-relation of these and other system characteristics.

Cost expressions are static in terms of time, having been derived for a particular product with a specific time, place, and form relationship. This static characteristic of cost relationships presents some limitations in their use, because of the dynamic nature of reality. This does not mean that static cost estimates are not useful. They are probably the most valuable guide to decision making in use today. Farmers and farm managers must use such estimates almost daily to project management into dynamic situations.

Equipment Costs

The cost data presented on the following pages were obtained from manufacturers and distributors of grain handling and processing equipment. In the author's opinion, these data represent typical price schedules for equipment available to Michigan farmers.

The reader should recognize some of the assumptions that are made in the preparation of such a cost schedule. First, a choice must be made concerning which equipment to include in the listing. This presents an immediate problem in ascertaining service requirements of the equipment for the particular operation in mind. Too, special features on each device, boldly advertised as preferable to any other product on the market, must be credited or discounted on an arbitrary basis.

The final price schedule is determined by an averaging process,[1] using the equipment and price schedules considered representative of the situation. This average price can then only be used as a guide in consideration of a specific situation. It must not be considered as an absolute value. The author believes that his farm experience, coupled with nearly ten years of professional experience in working with materials handling equipment and problems on farms, adds credence to the validity of the equipment and cost schedules presented in this thesis.

The equipment data are more accurate than the building data, because the equipment represents a more standardized product, subject to more accurate price determination. Too, since the equipment tends to be small, there are generally more manufacturers building such devices than farm building manufacturers. Consequently, more manufacturers are represented in the equipment schedules than in building schedules.

Grain handling equipment tends to be purchased as a complete package, ready to operate, whereas farm buildings are often built by the farmer. The latter is particularly true of wood, site constructed buildings. The descriptiveness and accuracy of the price schedules on building are,

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[1]The averaging process used in the development of cost schedules was of several forms. Given a number of devices, the cost schedule was determined by fitting a regression line using a least squares method. With two devices, the cost schedule is a simple average. With one device, the manufacturers price schedule was used.

consequently, directly proportional to the degree of standardization of each building type. The quotation on round metal bins can thereby be considered with much greater assurance of accuracy than the quotations on wood structures. Similarly, quotations on traditional wood structures, such as the single crib listing, can be used with greater assurance than the clear span crib estimate, since the latter represents a new plan from which few buildings have been built.

Use of cost data. The author wishes to impress on the reader that the cost data presented on the following pages is intended as a guide. To attain greater accuracy, local prices should be used in estimating the cost of all components for an actual farm situation. Using these local prices, the procedure outlined in the cost analysis can be applied.

Equipment Horsepower and Capacity

Formulating the horsepower requirements and output capacities of materials handling equipment presents as great a paradox as that of cost schedules. Manufacturers quotations are extremely inconsistent. They are most consistent in the presentation of no data, or in the listing of data in ranges so broad as to be meaningless.

Millier (31) presented a comprehensive study of screw conveyors. Graphic summaries of his findings are presented in Appendix A. Wiant and Sheldon (41) outlined the power requirements of bucket elevators for capacities up to 400 bushels per hour. McKenzie and Ross (30) present data on the power requirements of a flat-bottom bin unloader.

Capacity and horsepower requirement data for the remaining grain handling and processing equipment was determined by rather subjective methods. This generally consisted of reviewing manufacturers' quotations, and equating these to actual situations in the author's experience. Since the power requirements of most conveying devices are linear, an established relationship documented by experience was used as a base value. Capacity figures are more difficult to document from experience, because of the highly variable nature of grain materials, particularly ear corn. Manufacturers quotations, with adjustments based on the author's experience, were the final criteria used.

Table III is a presentation of the estimated horsepower requirements and output capacity for selected grain handling and processing equipment. It should be noted that some devices have been divided into light duty and heavy duty classifications. This is an attempt to recognize the highly variable service factor classification associated with some equipment.

TABLE III

ESTIMATED HORSEPOWER REQUIREMENT AND CAPACITY FOR SELECTED GRAIN HANDLING AND PROCESSING EQUIPMENT

Device	Approximate Size	Capacity Bu. per Hr.	Horsepower (Electric)	Reference
Bucket Elevators				
Ear corn	16" x 8"	1000	0.75 hp/10'	
Small grain	4" x 3"	300	0.12 hp/10'	Wiant (41)
	6" x 4"	750	0.25 hp/10'	
	8" x 4"	1000	0.45 hp/10'	
Chain Elevators				
Double chain				
Light duty	16" bed	800[1]	0.8 hp/10'	
Heavy duty	18"-20" bed	1000[1]	1.0 hp/10'	
Single chain	8"	500	0.5 hp/10'	
Screw Elevators				
Single pitch	4" dia.	400[2]	0.62 hp/10'	Millier (31)
	5" dia.	700	0.75 hp/10'	
	6" dia.	900[2]	0.93 hp/10'	Millier (31)
Silage Blower	7"-8" pipe	800	20-30 hp (tractor)	

[1]Based on 30° incline conveying ear corn. Reduce capacity 1/3 to 1/2 for small grain.

[2]Based on 30° incline conveying wheat. See Appendix I for other materials and inclines.

TABLE III (Continued)

Device	Approximate Size	Capacity Bu.per Hr.	Horsepower (Electric)	Reference
Horizontal Conveyor				
Double chain	14" bed	800	0.66 hp/10'	
Single chain	8" bed	600	0.5 hp/10'	
	5" bed	350	0.4 hp/10'	
Belt	7"	700	0.25 hp/10'	
	10"	1200	0.35 hp/10'	
Bin Unloader	6' dia.	600	0.75 hp/10'	McKenzie (30)
Tractor Scoop	40 cu.ft.	600	2 plow tractor	
Corn Sheller				
Cylinder type		125	7-1/2 hp(elec.) 10-15 hp(tractor)	
Feed Grinder				
Hammermill	10"	120(3-1/2T)[3]	10-25 hp(tractor)	
Burr mill-Vertical	12"	120(3-1/2T)[3]	10-25 hp(tractor)	
Grinder-Mixer				
Hammermill	6" x 14"	20 (1/2T)[3]	2 hp	
Feed Mixers-Vertical	700#	3000#/hr[4]	1 hp	
	1200#	4000#/hr[4]	2 hp	
	2000#	5000#/hr[4]	3 hp	
	3000#	6000#/hr[4]	5 hp	

[3]Estimate based on shelled corn--medium grind.

[4]Based on 10 minutes mixing time plus one minute per 300# each for filling and unloading.

Estimating Equipment Fixed and Variable Costs

Table IV lists the assumed schedule of interest, taxes, housing, and insurance for calculating fixed costs on grain handling and processing equipment. The values used are those suggested in the *Agricultural Engineers Yearbook* (1).

TABLE IV

ASSUMED INTEREST, TAX, HOUSING, AND INSURANCE SCHEDULE FOR STRAIGHT LINE DEPRECIATION OF GRAIN HANDLING AND PROCESSING EQUIPMENT--PER CENT OF NEW COST PER YEAR[1]

Item	Assumed Rate Per Year Per Cent	Formula[2]	Fixed Cost Per Year Per Cent
Interest	5.0	$\frac{(P+S)}{2} i$	2.75
Taxes	1.6	0.016P	1.6
Housing	1.0	0.01P	1.0
Insurance	0.4	0.004P	0.4
TOTAL			5.75

[1]Source: *Agricultural Engineers Yearbook*.

[2]Symbols: P is purchase price in dollars or per cent; S is salvage value in dollars or per cent; i is interest rate.

A complete schedule of fixed cost relationships for grain handling and processing equipment is presented in

Table V. The life in years for all values not footnoted were estimated from Kleis (24) and the Agricultural Engineers Yearbook (1). Summaries of these basic data are located in Appendix B. The repair schedule was determined from these same sources. The value selected was that considered most applicable.

The reader should note the difference in hours of life stated for light duty and heavy duty chain and auger conveyors. There is no basis for this difference in references cited. The values reflect the authors' judgment.

Equipment Cost Schedule

Table VI presents fixed and variable cost relationships for grain conveying equipment. The values are presented in terms of two figures, one for the basic length unit and a second value to be added or subtracted for the module length change. With this method of presentation, any length of conveyor with the range specified in Table VI can be evaluated on a cost basis.

The fixed cost schedules in Table VI are presented without including the motor cost. This is necessary because electric motor costs are not linear with respect to horsepower. When a conveyor unit is selected and the costs determined from Table VI, the motor fixed cost value is added to that of the conveyor. The variable cost value obtained from Table VI is unchanged.

TABLE V

ESTIMATED YEARLY DEPRECIATION, REPAIR, AND TOTAL FIXED COST FOR SELECTED GRAIN HANDLING, PROCESSING, AND CONDITIONING EQUIPMENT--PER CENT OF NEW COST

Device	Estimated Years Until Obsolete[1]	Estimated Life[1] Hours	Deprecia-tion Rate/Yr. Per Cent	Est. Repair Cost/Yr.[1] Per Cent	Other Fixed Costs/Yr. Per Cent	Total Fixed Cost/Yr. Per Cent
Bucket Elevators						
Ear corn-chain	15[3]	2000[3]	6.0	2.0[3]	4.75	12.75
Small grain-belt	15[3]	3000[3]	6.0	1.5[3]	4.75	12.25
Chain Elevators						
Double chain						
Light duty	15	750[3]	6.0	3.0	5.75[4]	14.75
Heavy duty	15	1500	6.0	3.0	5.75[4]	14.75
Single chain	15	750[3]	6.0	3.0	5.75[4]	14.75
Screw Elevators and Conveyors						
Light duty	15	750[3]	6.0	2.25	5.75[4]	14.00
Heavy duty	15	1500	6.0	2.25	5.75[4]	14.00
Forage Blower	12	2500	7.5	2.25	5.75[4]	15.50

[1]See Appendix B. [2]See Table IV. [3]Author's estimate. [4]Housing included.

TABLE V (Continued)

Device	Estimated Years Until Obsolete[1]	Estimated Life[1] Hours	Deprecia- tion Rate/Yr. Per Cent	Est. Repair Cost/Yr.[1] Per Cent	Other Fixed Costs/Yr. Per Cent	Total Fixed Cost/Yr. Per Cent
Horizontal Conveyors Chain or belt	15	1000	6.0	3.0[3]	4.75	13.75
Tractor Scoop (on manure loader)	10	2000	9.0	2.75	5.75[4]	17.50
Bin Unloader (small grain)	15	750[3]	6.0	2.25	4.75	13.00
Feed Grinders						
Hammermill	15	2000	6.0	5.0	4.75	15.75
Burr Mill	12	1500[3]	7.5	5.0	4.75	17.25
Grinder-Mixer	15[3]	--	6.0	4.0	4.75	14.75
Feed Mixer-Vertical	15	2500	6.0	3.0	4.75	13.75
Corn Sheller	15	1500[3]	6.0	3.0	4.75	13.75
Carrier Track	20	--	5.0	1.0	4.75	10.75
Aeration Fans and Drying Fans	15[3]	--	6.0	1.0	4.75	11.75

TABLE VI

ESTIMATED FIXED AND VARIABLE COSTS (EXCLUDING LABOR AND MOTOR COSTS) OF SELECTED GRAIN HANDLING EQUIPMENT (Source: Manufacturers Data)

Item (With motor drive but less motor)				Basic Unit (Less Motor)				Available Module (less Motor)			
	Capacity[1] Bu./hr	Horsepower[1] per 10' length hp/10'	Length Range Feet	Length Feet	New Cost Dollars	Fixed[2] Per Year Dollars	Variable[3] Per 1000 bu. Dollars	Length Feet	New Cost Dollars	Fixed[2] Per Year Dollars	Variable[3] Per 1000 bu. Dollars
Elevators, Bucket											
Ear corn, chain 16"x8" buckets-w/8' filling feeder	1000	0.75	24-48	24	790	100.75	0.036	2	14.15	1.80	0.003
Small grain, belt 4"x3" buckets-w/hopper	300	0.125	10-48	10	230	29.35	0.008	2	13.25	1.70	0.002
6"x4" buckets-w/ same as above	700	0.25	10-48	10	400	51.00	0.007	2	17.40	2.20	0.002
8"x4" buckets-w/ same as above	1000	0.45	10-60	10	500	63.75	0.009	2	22.80	2.90	0.002
Accessories											
Belt conveyor-7"	700	0.25	4-24	8	160	20.40	0.006	1	5.00	0.64	0.001
10"	1200	0.35	4-24	8	265	33.80	0.005	1	10.00	1.27	0.001
2-way valve-- 6"					25	3.20					
8"					30	3.80					
3-way valve-- 6"					33	4.20					
8"					41	5.25					

[1]See Table III. [2]See Table V. [3]Based on 1 hp-hr = 1 kw-hr and electricity at 2¢ per kw-hr.

