BULK HANDLING SPRING CROP POTATOES FROM HARVESTER TO PACKING LINE

Methods and Costs

Marketing Research Report No. 761

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Florida Agricultural Experiment Station

ACKNOWLEDGMENTS

The research was conducted cooperatively by the Transportation and Facilities Research Division, Agricultural Research Service, U. S. Department of Agriculture, under the general supervision of Joseph F. Herrick, Jr., investigations leader for horticultural crops, Handling and Facilities Research Branch, and by the Florida Agricultural Experiment Station through the Departments of Agricultural Engineering, and Agricultural Economics. Through the major part of the experimental work, E. S. Holmes, assistant agricultural engineer, Department of Agricultural Engineering, participated actively, making a vital contribution which is gratefully acknowledged. Mr. Holmes joined the Extension Service before this research effort was completed. Subsequently, Dr. I. J. Ross represented the Department of Agricultural Engineering.

William G. Grizzell, industrial engineer, Handling and Facilities Research Branch, Transportation and Facilities Research Division, assisted in determining the time required for labor and equipment, in planning handling methods and details of equipment for experimental systems, and in simulating commercial operations.

Facilities necessary for the installation and operation of experimental systems were made available by George M. Beach Farms, Hastings, Fla.; Huff Farms, Elkton, Fla.; and Sykes Packinghouse, Elkton, Fla. Alger Farms, Homestead, Fla., and Tropical Agriculture Cooperative, Goulds, Fla., made their packinghouses available for studies of selected bulk systems under commercial conditions.

Tractor forklift equipment was made available by the Florida Ford Tractor Company, Jacksonville, Fla., represented by Mr. R. P. Conway, and by the JMS Ford Tractor Company, Hastings, Fla., through Mr. James M. Stanton. Valuable assistance in the operation of the equipment was also given by each of these firms.

Mr. Preston Hill of the Federal-State Inspection Service gave generously of his time to assist in the examination of potatoes for injuries in the Hastings area; in the Homestead area, Mr. Gordon W. Brown cooperated in injury evaluation.

Washington, D.C. Issued November 1966

SUMMARY

As mechanical potato harvesters have been adopted in the spring crop area, means of bulk hauling, receiving, and temporarily holding potatoes at the packinghouse have required attention and action by growers and shippers. Generally, the action has consisted of the adaptation of facilities, built for previous harvesting and handling systems, to permit bulk handling. Most packinghouses in the area are over 10 years of age. While improvement in efficiency has been realized through mechanization, further steps toward better use of the bulk principle are needed.

A bulk-dumping system, developed and tested in the research covered in this report, showed potential for reducing costs for bulk-hauling potatoes from a mechanical harvester, receiving and temporarily holding them, and moving them out of bulk holding for entry into the packing line. Total cost for this system would be about $18 less per 1,000 packed hundredweight equivalents than for a pallet box system, and about $14 less than for the conventional system using hopper-body trucks and sloping-bottom bins. Annually, the cost reduction would be about $1,400 and $1,100, respectively, for a volume of 78,750 cwt.

Tuber injury with the bulk-dumping system was no greater than with the conventional hopper-body truck and sloping-bottom bin system.

The bulk-dumping system employs dump trucks for hauling the potatoes and bins especially designed for receiving the potatoes and fluming them to the packing line. With the bulk-dumping system, the equivalent of 110 packed cwt. of potatoes can be unloaded in 2.5 to 3 elapsed minutes. This compares with elapsed times of 9 minutes for a comparable load with the pallet box system and 14 minutes for the hopper-body truck and sloping-bottom bin system. This difference can make it possible to haul longer distances and maintain better coordination between harvesting and packinghouse operations with a given number of trucks than would be the case with the other systems mentioned.

Multiple uses of the trucks and the bin facility are possible with the bulk-dumping system. The dump trucks, which are basically flat-bed trucks, may be used in many other ways when potatoes are not in season, and the design of the bins permits the storage of equipment and other items in them during the off-season. Hopper-body trucks and sloping-bottom bins are used for 8 to 10 weeks and are idle for the remainder of the year.

The pallet box system, too, offers multiple-use possibilities with the flat-bed trucks which are employed. The shed for temporarily holding potatoes in pallet boxes can serve for storage of equipment when potatoes are not in season, if the empty boxes are stored in suitable areas of the packinghouse proper. The pallet boxes and tractor forklift, however, may not find good utilization except during the potato season.

BULK HANDLING SPRING CROP POTATOES FROM HARVESTER TO PACKING LINE—

Methods and Costs

By Earl K. Bowman, *industrial engineer*, and Gilbert E. Yost,[1] *agricultural engineer*, Transportation and Facilities Research Division, Agricultural Research Service; and R. E. L. Greene, *agricultural economist*, Florida Agricultural Experiment Station, University of Florida.

INTRODUCTION

Potatoes grown in the Southeast are prepared and packed for market the same day or within a day or two after they are dug. They are packed in packinghouses, some of which may handle the potatoes of one or only a few growers, but many of which serve a number of growers. Most packinghouses in operation are more than 10 years of age, and thus were built before the advent of present-day mechanical harvesters. Their layout and receiving equipment were designed for handling potatoes hauled to the packinghouse in field containers.

Current Systems of Harvesting and Handling Potatoes

The systems for harvesting and handling potatoes may be classified as conventional, completely mechanized, and partially mechanized. In a representative conventional system, a tractor-drawn two-row digger is used to lift the potatoes out of the rows and drop them back on the ground. They are picked up by hand and placed in field containers—bags or boxes. The field containers are loaded by hand on flat-bed trucks and are also unloaded by hand at the packinghouse.

Potatoes hauled in field containers may be graded and packed as they are unloaded from field trucks or they may be placed in temporary holding to be graded later. When grading and packing are done immediately, the field containers are unloaded from the trucks and emptied directly on a conveyor that moves the tubers to the packing line. Potatoes placed in temporary holding may be in field containers or, at houses in some areas, in holding bins. The holding facility for potatoes in field containers is essentially an open building with the floor at truck-bed height. Field bags are set off in areas usually subdivided by slatted partitions. Field boxes are stacked on the floor of the holding area.

Holding bins are normally filled by emptying the field containers directly into the bins as they are unloaded from the field trucks. The conventional bin holds enough field-run potatoes to pack about 150 100-pound bags. Many houses have eight bins—four in each of two rows facing each other.

In the harvesting and handling systems classified as completely mechanized, potatoes are dug with a two-row harvester which, by means of conveyors, loads the tubers directly into a hopper-body truck in which they are hauled in bulk to the packinghouse. The potatoes are unloaded mechanically by a conveyor in the bottom of the body. The unloading may be directly into the packing line or, if facilities such as sloping-bottom bins are available, the potatoes may be placed in temporary holding before they are graded.

In partial mechanization, mechanical equipment is used for a part of the harvesting and handling, and conventional methods and equipment are used for the remainder of the operations in the system. That is, potatoes are normally dug with one- or two-row harvesters on which the tubers are placed directly in field bags. The bags are set off along the rows as they are filled or they are accumulated on the harvester and unloaded at the end of the rows. From this point the field bags are handled as described in the conventional system.

Growth of Mechanical Harvesting and Handling

The development of equipment for complete mechanical harvesting and handling of potatoes

[1] Mr. Yost has transferred to the Agricultural Engineering Research Division, ARS.

has occurred mainly since 1950 (*7*).[2] Such equipment was first used commercially in the Southeast to an appreciable extent in Alabama in 1952. However, the greatest acceptance has been in Florida. In the Hastings area in 1954, about 522 acres of potatoes were dug with one-row harvesters and filled into field bags (*4*). On less than 900 acres mechanical harvesters dug the potatoes and loaded them into bulk trucks. In the 1964 season, more than 90 percent of the 24,000 acres of potatoes in the Hastings area was harvested mechanically. Data are not available, but observations would indicate that more than one-third of the acreage was harvested into field bags.

By the 1963-64 season, mechanical harvesting and handling equipment was also being used extensively in other Florida potato areas. Except on an experimental basis, complete mechanization was first used in Dade County in 1962. In the spring of 1964, most of the crop in that area was harvested and handled mechanically.[3]

The extent of use of harvesting and handling systems classed as completely mechanized varies in other potato areas of the Southeast. The amount is less where a large proportion of the crop is packed in packinghouses operated on a custom basis or by a cooperative association packing for a number of growers. Producers using such houses often do not have a large enough acreage to justify the cost of mechanical equipment. Problems of coordinating harvesting and packing are also greater in such houses. The amount of potatoes harvested per hour is one of the most important factors affecting cost per unit of harvesting and handling potatoes with mechanical equipment (*3*). The failure to coordinate harvesting and packing can substantially reduce a grower's rate of harvesting and thus result in a higher cost with mechanical equipment than with the conventional method.

Problems Associated With Mechanical Harvesting and Handling

The shift to current-day mechanized potato harvesting and handling equipment confronts both growers and packinghouse operators with new problems. There is a tendency to have problems with bulk handling. Situations may be especially difficult if growers using different systems of harvesting and handling haul their potatoes to the same packinghouse.

In the field, more accurate scheduling of trucks is necessary when using a mechanical harvester and hauling the potatoes in bulk since the entire operation will be delayed if a truck is not available. Also, flexibility is important. For example, truck scheduling must take into account fluctuations in harvesting rate which result from yield variation, and changes in truck travel distance with different fields.

At packinghouses where potatoes are received in bulk, special equipment is needed to unload bulk trucks. Also, mechanically harvested and bulk-handled potatoes tend to arrive at the packinghouse containing larger amounts of dirt, weeds, and grass. To deal more satisfactorily with this additional foreign matter, many Florida packinghouses have installed flumes for moving potatoes to the packing line either directly from bulk trucks or from bins provided for temporarily holding potatoes.[4] The first flume used in the Southeast was at a packinghouse at Elkton, Fla., during the 1954 season (*8*).

Effective coordination of the harvesting operation and the packing line is important for the completely mechanized system if adequate returns from the mechanization are to be realized. Also, deliveries by several growers to the same packinghouse require coordination.

Ideally, it would be desirable to grade and pack bulk-hauled potatoes directly from the bulk trucks because the less the potatoes are handled, the smaller the damage from cuts and skinning. Rate of harvesting with mechanical harvesters varies with field conditions, yield per acre, and equipment performance. Under many digging conditions, the rate of harvesting with two mechanical harvesters is not sufficient to keep the packinghouse operating efficiently. With ideal conditions and the same harvesting equipment, however, rate of harvesting may be greater than the capacity of the packing line. Three mechanical harvesters generally can provide potatoes at a higher rate than needed for the packing line. Thus, it is desirable to provide for temporary holding of potatoes. It is then possible to keep the packinghouse operating when there is an interruption in delivery of potatoes from the field, or, on the other hand, to unload the bulk trucks if deliveries exceed the capacity of the packing line. Also, temporary holding makes it possible to vary independently the number of operating hours per day of the harvesting equipment and of the

---

[2] Italic numbers in parentheses refer to Literature Cited, p. 26.

[3] The main part of this report describes research conducted in the Hastings area of Florida. Appendix B describes some commercial installations in Dade County, Fla., that used bulk handling methods for potatoes.

[4] Potato fluming is the moving of potatoes from one point to another by means of water flowing through a flume or sluice connecting the two points.

packinghouse, so that each works more nearly to capacity.

At packinghouses where potatoes are packed for a number of growers, the handling of potatoes hauled in bulk is often complicated by the fact that the house wishes to accumulate enough volume from an individual grower to pack at least a car or truck lot of potatoes. This makes it necessary to unload the bulk trucks when they arrive at the packinghouse if the harvester is to continue to operate. Temporary holding of potatoes must be provided under these circumstances.

In the Hastings area, some shippers modified sloping-bottom bins to receive bulk-hauled potatoes as well as potatoes hauled in bags. Some installed belt conveyors to move bulk-hauled potatoes from truck unloading stations to the various bins. Other packinghouses adopted a special bin loader conveyor which was movable along a row of bins. In either arrangement the cost of the equipment was relatively high. For example, one bin loader could serve only about a 40-foot row of bins moving between roof supports at each end of the row. Also, a need for two bin loaders arose where packinghouses had two rows of bins facing each other. The bin loader conveyor is available only on special order to the manufacturer and is priced at about $2,500.

The use of field bags in conjunction with mechanization, a situation already mentioned, permits temporary holding of potatoes in bags. This arrangement is expensive in terms of the higher labor requirements for handling potatoes in bags, however.

PURPOSE AND METHOD OF STUDY

The problem of coordinating the harvest and packinghouse operations appears to have been solved the least satisfactorily in the completely mechanized system. A key to solution of this problem appears to be more satisfactory facilities or methods for temporary holding and handling of potatoes hauled in bulk.

Purpose of Study

The purpose of this study was to obtain information needed for developing and planning efficient and economic facilities for receiving and temporary holding of early crop potatoes. Specific questions to be answered were: (1) What holding facility design would be desirable to provide more capacity under the same roof area than is provided by the present sloping-bottom bin? (2) What holding facility design or arrangement would permit use of lower cost conveying equipment for receiving potatoes or possibly eliminate such equipment altogether? (3) Could equipment less specialized than the hopper-body truck be adapted to the bulk handling of potatoes? (4) Since temporary holding facilities for potatoes are used only about 2 months each year, would it be possible to design a satisfactory facility that could be used to serve another purpose for part of the year, such as the storage of equipment and supplies?

Method of Study

Work on the study was conducted at commercial packinghouses in the Hastings, Fla., area during the four seasons 1960 to 1963. The research included studies of two experimental systems—bulk-dumping and pallet boxes—for receiving and handling potatoes hauled in bulk. In the *bulk-dumping* system, a truck equipped with a dump body was used for hauling the potatoes from the mechanical harvester. At the packinghouse, the loads of potatoes were dumped directly onto the floor of a flat-bottom bin constructed especially for the experimental operation. Workers flushed the potatoes into a flume, which carried them from the bin to the packing line. The *pallet box* system employed a flat-bed truck, a tractor forklift, and pallet-box dumper. Six pallet boxes per load were transportated on the truck. Each box held about 1,500 pounds of potatoes and was filled directly from a mechanical harvester. At the packinghouse, potatoes were emptied into the flume by a box dumper.

In each of the experimental systems, operations were carried out to simulate commercial conditions as nearly as possible. The primary basis of comparison for the experimental systems was the conventional hopper-body truck and sloping-bottom bin system, although some comparisons were for potatoes unloaded directly from bulk trucks into flumes.

For each system, observations were confined to operations involved in loading and hauling potatoes from the field and unloading and handling at the packinghouse until potatoes were placed either on conveyors or into flumes that moved the tubers to the packing line. Recognized industrial engineering techniques were used in making time studies of operations and developing labor inputs. Data on the purchase, operating, and maintenance costs of equipment and facilities were assembled and were used with labor inputs to develop estimated costs for the respective systems.

Samples of potatoes were collected and examined to obtain a measure of physical injuries in the experimental systems as compared to the present system of handling with hopper bodies.

Presentation of Data and Basic Assumptions

A brief discussion is first given of the hopper-body truck and sloping-bottom bin system, followed by data relating to the bulk-dumping and pallet box experimental systems. Each of the experimental systems is described and data are presented on physical injuries to potatoes. A recommended commercial layout and estimated costs for each system are presented.

The usual potato packinghouse has one line of potato packing equipment built to handle 300 to 400 packed hundredweight of potatoes per hour. Normally, a plant packs potatoes from 400 to 500 acres during a season. Specifications for the three systems treated were developed on the assumption that an attempt would be made to coordinate the operations of harvesting and packing so that maximum efficiency would be obtained for both operations. Additional storage space would be needed in houses packing for a number of growers if the house plans to be able to accumulate a large quantity of potatoes for an individual grower before packing. The basic assumptions for developing specifications and making estimates of cost for the present system and the two experimental systems are listed below:

1. An equal volume of potatoes could be handled through each system. All systems would be for a packinghouse operating one line of equipment. The rate of grading and packing would average 386 packed hundredweight equivalents of potatoes (all grades and all package sizes) per elapsed hour, which comprises 95 percent operating time and 5 percent delay.

Throughout this report harvesting and handling of potatoes are reported in hundredweight (cwt.) on a packed equivalent basis. When potatoes leave the packinghouse they are packed in various sizes of bags or other containers. Dirt, damaged potatoes, and culls have been removed. The only exception is in the tests of injured and damaged potatoes—these are on a field-run basis; this is stipulated in the tables on injury.

2. Two mechanical harvesters would be used to harvest the potatoes to be packed. Rate of harvesting for the two machines would average 300 cwt. per elapsed hour of harvesting time. Harvesters would operate an average of 9 hours per day and would average 0.86 acre per machine per hour, assuming a yield of 175 cwt. (packed) per acre.

3. In each system, six trucks that would carry 110 cwt. per load would be used to haul the potatoes from the harvesters to the packinghouse. Only four drivers would be needed. Two men would drive the trucks in the field while the potatoes were being loaded. The other two men would drive loaded trucks to the packinghouse, leave the loaded trucks there, and return empty trucks to the field. Truck drivers would work an average of 9.5 hours a day to allow for servicing trucks and starting and stopping the daily operation. All trucks would be owned by the grower. Four of the trucks would be used only during the potato harvesting season, while two would also be used for other farm work during the year. Estimated costs would include total annual costs for four trucks but only 40 percent of annual cost would be charged to the potato operation for the two trucks used throughout the year.

4. Each system would have adequate facilities for storing 1,320 cwt. of potatoes. The packinghouse would operate an average of 7 hours a day, normally starting for the day 3 hours after the harvester began digging potatoes and operating 1 hour after harvesting stopped. A packinghouse would pack the potatoes grown on 450 acres. At a yield of 175 cwt. per acre, this would be 78,750 cwt. per season. This would require that the packinghouse be operated 204 hours.

5. Structures for temporary holding of potatoes in both the bulk-dumping and pallet box systems would be available for other storage uses during the year except during the potato harvest season. Therefore, only a part of the annual cost of structure would be charged to potato hauling and handling in calculating costs for each of these.

6. Estimates of labor requirements and cost for each system were developed in terms of 1,000 packed hundredweight equivalents to facilitate comparisons.

HOPPER-BODY AND SLOPING-BOTTOM BIN SYSTEM

Description of System

The system using hopper-body trucks and sloping-bottom bins is the representative system in the Hastings area where potatoes hauled in bulk are placed in temporary holding facilities at packinghouses. Potatoes are delivered into hopper-body trucks directly from the mechanical harvester. The hopper bodies are essentially the same as those used for bulk potato handling in most commercial potato areas in the United States (fig. 1). These bodies are V-shaped, with a built-in draper chain conveyor in the bottom; the conveyor is covered by removable boards or retractable metal plates while loading at the field and uncovered as the potatoes are conveyed out of the hopper body at the packinghouse.

At the packinghouse an especially adapted bin loader is used to carry the potatoes from the hopper-body truck conveyor into the sloping-bottom bins (fig. 2). It is equipped with

BN-26702

FIGURE 1.—A hopper-body truck. Potatoes are being unloaded into the flume.