TABLE VI (Continued)

Item (With motor drive but less motor)	Capacity[1] Bu./hr	Horsepower per 10' length[1] hp/10'	Length Range Feet	Basic Unit (Less Motor) Length Feet	New Cost Dollars	Fixed[2] Per Year Dollars	Variable[3] Per 1000 bu. Dollars	Available Module (Less Motor) Length Feet	New Cost Dollars	Fixed[2] Per Year Dollars	Variable[3] Per 1000 bu. Dollars
Accessories											
6 way valve w/ remote control-6"					200	25.50					
8"					250	31.90					
Spout tubes-- 6"								1	2.50	0.37	
8"								1	3.00	0.44	
Weather-cover--motor					25	3.20					
Elevators, Double Chain Light duty-w/shovel hopper, swivel spout, carriage	800	0.8	24-48	24	397	58.55	0.048	4	36.25	5.35	0.008
Heavy duty-w/8'fitting feeder, swivel spout, carriage	1000	1.0	24-48	24	598	88.20	0.048	4	44.60	6.60	0.008
Heavy duty, extra long equipped same as above	1000	1.0	48-60	48	975	14.40	0.096	4	50.00	7.40	0.008
Elevators, Single Chain Steel-8" flared to 16" w/shovel hopper, carriage	500	0.5	16-32	16	242	35.70	0.032	4	22.80	3.35	0.008

TABLE VI (Continued)

Item (With motor drive but less motor)	Capacity[1] Bu./ hr.	Horsepower per 10' length[1] Hp/10'	Length Range Feet	Basic Unit (Less Motor): Length Feet	Basic Unit (Less Motor): New Cost Dollars	Basic Unit (Less Motor): Fixed[2] Per Year Dollars	Basic Unit (Less Motor): Variable[3] Per 1000 bu. Dollars	Available Module (Less Motor): Length Feet	Available Module (Less Motor): New Cost Dollars	Available Module (Less Motor): Fixed[2] Per Year Dollars	Available Module (Less Motor): Variable[3] Per 1000 bu. Dollars
Aluminum-8" flared to 16"-w/shovel hopper	500	0.5	12-24	12	155	22.85	0.024	4	33.40	4.95	0.008
Elevators--Screw											
6" dia.light duty	900	0.93	11-41	11	50	7.00	0.023	5	15.80	2.21	0.01
6" dia.heavy duty	900	0.93	11-41	11	125	17.50	0.023	5	25.80	3.61	0.01
6" dia.light duty w/carriage	900	0.93	16-41	16	159	22.25	0.033	5	36.60	5.12	0.01
6" dia.heavy duty w/carriage	900	0.93	21-41	21	385	53.90	0.043	5	33.75	4.73	0.01
5" dia.light duty	700	0.75	11-26	11	33	4.55	0.024	5	13.35	1.87	0.01
4" dia.light duty	400	0.62	11-26	8	24	3.30	0.34	5	7.45	1.04	0.016
Horizontal Conveyors											
14" double chain	800	0.66	7- 15	7+6[4]	165	22.70	0.022	2	17.10	2.35	0.003
goose-neck drag 40" lift,w/wheels											
60" lift	800	0.66	7-15	7+10[4]	208	28.60	0.028				
72" lift	800	0.66	7-15	7+12[4]	231	31.75	0.032				
90" lift	800	0.66	7-15	7+16[4]	263	36.15	0.038				

[4]The first figure is the horizontal section length, the second the inclined section length.

TABLE VI (Continued)

Item (With motor drive but less motor)	Capacity[1] Bu./hr.	Horsepower per 10' length[1] Hp/10'	Length Range Feet	Basic Unit (Less Motor) Length Feet	Basic Unit (Less Motor) New Cost Dollars	Basic Unit (Less Motor) Fixed[2] Per Year Dollars	Basic Unit (Less Motor) Variable[3] Per 1000 bu. Dollars	Available Module (Less Motor) Length Feet	Available Module (Less Motor) New Cost Dollars	Available Module (Less Motor) Fixed[2] Per Year--Dollars	Available Module (Less Motor) Variable[3] Per 1000 bu. Dollars
8" crib drag-flared to 16"-single chain straight delivery	600	0.5	16-48	16	150	20.65	0.027	8	42.50	5.84	0.013
5" crib drag kit-head, boot, & chain-straight delivery	350	0.4	16-48	16	115	15.80	0.031	1	1.50	0.21	0.002
Bin Unloader-6" dia. helicoid w/mounting assembly	600	0.75	6-16	6	250	32.50	0.015	1	10.00	1.30	0.003
Tractor Scoop w/15 bu snow scoop	600	2-3 plow			450	78.75	1.82[5]				
Forager Blower w/belt drive, auger feeder, carriage	800	3-4 plow			550	85.25	1.38[5]				
Blower Pipe Goose-neck-7"					25	3.85					
Pipe lengths-7"								4	10.00	1.55	

[5]Based on tractor cost of $1.10 per hour.

TABLE VI (Continued)

Item (With motor drive but less motor)	Capacity[1] Bu./hr.	Horsepower per 10' length[1] Hp/10'	Length Range Feet	Basic Unit (Less Motor) Length Feet	New Cost Dollars	Fixed[2] Per Year Variables	Variable[3] Per 1000 bu. Dollars	Avaliable Module (Less Motor) Length Feet	New Cost Dollars	Fixed[2] Per Year Dollars	Variable[3] Per 1000 bu. Dollars
Overhead Carriers											
I beam track								1	1.25	0.13	
Double angle track								1	1.25	0.13	
Swinging boom w/ I beam track			12		100	10.75					
Carrier-700# test					15.00	1.60					

The fixed cost values for electric motors are presented in Table VII. Note that fixed cost values are presented based on two different life estimates. This is based on the assumption that the life of an electric motor is equal to that of the device on which it is used. Although it may seem strange that an electric motor can have two lives, the author believes that a short life in grain handling equipment is associated with more rugged service. On this basis, the electric motor would have a reduced life.

Table VIII presents a fixed and variable cost schedule for selected grain processing and conditioning equipment. Since the devices listed are generally fixed in size and hence, horsepower requirements, the motor cost is included in the cost schedules.

Storage Cost Schedule

Table IX lists the estimated life, repair, and annual ownership values for grain storage structures. The life estimate values are slightly different than those often quoted. Wood grain storage structures are frequently listed with a 30-35 year life. Euler (10) lists a conventional double crib as 33 years, while placing the life of a metal structure at 25 years. This seems unrealistic to the author, first because the metal structure should remain in sound repair as long as a wood unit, and second, because obsolesence may void both structures before they are worn out.

TABLE VII

ESTIMATED NEW AND FIXED COSTS FOR SINGLE PHASE REPULSION-INDUCTION ELECTRIC MOTORS AND MANUAL AND AUTOMATIC MOTOR CONTROLS

Horsepower Rating	New Cost $	Control Cost $		Total Cost $	Fixed Cost/Yr.$[1]	
		Manual	Automatic		15 Year Life	12 Year Life
1/2	78.00	17		95.00	12.11	13.53
			35	113.00	14.41	16.10
3/4	96.00	17		113.00	14.41	16.10
			35	131.00	16.70	18.67
1	103.00	17		120.00	15.30	17.10
			35	138.00	17.60	19.67
1-1/2	139.00	17		156.00	19.89	22.23
			35	174.00	22.19	24.80
2	181.00	21		202.00	25.76	28.79
			39	220.00	28.05	31.35
3	242.00	21		263.00	33.53	37.48
			41	283.00	36.08	40.33
5	309.00	25		334.00	42.59	47.60
			41	350.00	44.63	49.88
7-1/2	511.00	25		536.00	68.34	76.38
			75	586.00	74.72	83.51

[1]Fixed costs computed using: Repairs--2.0%; Interest--5%; Taxes--1.6%; Insurance 0.4%; Housing--None. Total: 15 yr. life--12.75%; 12 yr. life--14.25%.

TABLE VIII

ESTIMATED FIXED AND VARIABLE COSTS (EXCLUDING LABOR) OF SELECTED GRAIN PROCESSING AND CONDITIONING EQUIPMENT. MOTOR AND CONTROL COST INCLUDED

Item	Capacity #/hr	Horsepower Required[1]	Cost-Dollars		
			New	Fixed[2] Per Year	Variable Per Ton[3]
Feed Grinders					
Hammermill-10" w/blower, wagon spout, belt pulley	3500	10-25 (tractor)	237	37.32	0.63/T
PTO drive-add			175.00	27.56	
Trailer mtd-add			75	11.81	
Burrmill-12" vertical, stationary, flat belt drive, no elevator	3500	10-25 (tractor)	506	87.28	0.63/T
Accessories					
9' elevator-add			60	10.35	
1' elevator section-add			7	1.21	
PTO drive			30.00	5.18	
6 groove "v" sheave			20.00	3.45	
4' horizontal discharge auger			50.00	8.63	
8' single chain mill-driven feeder			190.00	32.78	
Grinder-mixer Gravity fed unit complete screens, automatic controls, auger base	1200	2	645.00	95.14	0.066/T

[1]See Table III

[2]See Table V

[3]Tractor cost based on $1.10 l-hr, electric motors at 1 hp-hr = 1 kw-hr = 2¢.

TABLE VIII (Continued

Item	Capacity #/hr	Horsepower Required[1]	Cost-Dollars New	Fixed[2] Per Year	Variable[3] Per Ton
Accessories					
Control hopper for feeding from ground level, complete with power chords safety switches, auger base, bin level switches, wall switch panel.			374.00	55.17	
Safety switches-- 4 channel			11.25	1.66	
Corn Sheller-Stationary cylinder-type w/ flat belt drive, 9' cob stacker, corn blower & wagon spout	125 bu/hr	7-1/2 elec. 10-15, tractor	290	39.88	1.10/hr
Accessories					
PTO drive			65	8.94	
Trailer mounting			100	13.75	
Feed Mixers-Vertical type complete w/ 1 bagger, access hatch, 2 sight windows, "v" belt drive(top) less motor					
700# above floor hopper	3000#	1	406	55.83	0.013
1200# above floor hopper	4000	2	605	83.19	0.02
2000# floor hopper	5000	3	801	110.14	0.024
3000# floor hopper	6000	5	1053	144.79	0.033
Drying Fans-Ear Corn 6 blade direct connected-- 32"	2500bu	3	520	61.20	0.023/bu
36"	4000bu	5	780	91.70	0.023/bu
42"	6000	7-1/2	1060	124.50	0.023/bu

TABLE VIII (Continued)

Item	Capacity #/h[4]	Horsepower Required[1]	Cost-Dollars New	Fixed[2] Per Year	Variable[3] Per Ton
Aeration Systems Top mounted unit w/6' perforated pipe, motor, fan	3000bu		75	8.80	0.005/bu
Aeration Fans 18"-7 blade semi-pressure direct connected fan, motor		1/2	235	27.60	0.005/bu
18"-7 blade as above		1-1/2	360	42.30	0.005/bu
Aeration Duct-Metal 1 sq.ft.cross-section			4/ft	0.44	

TABLE IX

ESTIMATED CONSTRUCTION AND ANNUAL OWNERSHIP COSTS OF SELECTED GRAIN STORAGE STRUCTURES, BULK FEED BINS, AND SHELTER STRUCTURES

Type of Storage (On concrete foundation)	Rated Capacity, bu.	Approximate Over-all Height Feet	Estimated Life Until Obsolete, Years	Initial Construction Cost-Dollars-Material and Labor		Est. Fixed Cost/Year Per Cent		Annual Ownership Cost--Dollars $1 bu.
				Total	Per Bushel	Re-pairs	Total[1]	
Single Crib-- Conventional 6'width	700-3000	12	25	1190-3900	1.70-1.30	3.0	12.5	0.21-0.16
Single Crib-- Pole type 6'	700-3000	12	25	1050-3000	1.50-1.00	3.0	12.5	0.19-0.13
Double Crib-- Conventional no drive-way--4'x8'combination walkway-drying tunnel, drag tunnel.								
16'wide,6' cribs	2000-6000	22	25	2500-6300	1.25-1.05	3.0	12.5	0.16-0.13
24'wide,10'cribs	5000-10,000	26	25	5000-8000	1.00-0.80	3.0	12.5	0.13-0.10
Double Crib--Pole type Plan same as above except pole-type with welded wire cribbing.								
16' wide, 6' cribs	2000-6000	22	25	2000-5100	1.00-0.85	3.0	12.5	0.13-0.11
24'wide, 10' cribs	5000-10,000	26	25	4000-6000	0.80-0.60	3.0	12.5	0.10-0.08

[1]Total includes repairs plus Interest at 5%, Insurance at 1%, Taxes at 2%, plus depreciation at 100% divided by years life.

TABLE IX (Continued)

Type of Storage (On concrete foundation)	Rated Capacity, bu.	Approximate Over-all Height Feet	Estimated Life Until Obsolete, Years	Initial Construction Cost-Dollars-Material and Labor		Est. Fixed Cost/Year Per Cent		Annual Ownership Cost--Dollars $ 1 bu.
				Total	Per Bushel	Re-pairs	Total[1]	
Clear Span Crib--conventional double wall-weather tight outside, slat inside 32'span-10'plate	5000-10,000	20	25	6250-10,000	1.25-1.00	3.0	12.5	0.16-0.13
Clear Span Steel-Arch or rigid frame Double wall construction-weather tight exterior and slatted interior 32' span	5000-10,000	18	25	5500-8000	1.10-0.80	2.0	11.5	0.13-0.09
Circular Cribs Perforated sheet metal	1500-4500	14-30	25	1725-3825	1.15-0.85	2.0	11.5	0.13-0.10
Welded Wire w/roof	750-2500	15-25	20	450-1000	0.60-0.40	2.0	12.5	0.08-0.05
Cast-in-place drag tunnel, 18"x18"-add per bu.	1000-5000	--	25	100- 350	0.10-0.07	2.0	11.5	0.01

TABLE IX (Continued)

Type of Storage (On concrete foundation)	Rated Capacity, bu.	Approximate Over-all Height Feet	Estimated Life Until Obsolete, Years	Initial Construction Cost-Dollars-Material and Labor		Est. Fixed Cost/Year Per Cent		Annual Ownership Cost--Dollars $1 bu.
				Total	Per Bushel	Re-pairs	Total[1]	
Circular Metal Bin								
10' dia. x 8' sidewall	500		25	400	0.80	2.0	11.5	0.09
14' dia. x 8'	1000	12		512	0.51			0.06
x 10'	1250	14		580	0.46			0.05
x 12'	1500	16		652	0.44			0.05
14' dia. false floor				147	--			--
18' dia. x 8'	1750	13		813	0.47			0.05
x 10'	2150	15		871	0.41			0.04
x 12'	2550	17		917	0.38			0.04
x 14'	2950	19		1093	0.37			0.04
x 16'	3350	21		1215	0.36			0.04
18' dia. false floor				209	--			--
21' dia. x 8'	2350	14		975	0.42			0.05
x 10'	2950	16		1080	0.37			0.04
x 12'	3550	18		1256	0.35			0.04
x 14'	4150	20		1432	0.35			0.04
x 16'	4750	22		1513	0.32			0.04
21' dia. false floor				270	--			--
Clear Span-steel arch or rigid frame design	10,000-20,000	18	25	5500-8000	0.55-0.40	2.0	11.5	0.06-0.05
Clear Span-wood glue-nail truss design	10,000-20,000	20	25	6700-10,000	0.67-0.50	3.0	12.5	0.08-0.06

TABLE IX (Continued)

Type of Storage (On concrete foundation)	Rated Capacity, bu.	Approximate Over-all Height Feet	Estimated Life Until Obsolete, Years	Initial Construction-Cost-Dollars-Material and Labor		Est. Fixed Cost/Year Per Cent		Annual Ownership Cost--Dollars $ 1 bu.
				Total	Per Bushel	Repairs	Total[1]	
Silos								
Concrete stave-open top								
12' dia. x 40' high	3500	30	30	1400	0.40	2.0	10.8	0.04
14' dia. x 40' high	4700	40	30	1620	0.35			0.04
16' dia. x 40' high	6200	40	30	1825	0.30			0.03
Glass Lined-Hermetic w/screw conveyor unloader								
14' dia. x 22' high	2400	22	30	4210	1.76	1.0	9.8	0.17
x 26' high	3000	26	30	4425	1.47			0.15
x 40' high	4700	40	30	5410	1.15			0.11
17' dia. x 40' high	6800	40	30	6290	0.93			0.09
20' dia. x 40' high	9200	40	30	7800	0.85			0.08
20' dia. x 50' high	11,400	50	30	9040	0.79			0.08
Bulk Bins-Steel 60° hopper bottom-center draw-off								
6' diameter	3.0T	11	25	225.00[2]		1.0	10.5	7.90/T
	4.5T	13		240.00[2]				5.60/T
	6.0T	15		260.00[2]				4.35/T

[2]Price estimate includes 20% of steel cost for erection. No foundation cost is included.

TABLE IX (Continued)

Type of Storage (On concrete foundation)	Rated Capacity, bu.	Approximate Over-all Height Feet	Estimated Life Until Obsolete, Years	Initial Construction Cost-Dollars-Material and Labor		Est. Fixed Cost/Year Per Cent		Annual Ownership Cost--Dollars
				Total	Per Bushel	Repairs	Total[1]	$1 bu.
Bulk Bins-Wood 30°-1 way slops, side draw-off---6' wide by 10' long, 2 partitions	10T	12	25	300[3]		2.0	11.5	3.45/T
Hopper Bin-Steel 60°, 2 way slope side discharge-with 2-40 bushel and 2-15 bushel compartments	2-1/4T	12	25	450[3]		1.0	10.5	21.00/T
Processing Building clear span, 14' plate height, sliding doors	24'x32'	18	25	1540	2.00/sq.ft.	4.0	13.5	208/yr.
	24'x24'	18	25	1240	2.15/sq.ft.	4.0	13.5	167/yr.
	20'x24'	17	25	1080	2.25/sq.ft.	4.0	13.5	146/yr.

[3]Includes labor estimated at 50% of material cost. No foundation cost is included.

The estimated annual repair values were developed using Euler (10) and Wooley (44) as a guide. The interest, tax, and insurance schedule is footnoted on Table IX The total fixed cost values of Table IX are presented in terms of annual cost per bushel of storage. Thus, a direct comparison of estimated storage costs for each structure is possible

VII. COST ANALYSIS AND DISCUSSION

An Evaluative Framework

Analyzing System Costs

The costs of owning and operating the grain-feed handling systems presented in Section V can be analyzed from several view points. The primary consideration is the effect of through-put volume on unit handling costs. The through-put volume can be varied in two ways: (1) The system size (storage capacity) can be increased to handle a progressively larger volume of material; and (2) the system size can be held constant with the through-put variable. A discussion of these alternatives analyses and their effect on cost relationships is presented below.

Variable through-put--variable system size. Increasing the amount of storage to handle additional grain produced and fed is not unusual on many Michigan livestock farms. The grain may either be farm produced or purchased at harvest. In either event, the feed grain handling facilities are designed to hold a year's supply of feed.

In analyzing costs, increasing the grain volume handled by increasing the system size presents a changing fixed cost.

A given fixed cost is characteristic of a particular system; change the system, and the fixed cost will change.

The equipment components may also be altered, as the through-put of material is varied. Increasing the storage size entails some combination of increases in length, width, height, and diameter. Additional equipment length and/or capacity necessary to service this increased structure size adds to the system fixed cost. Modifications in the length or capacity of handling devices alter power requirements and thereby affect operating (variable) costs.

A discussion of the relationship between system grain storage size and equipment capacity is considered in a subsequent discussion.

Variable through-put--constant system size. Two types of grain-feed storage programs on farms operate by varying the amount of material handled through a given size facility. One is the farm operation that purchases feed grain throughout the year. The other is a farm enterprise with several storage locations on separate farmsteads, but with a centralized livestock operation.

This latter enterprise organization deserves some discussion. The growth in livestock and crop enterprise volume has generally been associated with purchase of additional land (38). But these land purchases are often located some distance from the headquarters farmstead. This distance presents problems in crop and livestock enterprise organization, just as it does in grain-feed handling system design.

Two considerations are important to the discussion at hand. Long hauling distances during grain harvest reduce harvest speed, thereby increasing the risk of field loss due to weather damage. The location of grain storage at or near the crop production site contributes to expedient harvest. Increases in livestock enterprise volume and efficiency, on the other hand, usually are associated with more production per man-hour (Table I). This generally means a more concentrated operation, so that the enterprise can be more efficiently serviced and supervised. Thus, while the farm acreage tends to spread out as the enterprise volume is increased, the livestock enterprise organization tends toward centralization. A logical answer, from the standpoint of grain-feed handling system design, is to construct an efficient storage and processing center at the livestock enterprise site. This facility is sized in terms of the grain production on the adjacent land and the efficient transfer of grain from outlying storage points. The fixed costs of the central facility are constant, and as the volume of material handled increases, the fixed cost per unit decreases. Variable costs are constant for each unit of material handled, up to the point at which equipment use exceeds the service factor for which it was designed.

System comparisons. The results of either analysis discussed above may be combined in a comparison of different systems operated under the same circumstances. Assuming that the systems are comparable in performance, conclusions based on comparative costs can be drawn.

Other Considerations

Equipment and storage capacity. Handling and processing equipment capacity is generally sized in relation to livestock enterprise needs. The effect of the grinding cycle on the choice of processing equipment was discussed previously in Section V. Ideally, processing equipment might be sized to grind a day's feed supply in 24 hours. With automatic equipment, something approaching this ideal design may actually be practical, although some allowance must be made for service and break-downs. In reality, a grinding cycle of less than 8 hours per day is desirable. In fact, the grinding cycle on a manually supervised operation must be sized in terms of the seasonal demands on labor. Spring planting is probably the most critical period. The marginal value productivity of labor in grinding feed must be compared to the marginal value productivity of labor for producing crops (or for any other competing enterprises) because this is what the labor would earn if invested in the other enterprises.

Unfortunately, information and methods that will permit an expedient evaluation of the marginal value productivity of labor in such circumstances is unavailable. Consequently, an arbitrary basis for analysis must be established.

It seems reasonable to the author that a grain processing system requiring manual supervision should have a capacity sufficient to process a one week supply of feed in one-half day. This arbitrary standard is based on the spring season as the critical period, and the assumption that inclement weather will occur at least once within the week. To plan to grind all day would disregard other competing rainy day activities, such as machinery repair, purchase of supplies, or leisure. To set a standard that allotted less time to grinding would appear unrealistic in terms of available equipment capacity.

Placing a time limit on any operation involving equipment presents a critical problem in estimating equipment capacity. If the capacity of a given device is underestimated, the unit is unduly discounted. The author wishes to emphasize again that the entire evaluation procedure based on costs and capacity data presented in this thesis should be viewed as a guide, rather than as an absolute measure.

Labor. In the presentation of all cost data in Section VI, labor was not included as a variable cost. This method of presentation was used to permit consideration of any equipment component as an automatic or manually supervised device. Too, man-power may be used to supervise several simultaneous devices, provided they are sufficiently close together that all may be observed and managed. Thus, labor requirements can be summed for any equipment combination used under several systems of operation.

The set-up and knock-down time associated with different grain-feed handling systems, however, cannot be estimated with any assurance of accuracy. The time required to move a flat-bottom bin unloader from one bin to another once per year is probably insignificant in terms of total system cost. But the time requires to move a 4 inch diameter screw conveyor from one bin to another on an everyday basis may be highly significant.

The author chooses not to attempt to estimate set-up and knock-down times for various and sundry grain handling equipment. To do so would be drawing on judgment with little credence or faith. The reader should recognize, however, that differences are apparent in the time required to get ready to do a job and to restore the original arrangement. These differences may be highly significant, particularly when automatic and manually supervised operations are equated.

Alternative equipment use. Some of the equipment included in this analysis can be used with other materials not connected with grain-feed handling. A double chain ear corn-baled hay elevator and a forage blower are examples. The system cost curves are developed assuming no alternative use.

Alternative building use. In the discussion of system layouts in Section V, the use of clear span structures for activities other than grain storage was mentioned. Suggested activities included machinery repair, fertilizer storage, machinery storage, et cetera. To measure this additional-use opportunity of clear span structures, however, presents a problem very similar to that involving the use of labor. The value of the additional-use opportunity of a clear span structure depends on the need for the space. If the structure is needed for re-storing corn from less efficient structures, the value of the space is the marginal value productivity of the structure in storing another bushel of corn. This value must be equated to the MVP of the structure in storing fertilizer or machinery. Assuming no more corn is to be stored, the additional-use value of the crib is the MVP of the structure in storing an alternative product.

In the final analysis, ear corn storage in a clear span structure may be more economical than some other method. This does not say that the flexibility of the open structure should not be added credit in its favor. Neither can one arbitrarily say that because an open crib is used only one-half year as an ear corn storage, then only one-half of its cost need be charged to corn storage.

Livestock--feed-grain relationships. One of the basic assumptions stated in Section V concerning the scope of this analysis limits the study to livestock grain-feed supplies. This means that the grain storage capacity of a given system must be planned to include a ratio of corn to shelled grain storage space in line with ration requirements.

Agricultural Extension and Experiment Station personnel were contacted for information on livestock rations. General rations sufficient for estimating storage and processing requirements were obtained and are presented in Table X.

The storage capacity ratio of corn to oats in each grain-feed handling system can be estimated from Table X. The oats component of each ration is between 20 and 35 per cent by weight of the corn component. Selecting a 1 to 4 oats-corn ratio as reasonably representative of all rations, one can convert the values to bushels and use them in establishing system storage capacity ratios. The 1 to 4 oats-corn ratio is approximately equal to 3 bushel of oats to 7 bushels of corn. This is the storage ratio, and can be applied to any system.

TABLE X

GENERAL LIVESTOCK RATIONS FOR ESTIMATING GRAIN-FEED HANDLING SYSTEM STORAGE AND CAPACITY RELATIONSHIPS

Item	Pounds of Material		
	Swine	Dairy	Beef
Corn-Cob Meal		1200	1825
Corn	1400		
Oats	300	400	
Supplement	300	400	175
Total	2000	2000	2000
Ave. Daily Intake per Head	7	10	15
Total Feed Req'd. per Head	800[1]	3300[2]	2000-3000
Pounds grain Req'd. per Head	680	2600	1825-2700

[1]Amount includes pro-rated charges for sow.

[2]Amount includes 60 day dry period at 4#/head/day.

The reader should be cautioned concerning the use of the rations in Table X. These are composite rations, considered sufficient for use in estimating grain-feed handling system requirements. Good quality beef cattle might be fed more corn than that listed in Table X. Limiting corn in a silage feeding program would involve less material. In estimating for a specific situation, values based on the actual operation should be used.