BN-26703

FIGURE 2.—Potatoes being unloaded from hopper-body truck into a sloping-bottom bin by a bin-loader conveyor. The bin loader moves on tracks parallel to a row of bins.

a hydraulic system and linkage which permit raising and lowering both ends of the conveyor as needed. A portion of the discharge end is hinged so it can go over the edge of the bin and be lowered to a position near to the sloping bin floor when starting to fill a bin. The bin-loader equipment is movable, usually on a track, to serve each bin in a row, generally consisting of not more than four bins.

Bins are normally constructed of wood with the bottom sloping at an angle of approximately 45° toward the outlet doors so that potatoes move out by gravity into a flume or onto a belt conveyor when an outlet door is opened (fig. 3).

Labor Requirements and Work Methods

Labor requirements per 1,000 cwt. are given in table 1. Truck drivers usually leave a loaded truck near the unloading area at the packinghouse and drive an empty truck back to the field. The unloader usually positions loaded trucks at the bin loader and removes the empty trucks. When the unloader is backing the truck into position, the bin-loader operator signals to assist him in properly placing the truck relative to the receiving hopper of the bin loader. After the truck is in position, the unloader climbs into the hopper body while the bin-loader operator attaches the motor for driving the hopper-body conveyor. The bin-loader operator switches on the bin loader and the hopper-body conveyor motor from his control position at the bin loader.[5] Inside the hopper body of the truck, the unloader removes cover boards from the hopper-body conveyor to permit the potatoes to move out onto the bin loader at a suitable rate. Also, he pushes the last potatoes of the load onto the conveyor and replaces the conveyor cover boards.

During the conveying of the potatoes from the truck into the bin, the bin-loader operator uses controls of the bin-loader hydraulic system to adjust the height of both the discharge and hopper ends of the machine as

[5] Wiring the current supply for the hopper-body conveyor motor through the control station of the bin-loader operator is desirable when the unloader must be inside the hopper body, out of reach of the conveyor motor switch, to remove the conveyor cover boards.

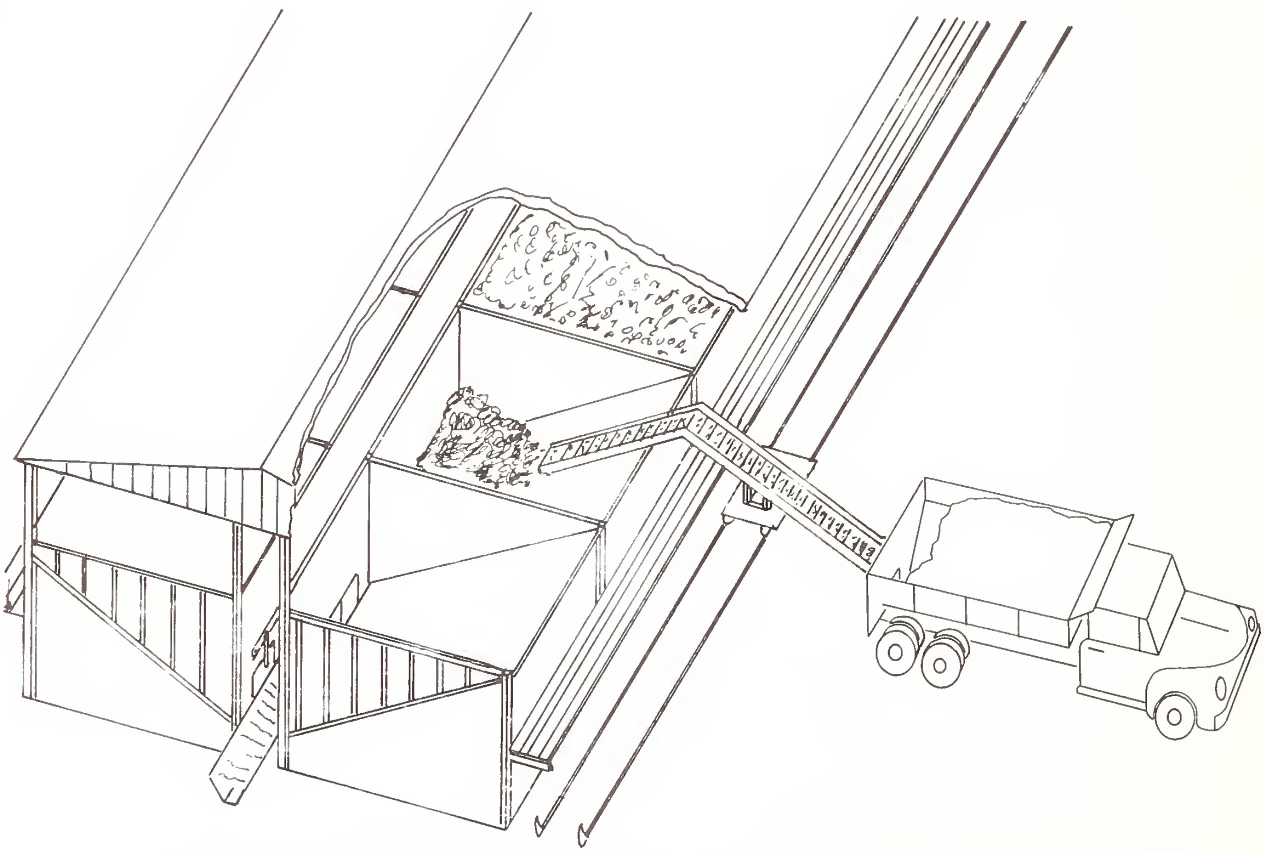


FIGURE 3.—Sloping-bottom bins and bin loader. Hopper-body truck in unloading position.

needed. When the bin loader is moved to another bin, the unloader assists the operator in manually pushing the machine.

Under some conditions, one or more additional workers may pick trash from the potatoes as they are carried along on the bin-loader conveyor.

The line-supply operator manually operates the bin outlet doors, allowing gravity flow of potatoes into a flume or onto a belt conveyor, as needed to properly supply the packing line.

Costs for System

Equipment and facilities used in hauling and handling potatoes in this system normally consist of six trucks and hopper bodies, two electric motors, a bin loader, a shed and four bins, a flume, and a pump. The estimated cost new of such equipment is $32,861 (table 2). Since it is assumed that only 40 percent of the use of two trucks would be in hauling potatoes, the investment charge to potatoes would be $28,661.

The estimated cost of loading, hauling, and handling potatoes from the field to packing line is $102.76 per 1,000 cwt.—$29.16 for labor and $73.60 for equipment and facilities (table 3). About 26 percent of the equipment and facility expense was for operating costs and 74 percent was for fixed or ownership costs.

TABLE 1.—*Labor required per 1,000 cwt. of potatoes for specified crew to haul, receive, and supply the packing line, using hopper-body trucks, bin-loader conveyor, and sloping-bottom bins* [1]

Activity	4 truck drivers [2]	1 unloader	1 bin-loader operator	1 line-supply operator	Total, 7 workers
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*
Productive labor:					
Haul potatoes	13.02	----	----	----	13.02
Unload potatoes into bins	----	2.10	2.10	----	4.20
Supply packing line	----	----	----	[3]2.46	2.46
Unavoidable delay	----	.06	.06	.13	.25
Set up and clean up	.74	----	----	----	.74
Total productive labor	13.76	2.16	2.16	2.59	20.67
Unproductive labor:					
Coordinate with harvesting operation	.32	1.17	1.17	----	2.66
Total labor	14.08	3.33	3.33	2.59	23.33
	Hours	*Hours*	*Hours*	*Hours*	
Elapsed time	3.52	3.33	3.33	2.59	----

[1] Truck loads of 110 cwt., round-trip distance of 10½ miles per trip between packinghouse and harvester.
[2] Truck drivers haul potatoes from 2 mechanical harvesters.
[3] Based on packing line down for delays 5 per cent of time.

TABLE 2.—*Estimated required investment in equipment and facilities for handling potatoes in hopper-body and sloping-bottom bin system*

Item	Units	Estimated purchase price or replacement cost [1]	Investment: Total	Charged to potatoes: Proportion	Charged to potatoes: Amount
	Number	*Dollars*	*Dollars*	*Percent*	*Dollars*
Truck[2]	2	3,500	7,000	40	2,800
Truck	4	3,500	14,000	100	14,000
Hopper body	6	800	4,800	100	4,800
Electric motor	2	45	90	100	90
Bin loader	1	2,500	2,500	100	2,500
Shed and bins	1	3,295	3,295	100	3,295
Flume	1	451	451	100	451
Pump	1	725	725	100	725
Total	----	----	32.861	----	28,661

[1] At 1964 prices.
[2] Used both for handling potatoes and other farm work.

TABLE 3.—*Estimated annual labor, equipment and facilities cost, and cost per 1,000 cwt., for hauling and handling potatoes using the hopper-body and sloping-bottom bin system*

[Based on an annual volume of 78,750 cwt. of potatoes (packed equivalents)]

Item	Annual costs	Cost per 1,000 cwt.
	Dollars	*Dollars*
Labor[1]	2,296	29.16
Equipment and facilities[2]	5,796	73.60
Total	8,092	102.76

[1] Based on 23.33 man-hours per 1,000 cwt. (table 1) and a wage rate of $1.25 per hour.
[2] Based on appendix tables 15 and 16.

BULK-DUMPING SYSTEM

Description of System

Arrangements were made for research on bulk dumping at selected potato packinghouses in the Hastings-Elkton area. For the studies, a standard farm truck with underbody hoist (fig. 4) and a special bin were provided. The 1½ ton stake-body truck was equipped with a hydraulic hoist and sideboards 24 inches high. A full width endgate, hinged at the top to allow the bottom to swing out, was installed; the control lever was operated from the cab. The inside dimensions of the body were 143 by 82 by 24 inches, giving a volume of 163 cubic feet.[6]

An experimental wooden bin was constructed, 20 feet long, 10 feet wide, and 2½ feet high on the sides and output end. The output end was connected to the packinghouse main flume while the other end was open to allow the dump truck

[6] In preparing for the 1962 season, the floor of the truck bed was covered with sheet aluminum to provide a smoother surface for movement of the potatoes in dumping, and to make it more durable.