System Cost Relationships

The cost analysis presented on the following pages is not a complete treatment of the systems presented in Section V. Considering the number of systems outlined coupled with the possible variations within a given layout, a complete cost treatment of each system with variations would involve time and space in excess of their total contribution to this thesis.

It is the principles behind the development of cost relationships that are important to this thesis. On this basis, handling systems and building and equipment components have been selected that serve to bring out these principles.

Storage and Handling Systems

Only grain storage and handling systems from the intake of the in-to-storage elevator to the output at a common point of the out-of-storage handling system are considered in the cost analysis. The reason is two-fold. First, the analysis of a specific feed processing system is of equal magnitude to that of the storage and handling systems. Secondly, the storage and handling systems can be treated independent of the method of processing used.

Grain processing may be done either on or off the farm. In either event, grain must flow from storage to a central point (a vehicle for transport to mill, or a grinder). Whether the storage is unloaded with a scoop shovel or a bin unloader, the grain ultimately is blended into the same ration. The equipment system for handling a given combination of grains at a particular level of mechanization is, therefore, rather independent of the processing system used.

The only situation in which the above statement may not apply is in continuous flow systems. In continuous flow, the flow rate is controlled by the processing rate. This may be completely different than the rate at which a batch may be assembled. This is of particular consequence in ear corn processing, since the latter does not flow well from batch bins.

In the final analysis, however, reducing the flow in ear corn handling equipment to rates below 500 bushels per hour is usually done by controlling speed, rather than in selecting smaller capacity units. Small capacity devices (in the 75 to 250 bushel per hour range) are simply not available. Although the reduction in speed reduces the motor cost, this is offset by the cost of speed reduction. Fixed costs are essentially unchanged.

Variable costs, however, are significantly changed when flow rates are reduced. The primary change occurs in the labor costs. Operating a system at one-half the normal capacity will double the labor costs per unit. Since labor constitutes a large share of variable costs, the additional cost of labor with the reduced system capacity is highly significant.

Capacity and cost data for processing equipment were presented in Section V, and can be used as a guide in estimating processing system costs. However, the consideration of different processing systems and their effect on total cost relationships is left for future analysis.

Cost relationships--Layout 8a. Tables XI through XIV present detailed cost data for Layout 8a equipped for batch assembly with no consideration of the method of processing. The data is presented for a system built around a 16 foot wide drying crib. Since the cribs are only 6 feet in width, they may be used with or without drying equipment. The small grain storage components considered are round metal bins. These bins are not equipped for drying, although aeration equipment is included as a cost in storages of 2000 bushels or more capacity.

Table XI presents a cost schedule for the static components of Layout 8a using the 16 foot conventional drying crib. These static components are the units that do not change with volume, and are thereby the same, irrespective of the size of cribs and bins used.

TABLE XI

COST RELATIONSHIPS FOR STATIC COMPONENTS OF LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT

Item	Size	Investment Dollars	Fixed Cost Per Year Dollars	Variable Cost Power Dollars per 1000bu.
Processing Bldg.	24'x24'	1240.00	167.00	
Elevator-single chain aluminum-unmounted	8"x24'	411.20	57.54	0.048
Screw conveyor-unmounted	6"x 16'	221.60	23.10	0 023
Screw drag	5'x 11'	145.80	18.96	0.024
Swinging boom carrier	6'	65.00	6.98	
Total		2083.80	279.58	

Table XII contains data for the components that vary with the volume of material handled. It also demonstrates the use of the building and equipment cost schedules presented in Section VI. Table XIII presents a summary of the investment and fixed cost values for several system sizes.

Table XIV presents the total and average variable costs for Layout 8a. The equipment variable costs are simply the summation of the variable costs for components. However, the

TABLE XII

COST RELATIONSHIPS FOR VARIABLE SYSTEM COMPONENTS IN LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT

Item	Size	Storage Volume Bu.	Storage Volume Ton	Invest-ment Dollars	Fixed Cost Per Year Dollars	Variable Cost Power $/1000 bu.
Drying Crib	16 x 32	2000	70	2500.00	312.00	
Grain Bin-round	14 x 8	800	13	512.00	59.00	
Drying Crib	16 x 48	3000	105	3600.00	450.00	
Grain Bin	14 x 10	1300	21	580.00	67.00	
Drying Crib	16 x 64	4000	140	4630.00	578.00	
Grain Bin	18 x 8	1700	27	813.00	94.00	
Drying Crib	16 x 96	6000	210	6300.00	788.00	
Grain Bin	18 x 12	2500	40	[871.00]	[100.00]	
Aeration System				[75.00]	[8.80]	5.00
Total--				946.00	108.80	
Elevator-mtd. Double chain						
Basic unit	24'			397.00	58.55	0.048
4-4'modules	16'			145.00	21.40	0.032
Tilting feeder	8'			125.00	18.45	0.008
Motor	5hp[1]			334.00	42.60	
Total				1001.00	141.00	0.088
Crib Drag-8"						
Basic unit	16'			150.00	20.60	0.027
Motor	3/4hp[2]			131.00	16.70	
Total				281.00	37.30	0.027
Basic unit	16'			150.00	20.60	0.027
1-8'module	8'			42.50	5.85	0.013
Motor	1-1/2hp[2]			174.00	22.20	
Total				366.50	48.65	0.04
Basic unit	16'			150.00	20.60	0.027
2-8'modules	16'			85.00	11.70	0.027
Motor	1-1/2hp[2]			174.00	22.20	
Total				409.00	54.50	0.054

[1]Manual control. [2]Automatic control.

TABLE XII (Continued)

Item	Size	Storage Volume Bu.	Storage Volume Ton	Invest-ment Dollars	Fixed Cost Per Year Dollars	Vairable Cost Power $/1000 bu.
Basic unit	16'			150.00	20.60	0.027
4-8'modules	32'			170.00	23.40	0.054
Motor	3hp[2]			283.00	36.08	
Total				603.00	80.08	0.081
Bin Unloader	6'			250.00	32.50	0.015
Motor	1/2hp[2]			113.00	14.41	
Total				363.00	46.91	0.015
Bin Unloader	6'			250.00	32.50	0.015
2-1'modules	2'			20.00	2.60	0.005
Motor	3/4hp[2]			131.00	16.70	
Total				401.00	51.80	0.020

labor charges are two-fold: One charge is for equipment supervision time and the other is for shoveling time. The former is the time required to move a quantity of material by the lowest capacity unit in the conveyor train. The crib drag, for instance, has a theoretical capacity of 600 bushels per hour. But the single chain elevator into which it discharges has a capacity of 500 bushels per hour. Hence, the latter determines the flow rate and the man-hours required.

The man-hours in shoveling are required to remove that ear corn which will not flow to the drag conveyor with agitation. The angle of repose (with agitation) is estimated

TABLE XIII

INVESTMENT AND FIXED COST SUMMARY FOR LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT

	Capacity Tons			
	83T	126T	167T	250T
Ear corn--bu.	2000	3000	4000	6000
Small grain--bu.	800	1300	1700	2500
	Investment Cost--Dollars			
Fixed complement	2084.00	2084.00	2084.00	2084.00
Cribs	2500.00	3600.00	4630.00	6300.00
Bins	512.00	580.00	813.00	946.00
Elevator	1001.00	1001.00	1001.00	1001.00
Crib drags, unloader	617.00	720.00	810.00	1004.00
Total	6740.00	7994.00	9338.00	11,334.00
	Fixed Cost/Year--Dollars			
Fixed complement	279.60	279.60	279.60	279.60
Cribs	312.00	450.00	578.00	788.00
Bins	59.00	67.00	94.00	108.80
Elevators	141.00	141.00	141.00	141.00
Crib drags, unloader	84.20	95.55	106.30	131.88
Total	875.80	1033.15	1198.90	1449.30
Fixed Cost/Ton	10.55	8.20	7.18	5.80

TABLE XIV

VARIABLE COSTS FOR LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT--16 FOOT DRYING CRIB WITH NO DRYING EQUIPMENT

Item	Variable Costs--Dollars			
	83 Ton	126 Ton	167 Ton	250 Ton
Equipment				
Single chain elev.	0.096	0.146	0.192	0.228
Crib drag	0.054	.120	.224	.486
Double chain elev.[1]	0.246	.290	.403	.572
6" screw-inclined	0.018	.030	.039	.058
5" screw-bin drag	0.019	.031	.410	.060
Bin unloader[2]	0.003	.003	.01	.01
Total	0.436	.620	0.906	1.474
Labor				
Supervising equip.	12.25	17.40	25.00	36.50
Shoveling[3]	3.80	5.70	7.60	11.80
Total	16.05	23.10	32.60	48.30
Sum of Totals	16.49	23.72	33.51	49.77
Per Ton	0.20	0.20	0.20	0.20

[1]Small grain capacity based on 50% of ear corn.

[2]Bin unloader only used on non-gravity flow quantity for center discharge.

[3]Shoveling is for ear corn that will not flow to drag--estimated to be that quantity reposing under a 45° line from the drag. Man-time estimated at 2 bushels per minute (ear corn). Supervising time per ear corn drag system was deducted from shoveling time on the assumption that a man can both supervise and shovel.

at 45 degrees.[1] Data by Ross (35) indicates that a man can shovel 150# of small grain per minute. Considering ear corn as more difficult to shovel than small grain, the shoveling rate was assumed 2 bushels (140 lbs.) per minute.

However, since supervision labor is already at hand to operate the equipment and agitate the corn for gravity flow to the drag, this same labor is considered available for shoveling. The supervision time for handling the non-flow quantity was, therefore, deducted from the shoveling time.

The use of automatic motor controls on the conveyor system is considered necessary to permit supervision and shoveling at the same time. A control switch on an extension cord can be carried to any point in the crib, permitting remote control. The use of an automatic shut-off switch at the discharge in case an over-flow occurs would enhance the system.

Incidentally, unless additional labor is used to remove the non-flow quantity of material, the system capacity will drop from 550 bushels per hour to 120 bushels per hour (rate of one man shoveling ear corn). It is obvious that additional man-hours must be charged to removal of the non-flow quantity.

Tables XV through XVII present summary cost data for variations in the crib type and size used in Layout 8a. The

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[1]Actually ear corn does not have a specific angle of repose. The author believes that an angle does exist above which ear corn will flow with a minimum of manual agitation. Below this angle, the ear corn must be shoveled. This angle is assumed to be 45 degrees.

TABLE XV

VARIABLE COSTS FOR LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT---24 FOOT DRYING CRIB WITH DRYING EQUIPMENT COSTS INCLUDED

Item	Variable Costs--Dollars			
	134 Ton	202 Ton	268 Ton	403 Ton
Equipment[1]	74.34	121.83	162.57	243.63
Labor				
Supervising equipment	20.50	28.90	40.20	60.50
Shoveling[2]	10.15	15.20	19.45	30.35
Total	104.99	165.93	222.22	334.48
Per Ton	0.78	0.83	0.83	0.83

[1]Includes unheated air ear corn drying costs estimated at 2.3¢/bu. (McKenzie, 29) and areation costs for small grain (in storages 2000 bushels or more) of 1/2¢/bushel.

[2]See Table XIV for description.

variable costs presented in Table XV include the charge for shoveling the non-flow quantity of material, However, this quantity is considerably greater in a 10 foot wide crib as opposed to a 6 foot width. Costs are proportionally increased.

The variable costs in Table XV also include charges for drying the corn. The 10 foot crib width requires forced air drying. Hence, the cost of such equipment must be considered

TABLE XVI

SUMMARY OF TOTAL INVESTMENT AND AVERAGE FIXED, VARIABLE AND TOTAL COSTS FOR LAYOUT 8a ADAPTED FOR BATCH ASSEMBLY WITHOUT PROCESSING OR FEED STORAGE EQUIPMENT

	Capacity-Tons (Small Grain & Ear Corn)			
Description	83 Ton	126 Ton	167 Ton	250 Ton
Drying Crib-size	16x32	16x48	16x64	16x96
16' conventional				
Total investment	6740.00	7994.00	9338.00	11,334.00
Fixed cost/ton	10.55	8.20	7.18	5.80
Variable cost/ton	0.20	0.20	0.20	0.20
Total cost/ton	10.75	8.40	7.38	6.00
16' Pole				
Total investment	6240.00	7279.00	8369.00	10,096.00
Fixed cost/ton	9.78	7.48	6.46	5.17
Variable cost/ton	0.20	0.20	0.20	0.20
Total cost/ton	9.98	7.68	6.66	5.37
Description	134 Ton	202 Ton	268 Ton	403 Ton
Drying Crib-size	24x32	24x48	24x64	24x96
24' conventional				
Total investment[1]	8099.00	10,299.00	12,033.00	15,481.00
Fixed cost/ton[1]	7.82	6.58	5.70	4.70
Variable cost/ton	0.78	0.83	0.83	0.83
Total cost/ton	8.60	7.41	6.53	5.53
24' Pole				
Total investment[1]	7499.00	9329.00	10,763.00	13,561.00
Fixed cost/ton[1]	7.26	5.92	5.11	4.24
Variable cost/ton	0.78	0.83	0.83	0.83
Total cost/ton	8.04	6.75	5.94	5.07

[1]Includes unheated air drying equipment based on an approximate 1 fan horsepower per 800 bushels of ear corn.

as a system cost, and the dryer operating cost a variable structure cost.

Table XVII is a summary of the crib and small grain bin sizes and capacities considered in Layout 8a.

TABLE XVII

DRYING CRIB AND GRAIN BIN SIZES AND CAPACITIES FOR COST RELATIONSHIPS DEVELOPED FOR LAYOUT 8a

	Capacity--Tons			
Storage	83 Ton	126 Ton	167 Ton	250 Ton
Crib Size	16x32	16x48	16x64	16x96
Capacity bu.	2000	3000	4000	6000
Bin[1] Size	14x8	14x10	18x8	18x12
Capacity bu.	800	1300	1700	2500
Storage	134 Ton	202 Ton	268 Ton	403 Ton
Crib Size	24x32	24x48	24x64	24x96
Capacity bu.	3200	4800	6400	9600
Bin[1] Size	14x12	18x10	18x14	2-18x10
Capacity bu.	1350	2050	2740	4100

[1]Round metal--figure is diameter x height. The capacity figures are the quantity necessary for the system, not the exact capacity of the bin.

Figure 19 is a graphical presentation of average fixed, variable, and total costs at different levels of capacity for Layout 8a adapted for batch assembly. The variable costs

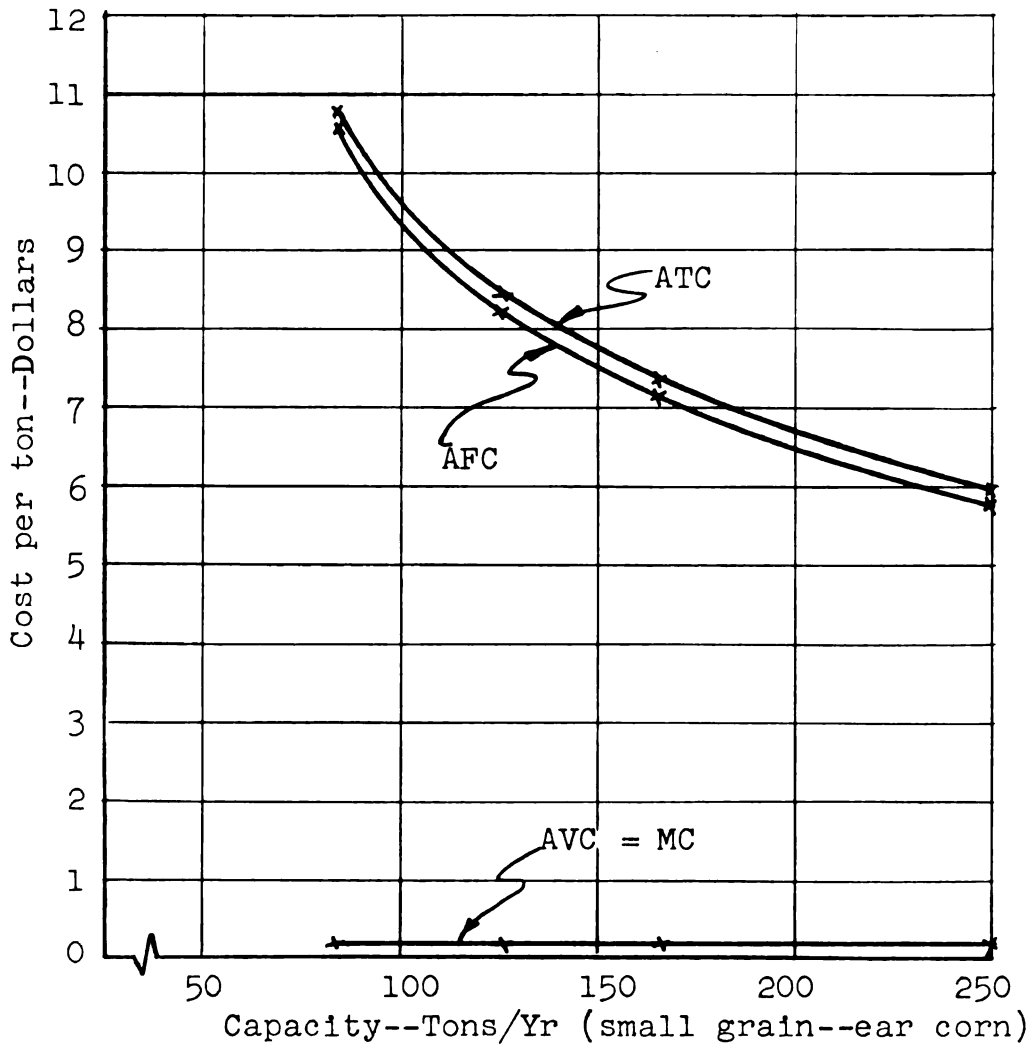

Figure 19. Average fixed, variable, and total cost curves for Layout 8a with 16-foot wide conventional construction drying crib without drying, processing, or feed storage equipment.

are so small that they seem almost insignificant. However, it should be remembered that in the short run, variable costs are the only costs considered. Over a longer period of time, modification in the system can materially change fixed costs, which must therefore be considered in long range decisions.

From a theoretical view point, one would expect this total cost curve to decrease to a minimum point, and eventually increase as additional volume is handled. The minimum point would be the volume that should be handled to attain the lowest average total cost. Minimum average total costs may extend over a wide volume range. With the assumptions and equipment limitations considered in this analysis, however, the minimum ATC volume is never attained.

This analysis is based on a constant equipment capacity and an essentially linear horsepower and equipment cost-length relationship. Labor is also considered directly proportional to the volume of material handled. Actually, some of these assumptions are not true. The constant equipment capacity with changing length is generally sound. But a constant equipment cost-length ratio holds true only within specific limits. At the point at which a heavier built drag unit must be employed to compensate for the increased chain load of a longer drag, the fixed costs will increase. Horsepower requirements also may increase.

Labor, however, is probably the major cost that will force the ATC curve to increase. As the crib increases in length, the time to reach the point in the crib where corn is being removed increases. Consider an extreme case: If the crib were a mile long, the time to get to the service point and return would be highly significant. However, in this analysis, no consideration is given to set-up time. Hence, increased labor costs with increased storage length are not included.

A second and probably more significant source of increased labor costs can be attributed to the opportunity cost of labor.[1] As a progressively greater volume of material is handled, the time involved in handling encroaches on the time needed for other tasks. At the point at which the marginal value productivity of labor used in any other process is greater than the MVP of labor used for handling grain, the labor charge for handling grain must be the MVP of labor used in the other process. Hence, labor costs rise. Grain handling labor must henceforth be hired (an added cost) or the handling capacity increased (adding to system costs).

Thus, in reality, each system cost will reach a minimum ATC point at some volume through-put. The lack of data

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[1]Opportunity cost is the value of a given input that could have been attained in producing one product when the input is actually being used in another production process.

for evaluating set-up and knock-down labor costs and the opportunity cost of labor, however, prevents an accurate presentation of such a system curve.

Figure 20 presents average cost relationships for Layout 8a using a wide crib with drying equipment. Only batch assembly is considered. Average variable costs are higher than for the system presented in Figure 19, because of the cost of operating drying equipment coupled with the labor costs of shoveling the non-flow quantity from the 10 foot wide crib.

Figure 21 presents four ATC curves for Layout 8a with different crib widths and types. The reader should be cautious in drawing conclusions from the intersection of two system curves. Ordinarily, this intersection point can be interpreted as the volume at which one should change systems. With very accurate cost data, this interpretation is sound. However, the differences in the system costs of Figure 21 are so small that an error due to the accuracy of estimating data could materially change the relationships.

The drying costs included in the wide cribs presented in Figure 21 also distort the system cost relationships. Figure 22 presents both the wide and narrow conventional crib with a 3 per cent reduction in field loss credited to the wide crib equipped for drying. The same credit could be

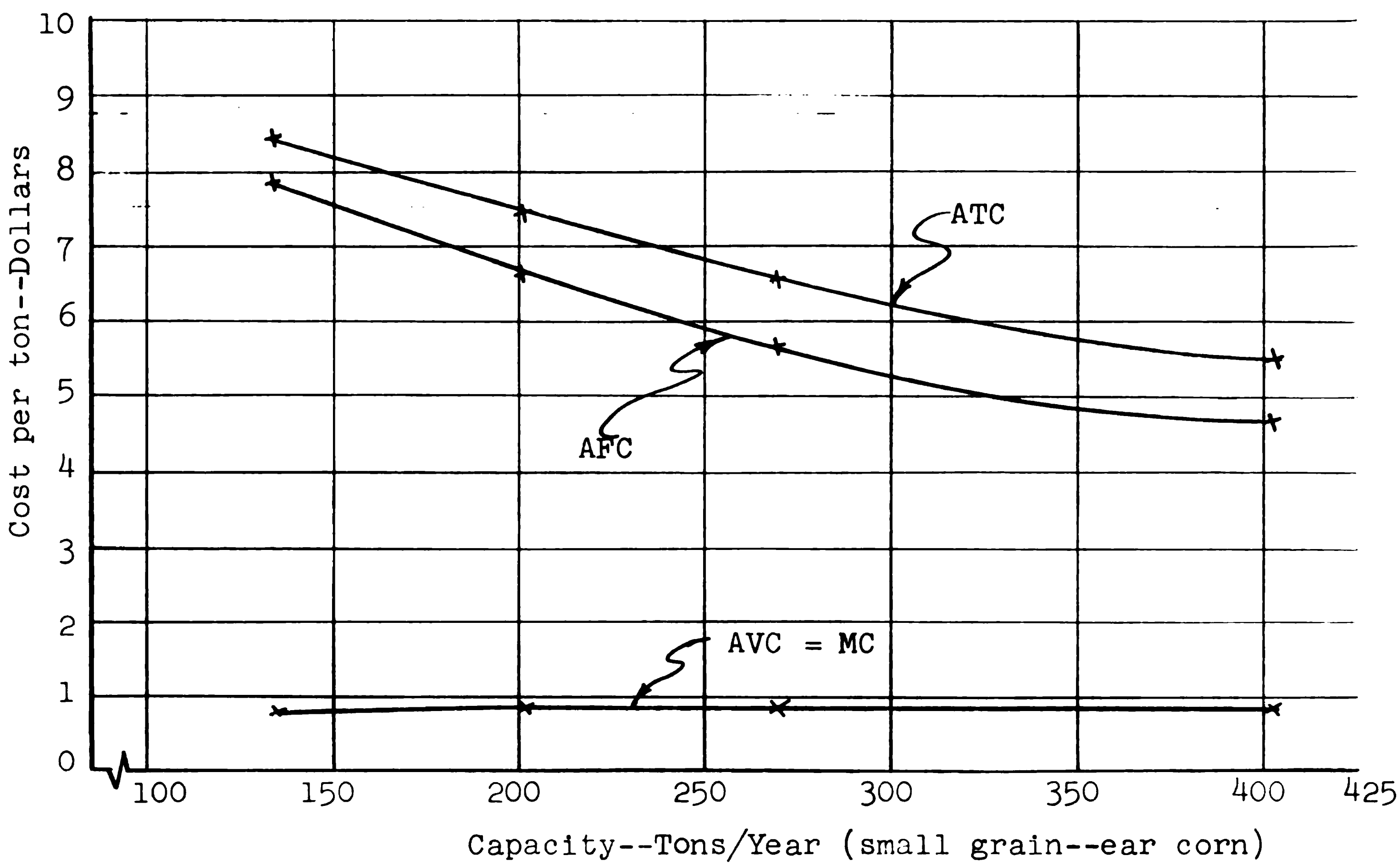

Figure 20. Average cost curves for Layout 8a with 24-foot wide conventional construction drying crib. Costs include unheated air drying equipment but no processing or feed storage equipment.