BN-26704

FIGURE 4.—Standard farm dump truck with underbody hoist used in study.

to enter the bin, by backing up an earth-filled inclined ramp. From results of experimental operation, modifications were made on the bin from time to time. Finally, the bin floor had a flume channel along the center, 12 inches wide by 5½ inches deep; the floor sloped ½ inch from each side of the bin to the center flume. The bin sloped 1 inch in 10 feet toward the main flume.

The pattern of operation for the bulk-dumping system was to load the dump truck in the field directly from a mechanical harvester, travel to the packinghouse, and dump the load of potatoes onto the floor of the bin. A worker with a water hose flushed potatoes out of the bin and into the main flume (figs. 5 and 6). Water was supplied through a connection with the pump that normally supplied water directly into the main flume to the packing line.

A relatively simple and easily operated de-

BN-26707

FIGURE 6.—Potatoes flowing out at front of the experimental bin and into the packinghouse flume.

BN-26706

FIGURE 5.—Potatoes being washed into bin flume of the experimental bin with a water hose. Operator normally works from the front to the back along one side. Potatoes flow out at front of bin just behind hose.

vice was developed to prevent potatoes from rolling back under the truck during unloading and being crushed by the wheels. This was a stopboard made of plywood and attached underneath the truck frame behind the rear wheels (fig. 7). A rope and pulley control arrangement permitted the driver to operate the potato stopboard from the front of the truck bed.

Injury to Potatoes

Since physical damage would be of key importance in the commercial possibilities of the bulk-dumping method, arrangements were made with the operator of a packinghouse to conduct experiments in the 1960 season to yield information on tuber damage in bulk dumping. Potatoes were dumped from a dump-body farm truck directly onto a concrete floor. Samples were taken from the pile of potatoes after they were dumped. Samples were also taken from a hopper-body load that was unloaded into a flume; these potatoes were harvested about the same time and from the same location in the field as the dump-body load. The samples were examined the day the potatoes were dug and after a 7-day holding period.[7] The results indicated that injuries in bulk dumping would be no more than injuries associated with the conventional hopper-body system (*1*). This work paved the way to the construction of the flat-bottom bin used in other seasons to extend the research.

In subsequent seasons, the amount of physical injury to potatoes in bulk dumping was compared with injuries to potatoes hauled in hopper bodies and unloaded by a conveyor into sloping-bottom bins. Samples were selected from the same places in the operation for each method, so that the injuries were those received in digging, loading, unloading, and moving the potatoes out of the storage bins. Tests during

[7] Potatoes with physical injuries were classified according to degree, as minor injury, major injury, and cut or crushed potatoes. *Minor injury* was damage that could be removed with a loss of 5 percent or less of the weight of the tuber. *Major injury* was damage that could not be removed without a loss of more than 5 percent of the weight of the tuber. *Cut or crushed potatoes* were those obviously injured by the digger blade.

BN-26708

FIGURE 7.—The potato stopboard (below rear end of body) is shown in raised position as dump truck is backed into bin. During unloading the board is lowered.

three seasons[8] showed that, on the average, those handled through the flat-bottom bins contained about 2 pounds less potatoes with minor injuries per 100 pounds of field-run potatoes and no more major damage than those handled through sloping-bottom bins (table 4).

On potatoes susceptible to skinning, appreciably less skinning occurred on those handled through the experimental flat-bottom bin.[9] The potatoes from the experimental bin were also of brighter appearance, as less rolling occurred and less dirt was pressed into the flesh of the potatoes.

Although very few red-skinned potatoes are grown in the Hastings area, some samples were obtained for Red LaSoda potatoes handled through the bulk-dumping system one day in the 1963 season. They were harvested and handled very carefully. Part of the potatoes were hauled in a dump truck and unloaded into a flat-bottom bin, and part were hauled in a hopper-body truck and unloaded directly into a flume. Results of the tests were similar to those for Sebago potatoes. In samples collected after

[8] Major emphasis was placed on obtaining a comparison of injuries by the two methods in the 1961 and 1962 seasons. Only enough samples were examined in 1963 to see if results were similar to those obtained in the two previous seasons. See appendix A for a more detailed presentation of data on injury.

[9] On one occasion, the operator of the packinghouse where the experimental bin was located estimated that at least one-fourth less skinning had occurred on potatoes that had passed through the experimental bin. There was also less evidence of scraping on potatoes from the experimental bin.

TABLE 4.—*Extent of injuries to mechanically harvested Sebago potatoes, by method of handling from field to packinghouse, Hastings, Fla., 1961–63*

Handling method and extent of injury	Pounds of injured potatoes per 100 pounds of field-run potatoes		
	1961 season[1]	1962 season[1]	1963 season[2]
	Pounds	*Pounds*	*Pounds*
Potatoes handled in a truck equipped with a dump body and unloaded into a flat-bottom bin:			
Minor	9.0	27.1	12.1
Major[3]	2.3	2.0	3.7
Total	11.3	29.1	15.8
Potatoes handled in a hopper-body truck and unloaded into sloping-bottom bins:			
Minor	11.9	27.9	14.4
Major[3]	2.3	3.2	2.6
Total	14.2	31.1	17.0

[1] Average of 3 tests; twenty 25-pound samples were evaluated for each method at each test.
[2] Average of 4 tests; five 25-pound samples were evaluated for each method at each test.
[3] Includes potatoes crushed or cut with the digger blade.

TABLE 5.—*Extent of injuries to mechanically harvested Red LaSoda potatoes, by method of handling from field to packinghouse, Hastings, Fla., 1963*

Handling method and extent of injury	Pounds of injured potatoes per 100 pounds of field-run potatoes[1]			
	Test 1	Test 2	Test 3	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*
Potatoes handled in a truck equipped with a dump body and unloaded into a flat-bottom bin:				
Minor	4.0	8.5	7.3	6.6
Major	.4	.4	--	.3
Cut or crushed potatoes	1.7	6.1	4.9	4.2
Total	6.1	15.0	12.2	11.1
Potatoes handled in a hopper-body truck and unloaded directly into a flume:				
Minor	5.6	9.4	9.6	8.2
Major	.8	.8	.6	.7
Cut or crushed potatoes	2.0	3.7	4.3	3.4
Total	8.4	13.9	14.5	12.3

[1] Five 25-pound samples were evaluated for each method at each test.

the potatoes had passed over the washer, minor damage averaged 6.6 pounds per 100 pounds of field-run potatoes unloaded into the flat-bottom bin and 8.2 pounds for the potatoes unloaded directly in the flume (table 5). Major damage was slight for both systems but slightly less for the flat-bottom bin.

Recommended Commercial Layout and Requirements

Equipment Requirements

The major equipment requirements are dump-body trucks and a water supply pump with valves, piping, and hoses for directing the water for fluming. Dump-body trucks with a capacity of approximately 120 cwt. of field-run potatoes per load, or a volume of approximately 250 cubic feet, are comparable to the capacity of a representative hopper-body truck. The end-gate should be full width, hinged at the top, and smooth on the inside. The trucks should be equipped with a stopboard to prevent tubers from rolling back around the rear wheels of the truck during unloading where they would be injured or completely mashed. This stopboard should be hinged on a metal rod so that it can be lowered to an inclined position with the bottom edge on the bin floor during dumping and while moving the truck forward out of the bin. Details of the stopboard construction and attachment are given in figure 8.

The water supply pump should be capable of supplying water to the system at rates ranging from 300 to 600 gallons per minute.

Facility Requirements

Facilities required are a roofed area with bins designed so that potatoes may be dumped directly in them from trucks (fig. 9). Bins must include flumes for moving the potatoes to the packing line.

The flume slope and shape must be such that there is neither undue settling of soil and clogging by potatoes nor high velocity to injure potatoes. The bottom and sides of the flumes should be as smooth as possible. Flumes are designed for soil-scouring velocities of 150 feet per minute or higher. Such velocities should be used only during cleanout runs when no pota-

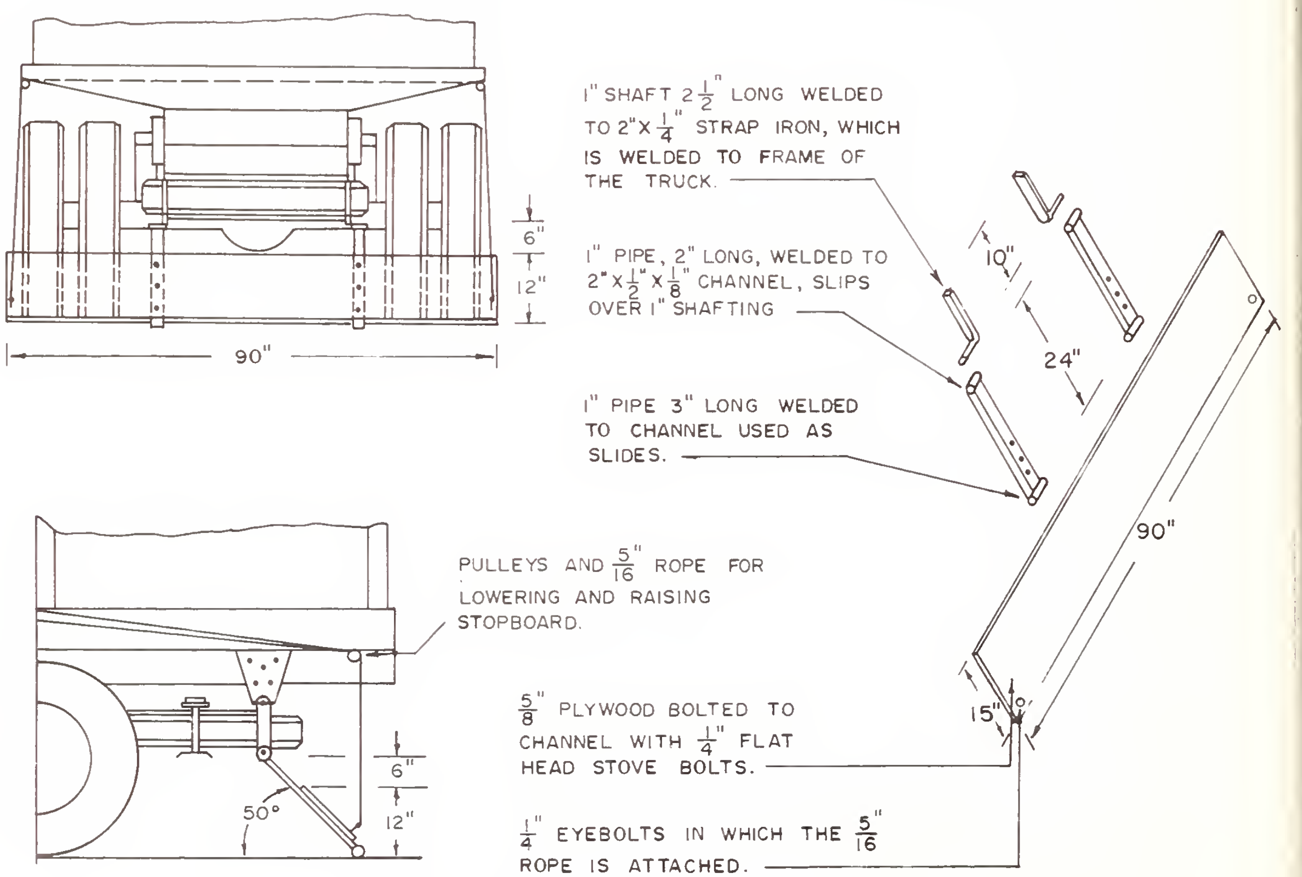


FIGURE 8.—Details of construction for stopboard.

toes are being carried. Although flume slopes of 1:120 to 1:240 (one inch drop to 120 inches or 240 inches of flume) have been used, the potato and water level remains most nearly constant with a bottom slope of 1:180. Flumes should be deepened near the outlet so that when potato velocities are kept below 60 feet per minute (f.p.m.) and potatoes and water back up during runs, there will be no overflow of water. (*2*)

Good flume design is the result of a series of compromises: (1) The flume should be large enough so that the potatoes do not wedge crosswise and clog the flume but small enough to handle usual volumes of potatoes with 300 to 600 g.p.m. (gallons per minute) of water; (2) the flume should be designed so that potatoes move less than 60 f.p.m., but the slope should be such that soil-water velocities of 150 f.p.m., or more, are possible for cleanout runs; and (3) if possible, the flume should be designed to hold potatoes in water for 6 to 8 minutes to soften soil, but it should supply a uniform flow of potatoes to the packing line even with alternate stoppage and overloading of the bin (*2*). Details of practical design for flumes are given in figure 10.

A suggested layout for the bins along with details relative to floor slope and cast-in-place flumes in the concrete floor are given in figure 12. The four bins, as illustrated, provide a total capacity of 12 truckloads. This capacity may be varied according to the needs in each plant, however, by the bin length and number of bins chosen. Individual bins are formed by partitions 30 inches high; bins are 40 feet long and 10 feet wide, as illustrated (fig. 11). Width should not vary appreciably from 10 feet without a corresponding variation from 8 feet as the outside width of the dump body. If the partitions are removable, the total space will have a wider range of possible uses during the large portion of the year when potatoes are not in season.

The temporary holding bins must have a roof which allows clearance for dump-truck bodies in raised position while the trucks are in the bins and as they are driven out empty. This requires a minimum height of approximately 16 feet. When planning construction, however, measurements of trucks to be used should be carefully noted and roof overhang taken into account. Pole-type construction may be used for economy, and roof type may be whatever is best suited to the individual circumstances. The

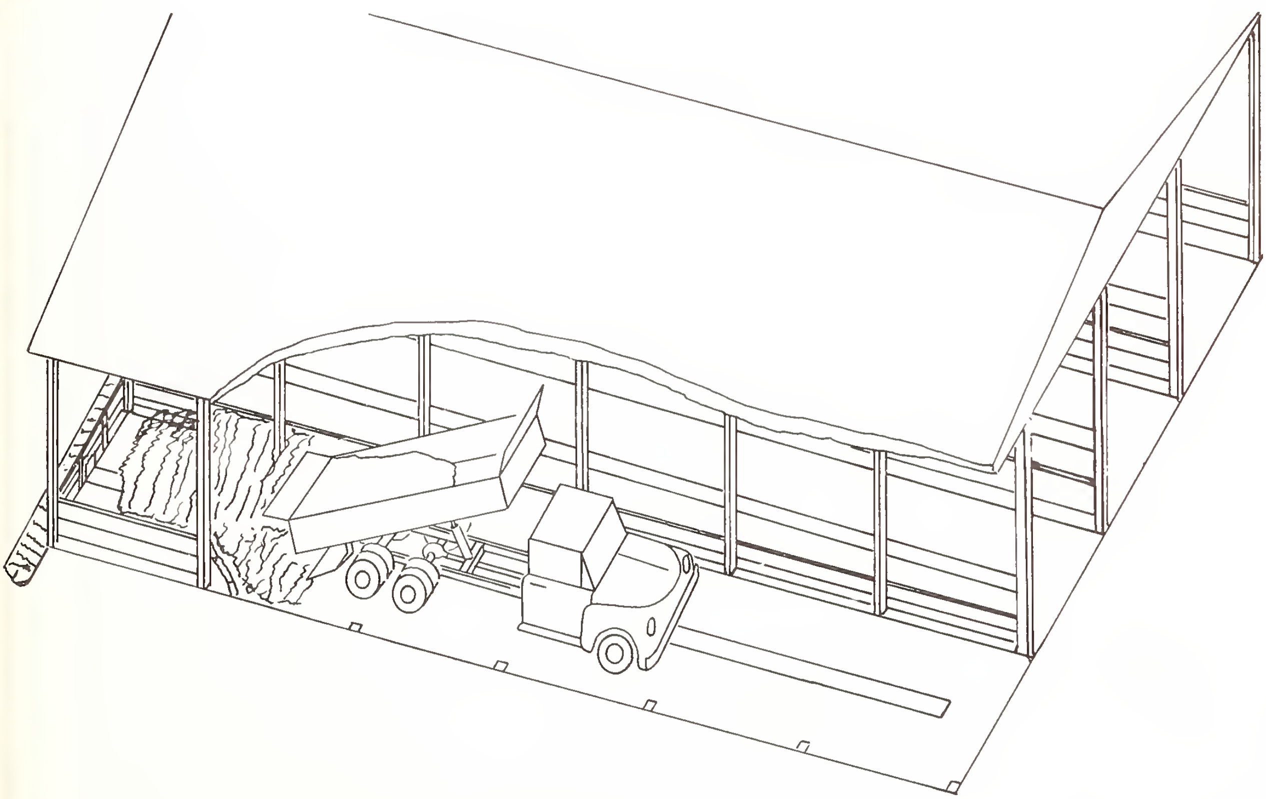


FIGURE 9.—Bin facility for bulk-dumping system.

overhang allowed should be generous, to shade the tubers from direct sunlight. It is preferable to position the holding bins with the open end (truck entry) toward the north to aid in shading the tubers.

Labor Requirements

The labor requirements per 1,000 cwt. are given in table 6. In this system, it is expected that truck drivers will unload each truck they drive to the packinghouse. Because of the short time required for unloading by bulk dumping (2.63 minutes per load), this can be included in the driver's cycle without conflict, in most cases. Moreover, use of a "house" driver for unloading involves time for changing drivers which is out of proportion to the time needed for unloading when the truck driver may unload without delay.

The line-supply operator carries on the fluming operation to move potatoes from the proper bin and on through the main flume to the input conveyor to the packing line. This worker is important in achieving the proper flow of potatoes to the packing line, which in turn affects the efficiency attained by the line. Rate of flow assumed in this report is 386 cwt. per elapsed hour. The line-supply assistant helps in moving the hose from bin to bin and also clears out small quantities of potatoes which may be left in the bin.

In respect to work methods, several procedures, or patterns, for fluming were tried in the experimental bin. In the one which seemed the most satisfactory and involved the least number of moves for the worker, the worker progressed from the discharge end of the filled bin to the other end, emptying one side of the bin, then flushed potatoes from the remaining side while moving back to the discharge end of the bin (fig. 12).