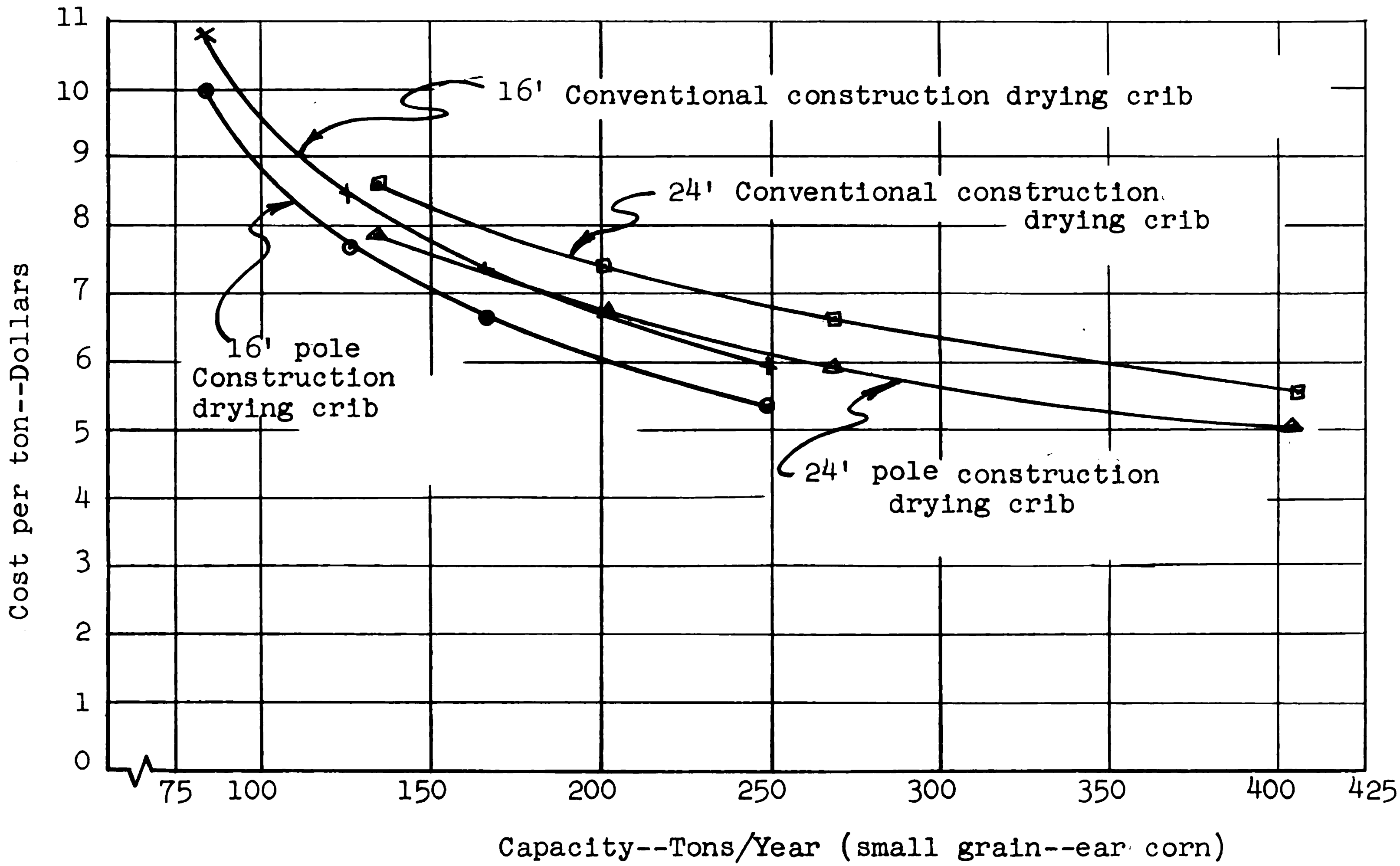

Figure 21. Average total cost curves for Layout 8a for two crib widths and two types of crib construction. Twenty-four foot widths include drying equipment costs. No processing or feed storage equipment included.

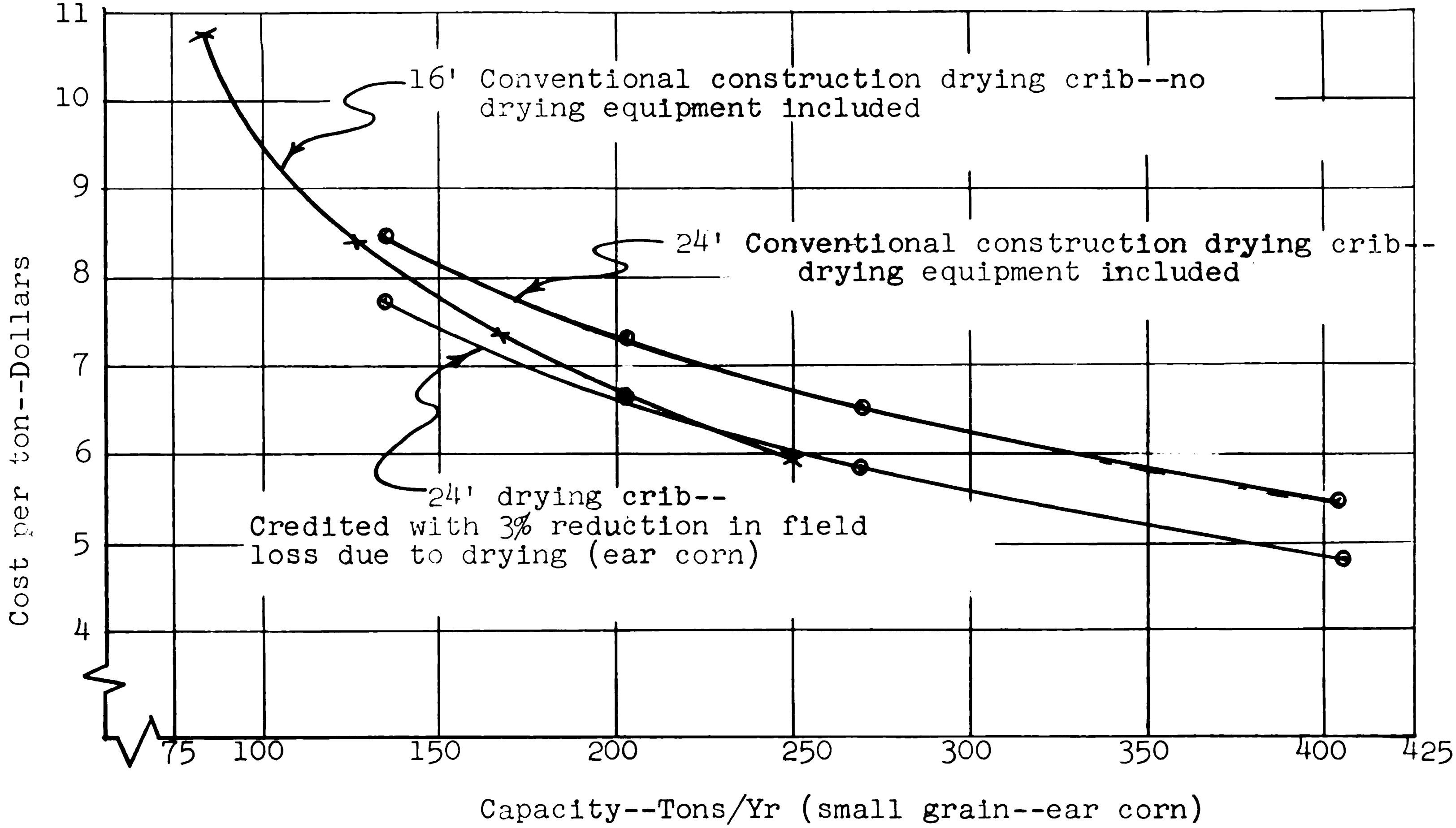

Figure 22. Average total cost curves for 16 and 24 foot drying cribs showing effect of a 3 per cent credit for field loss reduction due to drying. (Layout 8a without processing or feed storage equipment.)

applied to the narrow crib, provided corresponding equipment charges were added. With storage loss data for storages of different construction, the additional in-storage loss of one structure as opposed to another could also be considered.

Cost relationships with fixed versus variable system size. Any of the previous systems for Layout 8a may be fixed at a given size, and unloaded and refilled to attain additional through-put. Table XVIII lists cost relationships for the 83 ton capacity system with a conventionally constructed drying crib. The fixed, variable and total cost values are computed for four levels of through-put.

TABLE XVIII

INVESTMENT AND AVERAGE COSTS PER TON FOR LAYOUT 8a WITH A 16 FOOT BY 32 FOOT CONVENTIONAL CONSTRUCTION DRYING CRIB OPERATED AT VARIOUS GRAIN THROUGH-PUT LEVELS

		Capacity--Tons			
	Total	83Ton	126Ton	167Ton	250Ton
	Dollars	Dollars/T	Dollars/T	Dollars/T	Dollars/T
Investment	6740.00	813.00	535.00	403.00	270.00
Fixed Cost	875.80	10.55	6.95	5.24	3.50
Variable Cost	16.49	0.20	0.20	0.20	0.20
Total Cost		10.75	7.15	5.44	3.70

The average cost values are plotted in Figure 23, along with the average costs for the same system when size is varied to increase through-put. As would be expected, the fixed system gives lower average total and fixed cost. Variable costs are equal for both systems.

These curves do not present a true picture from the standpoint of many farm situations. The only situation in which the fixed system curve is indicative of total farm grain handling costs is with an operation purchasing grain supplies throughout the year. In this case, the one grain handling facility is the only unit needed. On a farm with storages located on outlying farms, but with the fixed system of Figure 23 located at a central livestock feeding site, the cost of owning and using the outlying storages must be considered in the total handling costs. The labor and equipment to move the grain to the central facility must also be included.

Storing grain in outlying locations for subsequent movement to the central facilities presents problems in estimating total grain handling costs. Some of the handling equipment such as the in-to-storage elevator may be used on all storages, including both harvest and rehandling operations. Hence, the equipment costs should be spread over the entire quantity of material handled.

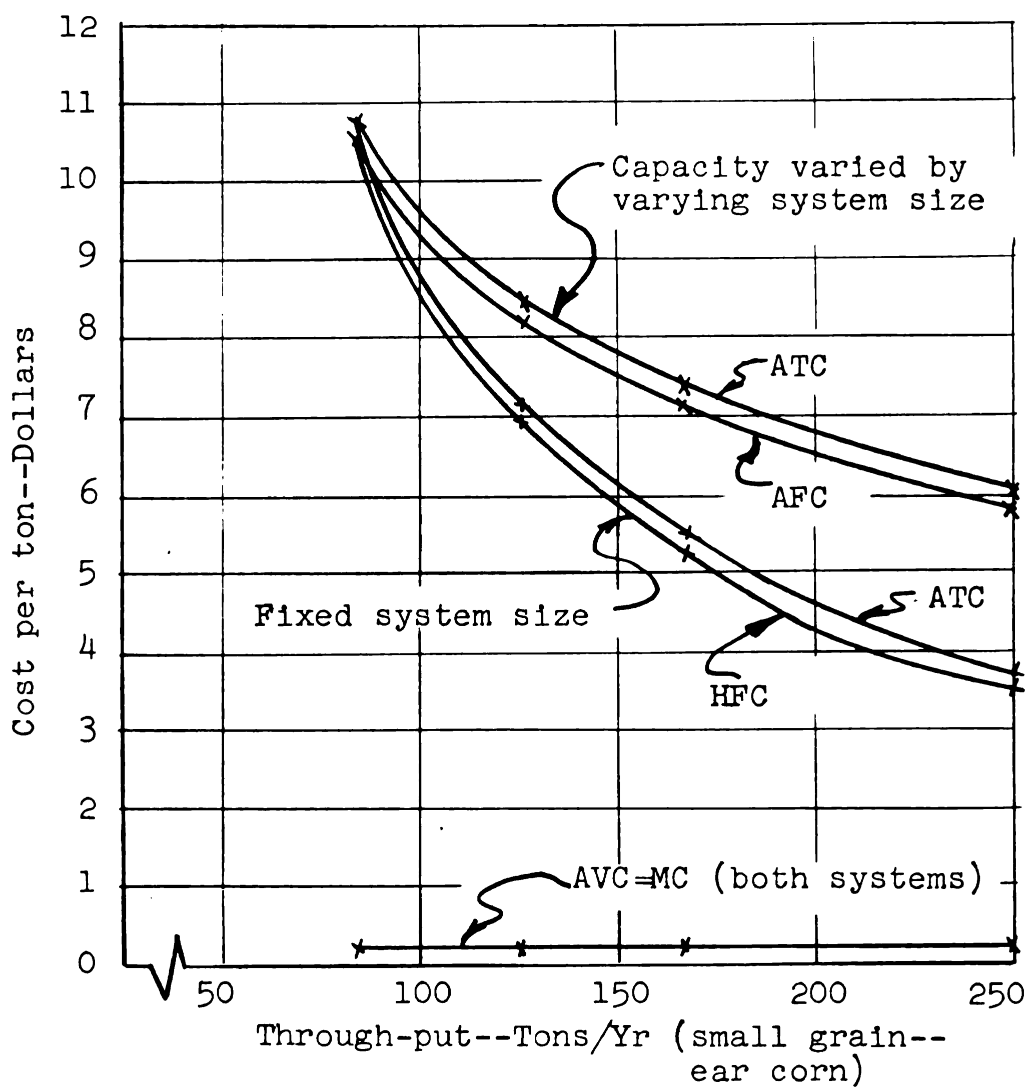

Figure 23. Average cost relationshps for various levels of through-put for Layout 8a with a 16-foot conventionally constructed drying crib. One system is fixed at 83 tons capacity, the other is variable in size from 83 tons to 250 tons capacity.

On the other hand, if the grain had all been stored in one central facility, the elevator would handle the material only once. Although the total cost per bushel handled would be greatest for one handling, the total cost of grain handling with the elevator would be a minimum for the particular system, since variable costs are minimum.

As pointed out in an earlier discussion, however, the location of storages on outlying acreage permits more expedient harvest than with a central facility. Labor requirements tend to be high at harvest time. If storages are located near crop production, transport time is reduced. Surplus labor during the winter season may then be used in moving the material to the central facility. Since the opportunity cost of labor in the winter is generally lower than at harvest time, labor charges for moving the material in the winter should be below labor for moving at harvest time.

The equipment costs for mechanizing and grain movement from outlying storage sites may be below that of a central facility. The central facility used for rehandling material from outlying storages is smaller than for a centralized storage system. Drags, elevators, and screw conveyors may all be reduced in length. Some of these units may also be used in unloading the outlying storages. Moving sufficiently large quantities of material in one time period to justify the set-up and knock-down of labor saving devices is an important consideration in reducing costs.

Other Cost Considerations

Two questions revolve around the use of mechanical equipment. One question concerns the cost of mechanical versus hand methods, and the other involves the cost relationships between several devices performing the same task.

Figure 24 indicates the quantity of material reposing on the floor of a circular flat-bottom bin after gravity removal through a centered floor outlet. This is the quantity of material that should be considered in estimating the value of a flat-bottom bin unloader. The drag conveyor that removes the material from the centered outlet on a ground level bin, in contrast, handles all of the material stored. Hence, the base quantities for the two devices are completely different.

Figure 24 presents average total cost relationships for shoveling by hand versus mechanical handling with a flat-bottom bin unloader. Two labor costs are shown. On the basis of this comparison, the unloader cannot compete with the man at $1.25 per hour in the volume range shown. At $2.00 per hour for labor, however, the unloader cost per bushel is equal to the hand method when approximately 4000 bushels are handled. No set-up or knock-down costs are included in either method.

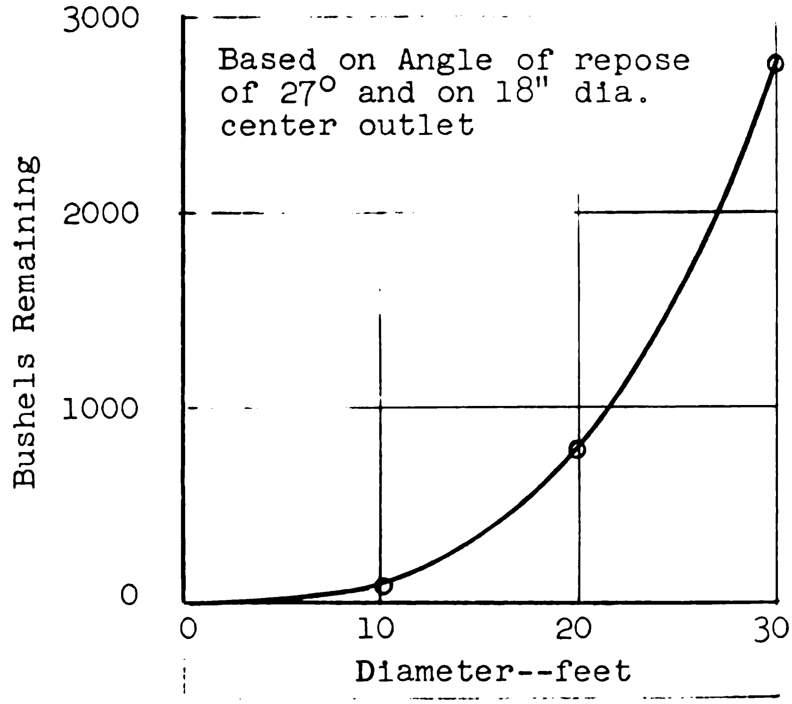

Figure 24. Bushels remaining in circular bin after gravity removal through a center outlet in the bin floor.

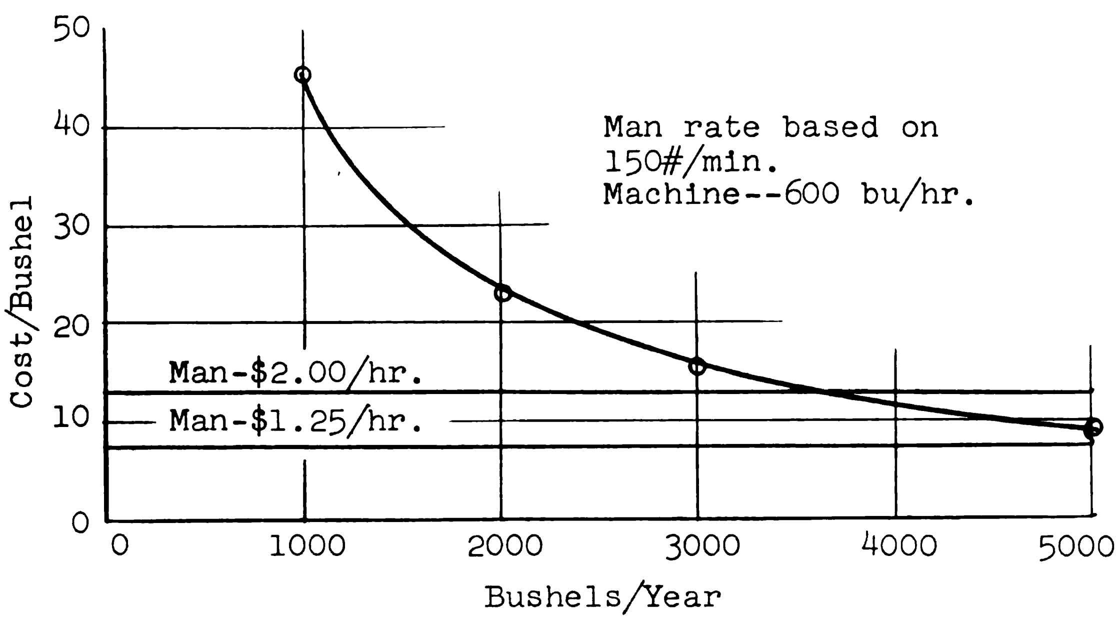

Figure 25. Cost per bushel in handling grain from circular storage by hand and with a 6-foot flat-bottom bin unloader.

Several conclusions can be drawn from the curves in Figure 25. The justification of mechanical handling methods is directly related to labor cost and availability. The time required for the man to shovel 5000 bushels at the rate of 160 bushels per hour may conflict with other time requirements. This is the opportunity cost of labor. This is of particular consequence on one-man operations, wherein the operator is manager, capitalist, and laborer. Time spent in pushing a dull scoop shovel instead of a sharp pencil may prove costly. His time as a manager is worth more than is justified in manual labor that can be mechanized.

The justification of mechanical handling that removes drudgery and hard work is also of importance on farms using family labor or operated by individuals with a cardiac condition.

The question of which of two devices to use for a given task can be approached on much the same basis as the unloader versus hand methods comparison of Figure 25.

VIII. SUMMARY AND CONCLUSIONS

Grain-feed handling on livestock farms can be divided into functions of:

1. Storage
2. Assembly
3. Processing
4. Distribution

Each of these functions can be analyzed independently of the whole system, with options developed for each function finally integrated into a particular system.

The fundamentals of efficient grain-feed handling system design are the same irrespective of the level of operation involved. The degree of mechanized handling that a given operation can justify, however, is a function of the scale of operation.

The design fundamentals for feed-grain handling system include:

1. Minimize distance.
2. Minimize set-up and knock-down time.
3. Design for multiple use of equipment.
4. Use man-time first to think and last for power.
5. Process in batches. Use high capacity, manually supervised batch assembly.

6. Plan in an open-end manner for future growth and alternative action.

In terms of feed-grain handling system design, man-time should be used first to think, second as a floating control device, third as an expediter, fourth as an agitator, and last as a producer of horsepower. This sequence in the use of man-time can be reversed and used as a guide in mechanizing any operation. The mechanization would proceed as follows:

1. Remove drudgery.
2. Mechanize all handling.
3. Apply simple on-off control.
4. Integrate the control system.
5. Introduce automatic programming.

The grain-feed handling systems developed are considered representative of the needs of Michigan livestock farms, both large and small. The systems presented tend toward large scale operations. This is in line with one of the objectives: To develop systems that permit a maximum level of mechanization. It should be recognized that it is easier to reduce the scale and eliminate some features of a given system than to project a small system beyond limits considered in its design. It should also be recognized that scale and mechanization go hand in hand. A small operation may afford little mechanized handling.

The system layouts present a plan for the future. The storage structures considered are representative of the most modern building types and storage practices available. The construction-by-components feature of the systems permits a gradual transition from an existing to a desired layout. Sound existing structures may become a part of the new facility, or be relegated to a minimum re-investment status to permit expedient economical replacement.

The systems use ground level structures for all bulk grain storage. This is essential to the construction-by-components feature, wherein each structure must be a unit. Elevated bins are limited to small working bins in the processing area. These small elevated bins are generally free-standing units with hopper bottoms. Free-standing units permit rearrangement of the processing area, or organization of the processing facility in an existing building, to be moved at a later date to new facilities. The free-standing bins may also be owned by the tenant, thereby giving him more control over the feed handling facilities.

The use of one-way hopper bins with a gentle slope that requires some agitation should be considered in place of four-way and circular hoppers with steep slopes. The simplicity of the one-way slope bin reduces construction costs. Since bins with steep slopes occasionally bridge, supervision

during unloading is necessary. The gentle slope bin makes use of this supervision labor for agitation that requires little effort. Some of the reduced cost of one-way hoppers may be used in making agitation easier.

Ground level storage structures used in conjunction with a grain elevating device are an alternative to gravity storage unloading from elevated bins. The grain elevator should remove grain from the same point in the bin, and deliver it at a rate and height comparable to the elevated structure. Whereas elevated construction for gravity flow involves a duplicate investment in multiple bin systems, one mechanical grain elevating device can be used on a number of ground level bins.

Hoppering a bin floor for complete gravity removal of material is an alternative to the use of a flat-bottom bin unloader. Both devices involve material that reposes in the bin. Some adjustment for the storage loss associated with a hopper floor should be included in any cost comparisons.

Elevating a bin and hoppering a bin are two separate but complementary methods of storage unloading and they should be so considered in analyzing systems and costs.

The cost of a given system of storage unloading, either gravity or mechanical, is a function of the total amount of material handled and the handling cycle. Gravity flow usually involves opening a slide valve. In contrast, the mechanical system may involve equipment set-up prior to operation. If the set-up occurs once per bin per year, it is probably insignificant. A set-up repeated many times per year may be highly significant.

The cost data presented should be used only as a guide in estimating a system for a specific situation. Local prices for all components should be used in preparing a final estimate.

In preparing cost estimates of different systems or system components, only the additional costs should be considered. If batch assembly for commercial processing involves a given quantity of labor, this quantity should be deducted from labor charges for on-the-farm processing, since batch assembly labor is required in both operations.

The form in which a given grain material is to be stored is a critical problem in the selection of a grain-feed handling system. The use of high moisture corn storage methods may ultimately eliminate ear corn handling. High moisture storage, handling, and feeding methods are still largely in an experimental stage. The apparent cost reduction opportunity in handling and feeding a high moisture product, however, place conventional storage and handling methods in a critical perspective.

IX. SUGGESTED FUTURE STUDIES

There are two general alternatives in studying materials handling on the farm. One is to study a specialized segment of the total problem, and the other is to consider the overall problem. If a specific outline of a materials handling system is the goal, the segment approach is preferable. The reason is that a meaningful system, in this author's opinion, can only be developed when each segment is identified and developed to an optimum extent.

There are, however, general studies that can be conducted considering the total farm materials handling problem. An extension of the design fundamentals as outlined in this thesis might be an example.

Some studies that appear worthy of consideration include:

1. A study of grain processing methods and systems for livestock farms.
2. A study of methods and systems for distributing and feeding grain-feed to livestock.
3. A study of set-up and knock-down time in relation to operating time for farmstead tasks with various degrees of mechanization.

4. A study of methods and systems for handling forages.
5. The development of materials handling fundamentals applicable to all farm materials.
6. A study of methods and systems for handling fertilizer on the farm.
7. A study of methods and systems for handling liquid manure in centralized swine feeding.
8. An analysis of the impact of centralized feeding of livestock on total production efficiency and cost.
9. A study of the marginal value productivity of investments in farmstead mechanization in relation to other enterprise investments.