Costs for System

Estimated equipment and facilities that would be needed to handle potatoes in the bulk-dumping and flat-bin system consist of six trucks with flat-bed bodies equipped with hydraulic lifts, a shed with four bins, a pump,

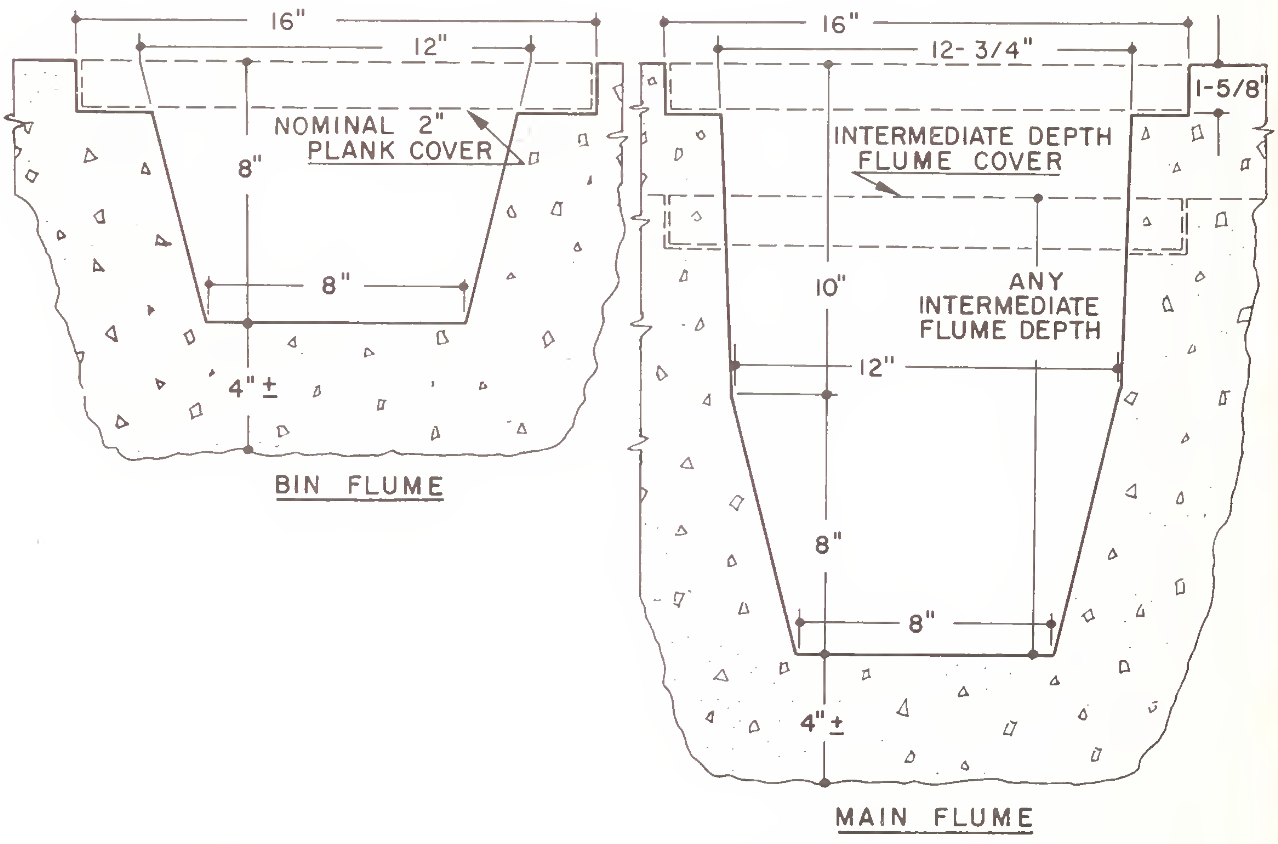


FIGURE 10.—Flume design recommended for bin flumes and main flume. (Note that depth of main flume increased because of required slope and drops at turns. All flume covers are the same length) (*2*).

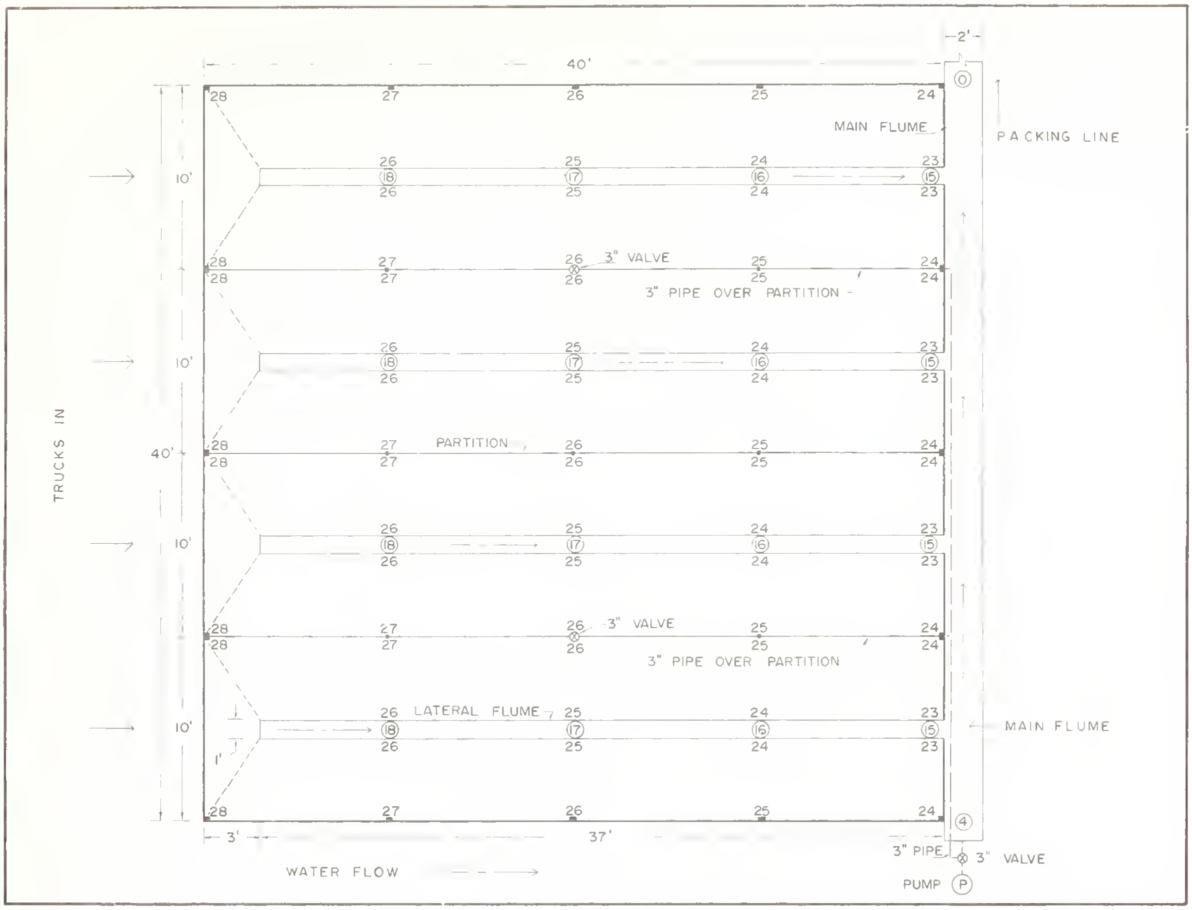


FIGURE 11.—Bin layout and flume details for holding facility for bulk-dumping system. Elevations of flume bottom (circled numbers) and floor (uncircled numbers) are shown at 10-foot intervals and are measured in inches above the point on the bottom of the main flume designated "O" (upper right of illustration). This layout allows 12-inch depth of water in the main flume.

TABLE 6.—*Labor required per 1,000 cwt. of potatoes for specified crew to haul, receive, and supply the packing line using a bulk-dumping system* [1]

Activity	4 truck drivers[2]	1 line-supply operator	1 line-supply assistant[3]	Total, 6 workers
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*
Productive labor:				
Haul potatoes	12.94	--	--	12.94
Unload potatoes into bins	.40	--	--	.40
Supply packing line	--	2.46	2.46	4.92
Set up and clean up	.74	--	--	.74
Unavoidable delay	--	[4].13	[4].13	.26
Total productive labor (no unproductive labor)	14.08	2.59	2.59	19.26
	Hours	*Hours*	*Hours*	
Elapsed time	3.52	2.59	2.59	--

[1] Truckloads of 110 equivalent packed hundredweights; round trip distance of 10½ miles per trip between packing house and harvester.

[2] Truck drivers haul potatoes from 2 mechanical harvesters.

[3] Assists as needed in line supply, directs trucks in backing into bins; cleanup and miscellaneous duties as needed during remainder of time.

[4] Based upon packing line down for delays 5 percent of time. Operation of fluming to properly supply the packing line requires continuous attention while packing line is operating.

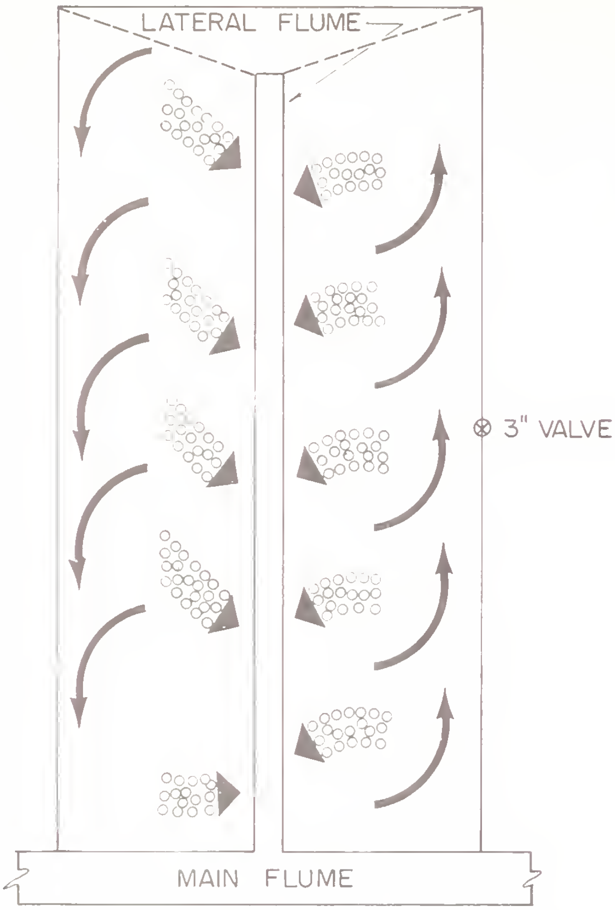


FIGURE 12.—Pattern found most satisfactory for flushing potatoes into flume in experimental operation. Small curved arrows indicate approximate pattern of hose movement and large arrows indicate movement of potatoes.

pipe and valves, and hose for flushing the potatoes into the flume. The estimated cost new of such equipment is $31,859 (table 7). Since it is assumed that only 40 percent of the use of two trucks would be in hauling potatoes and only one-fourth of the cost of the shed and bins would be charged to potato handling, the investment charge to potatoes would be $23,673. This would be about $5,000 less than the investment cost for the system using hopper-body trucks and sloping-bottom bins.

The estimated cost of loading, hauling, and handling potatoes from the field to the packing line is $88.14 per 1,000 cwt. and $6,940 per year (table 8). This is $1,149 per year less than the hopper-body and sloping-bottom bin system. Labor cost is lower than in the hopper-body truck system because one worker receiving potatoes is eliminated. About 28 percent of the equipment and facilities expense is for operating costs and 72 per cent for fixed or ownership costs.

TABLE 8.—*Estimated annual labor, equipment and facilities cost, and cost per 1,000 cwt. for hauling and handling potatoes using the bulk-dumping and flat-bottom bin system.*

[Based on an annual volume of 78,750 cwt. of potatoes (packed equivalents)]

Item	Annual costs	Cost per 1,000 cwt.
	Dollars	*Dollars*
Labor[1]	1,896	24.08
Equipment and facilities[2]	5,044	64.06
Total	6,940	88.14

[1] Based on 19.26 man-hours per 1,000 cwt. (table 6) and a wage rate of $1.25 per hour.

[2] Based on appendix tables 15, 16, and 17.

TABLE 7.—*Estimated required investment in equipment and facilities for handling potatoes in bulk-dumping and flat-bottom bin system*

Item	Units	Estimated purchase price or replacement cost [1]	Investment: Total	Charged to potatoes: Proportion	Charged to potatoes: Amount
	Number	*Dollars*	*Dollars*	*Percent*	*Dollars*
Truck[2]	2	3,500	7,000	40	2,800
Truck	4	3,500	14,000	100	14,000
Flat-bed body[2]	2	300	600	40	240
Flat-bed body	4	300	1,200	100	1,200
Hydraulic lift for body	6	500	3,000	100	3,000
Shed and bins	1	4,834	4,834	25	1,208
Pump	1	925	925	100	925
Pipe (3-in. diameter, 70 ft.) and valves (3)	--	180	180	100	180
Hose (40 ft.)	--	120	120	100	120
Total	----	----	31,859	----	23,673

[1] At 1964 prices.

[2] Used both for handling potatoes and for other farm work.

PALLET BOX SYSTEM

Description of System

For the experimental operation of handling potatoes in pallet boxes, the equipment consisted of a flat-bed truck, a pallet box dumper, a tractor forklift, and about 20 pallet boxes. The box dumper was installed in the roofed receiving shed at a commercial packinghouse so that potatoes could be emptied into the flume to the packing line. The boxes were a commercially made wirebound type, with slatted sides and bottoms. Outside dimensions of the boxes were 47 by 47 by 33 inches (fig. 13). These boxes were available from another project on produce handling, and thus the dimensions were not specifically chosen for potato handling. Calculations indicated that box capacity was approximately 25 bushels or 1,500 pounds of potatoes. One-ton-capacity pallet boxes, deeper than those just mentioned, have been used in other areas where pallet box systems were used for potato handling operations (*6*).

A truckload consisted of a single layer of six boxes, which were filled on the truck directly from a mechanical harvester. At the packinghouse, a tractor forklift was used to unload the filled boxes from the truck and to move them into and out of a holding area and to the box dumper (fig. 14). The tractor forklift was an industrial type, 3,500-pound capacity at 24-inch load center. The lift was rear-mounted and included a side shifter attachment. Other features were reversed operator position and shuttle transmission. The same tractor forklift was used to move empty boxes away from the dumper, set them aside in stacks if desired, and load them onto the flat-bed truck. The travel pattern used in the 1962 season is shown in figure 15.

The box dumper was a hydraulic type with rated capacity of 1,500 pounds. Boxes were manually pushed into and out of the dumper on 10-foot sections of roller conveyor attached at each side of the dumper.

Space requirements for temporarily holding potatoes may be kept to a minimum with the pallet box system. It easily accommodates more product per square foot of floor area than either of the other systems covered. For example, with 3-high stacking of 1-ton capacity pallet boxes and allowing 5 percent of the floor area for space between boxes, the capacity is approximately 350 pounds per square foot of floor area.

BN-26710

FIGURE 13.—Pallet boxes used in experimental operation for potatoes. Top edges were covered with polyethylene foam to reduce possibility of tuber injury.

BN-26711

FIGURE 14.—Tractor forklift used in the experimental pallet box operation; view of removing a filled box from truck.

For the bulk-dumping system, bin capacity is approximately 100 pounds per square foot of floor area when the average depth of potatoes is taken as 2½ feet. It should be noted: (1) The maximum depth depends on the height of the truck body; and (2) The average depth actually attained, with a given truck, depends upon the skill and technique of the operator in dumping the potatoes. Sloping-bottom bins of representative size have a capacity of approximately 240 pounds of potatoes per square foot of ground area.

Injury to Potatoes

The extent of injury to potatoes handled in pallet boxes was evaluated in the same way as for the experimental bulk-dumping system. At the packinghouse where the pallet box system was tested, the regular bulk system was one in which the hopper bodies were unloaded directly into a flume. Injury measured was that resulting from digging, loading, and unloading the potatoes into the flume at the packinghouse.

In the 1961 season, Sebago potatoes handled in pallet boxes had about 2.4 pounds more injured potatoes per 100 pounds than those hauled in hopper bodies and dumped directly into a flume (table 9). In the 1962 season, the amount of damage was the same for the two systems. A factor in the large amount of major damage in both systems was the amount of digger cuts. In the 1961 season, the amount of digger cuts at this packinghouse was about 3 pounds more per 100 pounds than at the pack-

TABLE 9.—*Extent of injuries to Sebago potatoes harvested mechanically and handled in pallet boxes and hopper bodies unloaded directly into a flume, Hastings, Fla., 1961 and 1962.*

Handling method and extent of injury	Pounds of injured potatoes per 100 pounds of field-run potatoes [1]	
	1961 season	1962 season
	Pounds	*Pounds*
Handled in pallet boxes:		
Minor	11.4	18.1
Major [2]	5.8	6.6
Total	17.2	24.7
Handled in a hopper body and unloaded into a flume:		
Minor	10.0	18.0
Major [2]	4.8	6.7
Total	14.8	24.7

[1] Average of 3 tests; twenty 25-pound samples were evaluated for each method at each test.

[2] Includes potatoes crushed or cut with the digger blade.

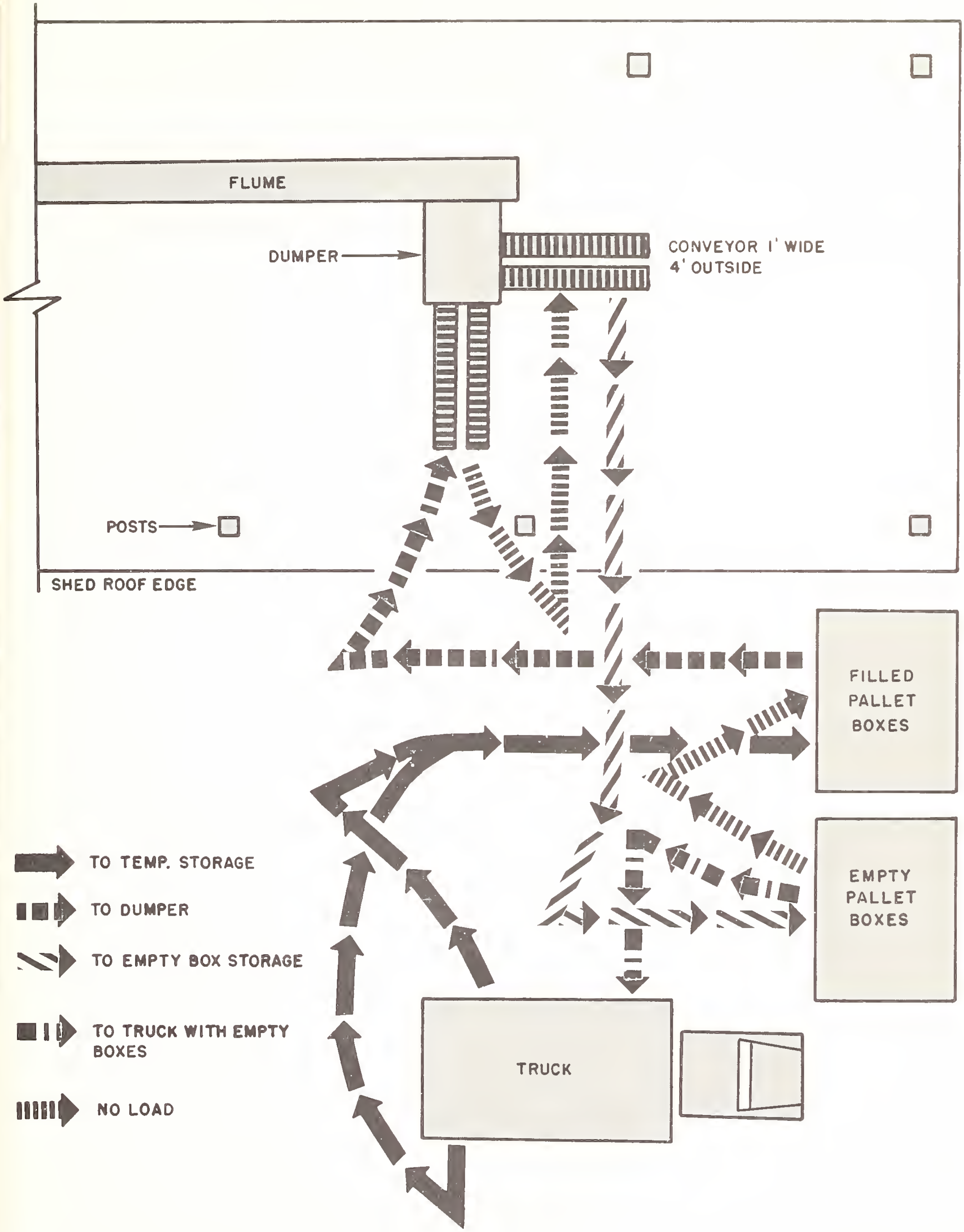


FIGURE 15.—Layout used in experimental handling of potatoes in pallet boxes (1962). Travel pattern used by fork-lift truck in moving filled and empty pallet boxes during handling is indicated.

inghouse where the experimental bulk-dumping system was tested.