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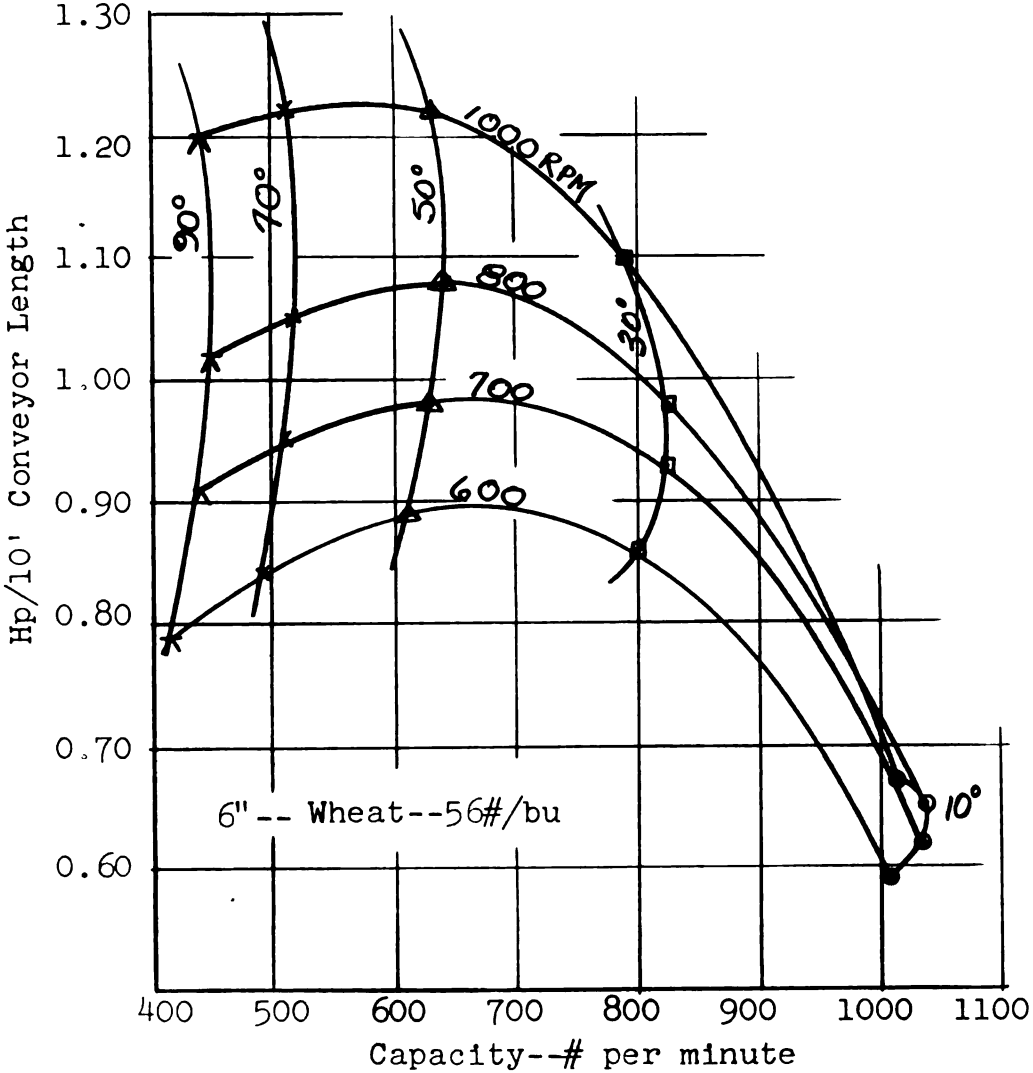
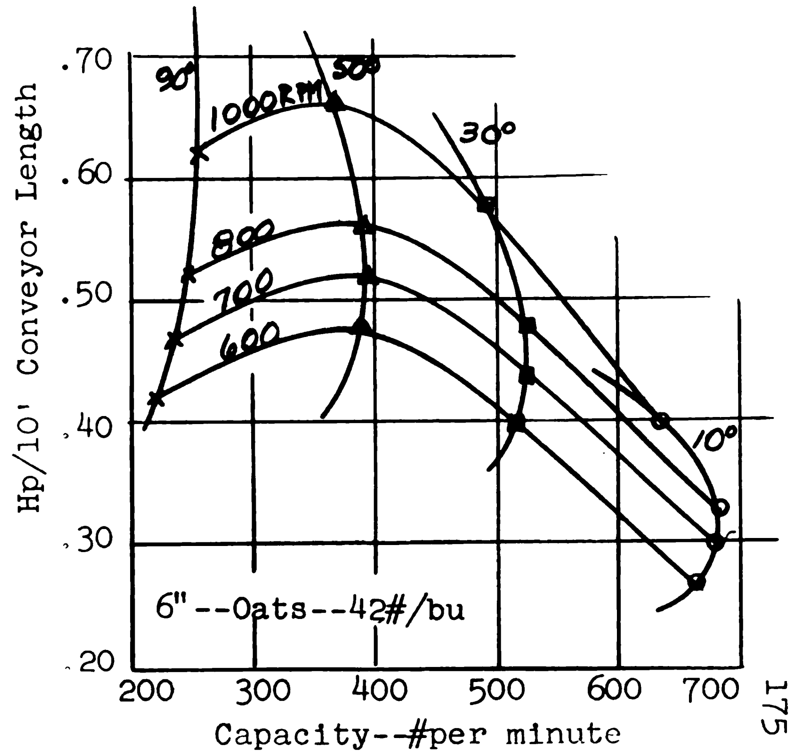
APPENDICES

A. PERFORMANCE RATES AND HORSEPOWER REQUIREMENTS OF 4 AND 6 INCH DIAMETER SCREW CONVEYORS HANDLING WHEAT, OATS, AND CORN-MEAL.

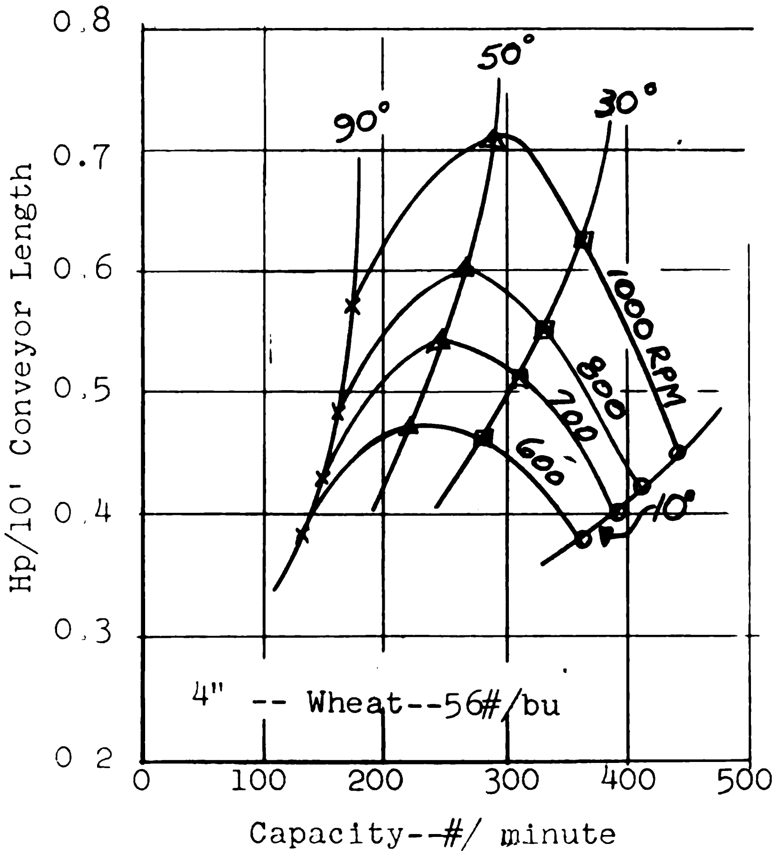
B. ESTIMATED LIFE AND REPAIR COST FOR SELECTED MATERIALS HANDLING EQUIPMENT.

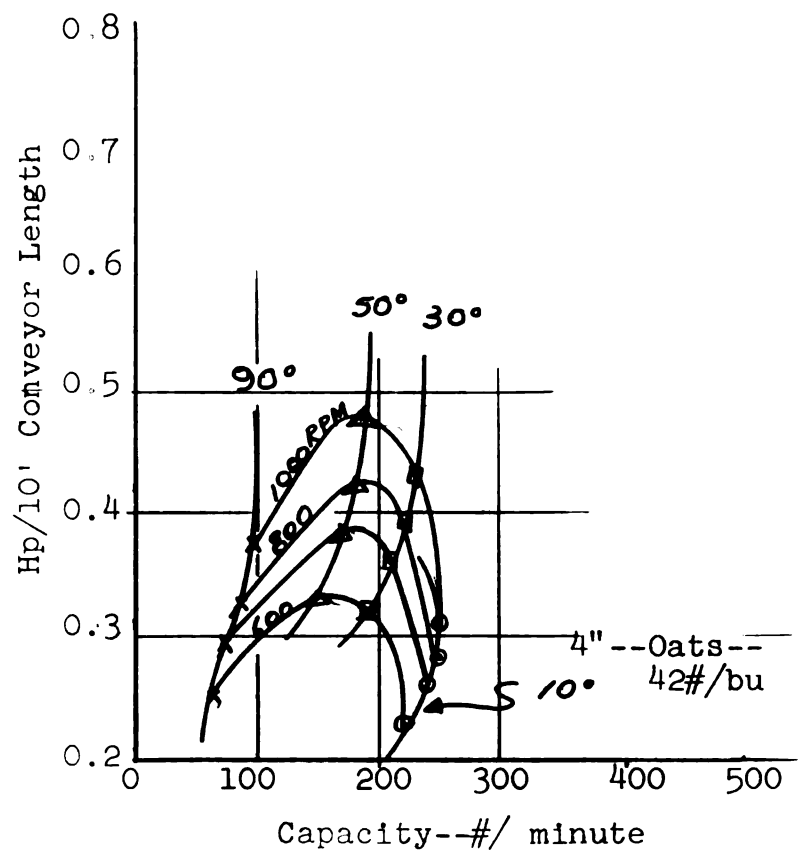
APPENDIX A. PERFORMANCE RATES AND HORSEPOWER REQUIREMENTS OF 4 AND 6 INCH DIAMETER SCREW CONVEYORS HANDLING WHEAT, OATS, AND CORN-MEAL (Source: Millier, 31)



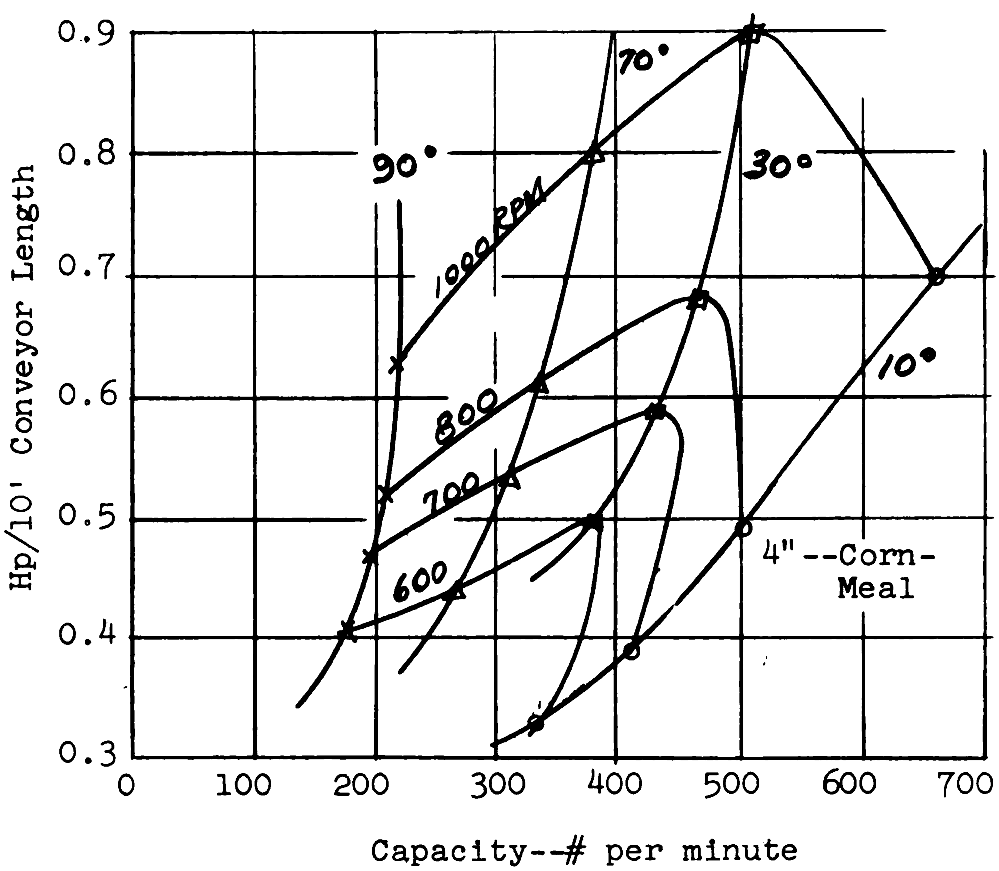


APPENDIX A (Continued)





APPENDIX A (Continued)



APPENDIX B

ESTIMATED LIFE TO OBSOLESENCE, WEAR OUT HOURS, AND ANNUAL REPAIR COST FOR SELECTED MATERIALS HANDLING EQUIPMENT*

Machine	Years Until Obsolete	Hours To Wear Out	Repair Cost Per Year Per Cent
Portable elevator	15	1500	1.0
Feed grinder	15	2000	1.7
Manure loader	10	2000	2.5
Forage blower	12	2500	2.1

*Source: Agricultural Engineering Yearbook (1).

ANNUAL REPAIRS, HOURS USED, AND EXPECTED LIFE OF MATERIALS HANDLING EQUIPMENT*

Item	Average First Cost Dollars	Annual Repairs		Hours Used Per Year	Total Expected Life Years
		Cost $	New Cost		
Auger elevators	115	2.65	2.3	31	13.3
Chain or belt elevator	401	11.45	2.85	81	14.2
Blowers	516	11.70	2.27	74	13.3
Unloading wagons	388	18.50	4.77	77	13.8
Tractor manure loaders	352	11.20	3.18	115	13.7
Monorail carriers	217	.95	.437	154	20.7
Hammermills	222	13.00	5.86	67	15.8
Burr mills	385	19.40	5.05	90	12.3
Corn shellers	439	12.90	2.94	41	15.5
Feed mixers	394	10.55	2.68	100	16.8

*Source: Kleis (24).