One test was made for Red Pontiac potatoes handled in pallet boxes. In this test, minor injuries were about 7 pounds more per 100 pounds than for potatoes handled in a hopper body and unloaded directly into a flume (table 10). The difference in other types of injuries

TABLE 10.—*Extent of injuries to Red Pontiac potatoes harvested mechanically and handled in pallet boxes and hopper bodies, Hastings area, Florida.*

Extent of injury	Pounds of injured potatoes per 100 pounds of field-run potatoes [1]	
	Handled in pallet boxes	Handled in hopper bodies
	Pounds	*Pounds*
Minor	23.6	16.5
Major	.7	.3
Digger cuts and crushed potatoes	1.3	2.2
Total	25.6	19.0

[1] Twenty 25-pound samples were evaluated for each method of handling.

was not very great. Red Pontiac potatoes are more subject to physical injuries in handling than Sebago potatoes. Therefore, a wide difference in amount of injuries for the two systems is not unexpected for the Pontiac variety, since hitting on the side of a pallet box is likely to result in an injury.

Recommended Commercial Layout and Requirements

The major items of equipment required are pallet boxes, forklift unit, box dumper, roller conveyor, and flat-bed trucks. Dimensions of 1-ton-capacity pallet boxes may be close to those of a 4-foot cube. The height should be such that the desired capacity will be provided with at least one of the dimensions slightly less than 4 feet. This is to permit satisfactory loading of two rows of boxes on a truck bed 8 feet wide (the legal limit on highway truck width in Florida). Satisfactory pallet boxes made of wood are available commercially. Additional information on types of pallet boxes, details of their construction, and certain test results are available (*5*).

The inside surfaces of boxes should be smooth enough for handling produce susceptible to skinning. Firms supplying boxes have gained experience in recent years on the application of pallet boxes to produce handling and should be able to interpret such requirements satisfactorily. The bottom and sides may be slatted, that is, spaces of 1/4 to 1/2 inch allowed between boards with the inside edges of the boards chamfered. When pallet boxes are designated as two-way entry, it indicates that the forks of the lift equipment can only enter from two opposite sides of a pallet, whereas four-way entry indicates that the forks can enter from any side. The prospective user of pallet boxes must take into consideration each step involved in the cycle in which it is planned to use the boxes to determine the need for this feature.

For use in the layout illustrated in figure 16, two-way entry pallet boxes should be constructed with skidboards on the pallet because travel patterns for forklift equipment involve approach to the conveyors from the side instead of the end. This results in pallet stringers being at right angles to the conveyor as boxes are released on it with the forklift equipment. The skidboards, running across the pallet stringers, provide suitable bearing surface on the conveyor rollers (fig. 17).

Forklift equipment should be chosen with primary consideration to the following factors:

(a) Load to be handled. Determine the maximum weight per box and number of boxes to be handled at a time.

(b) Travel distances. Greater top speed (over 5 miles per hour) is efficient for one-way trips of more than 100 feet where paving surface permits the faster speed.

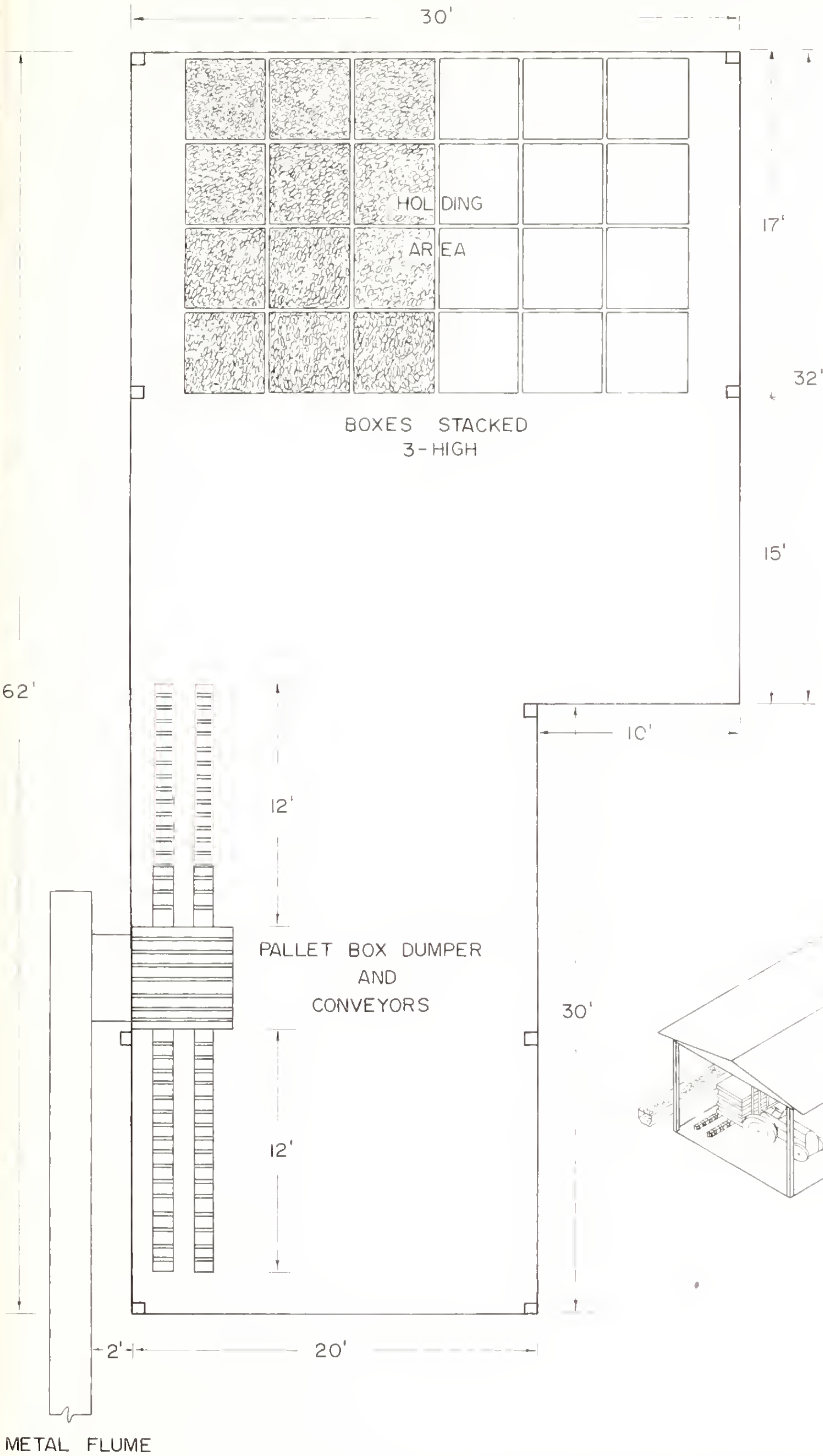
(c) Height of stacking. Determine the maximum lift height needed for forklift equipment.

(d) Surface on which equipment will be used. Stability and smoothness of surface influence type of forklift unit and the tires with which it should be equipped. Unpaved surface would normally require a tractor forklift rather than a forklift truck. If surface is smooth and stable enough, cushion tires rather than pneumatic could be used on forklift trucks.

The aim should be to choose forklift equipment having the capability needed at the least cost.

Generally, the box dumper should be of moderate cost. Approximately $1,800 is representative for such a commercially made unit, exclusive of conveyors and installation. Such features as an automatic control system, for example, would be difficult to justify for the annual volume which many potato firms handle.

It is necessary to have conveyors on which filled boxes are placed and moved into the dumper, and other conveyors on which empty boxes move out of the dumper. It is desirable that both ingoing and outgoing conveyors be



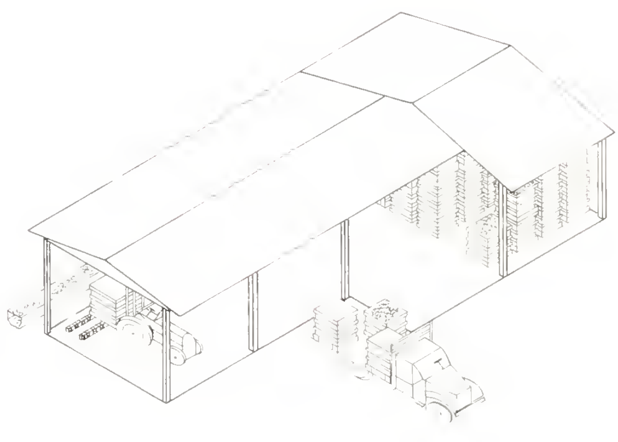


FIGURE 16.—Layout for holding and dumping facility for pallet box system.

long enough to hold three boxes. The gravity roller conveyor is the simplest and most inexpensive type, but necessitates the use of one to two additional workers, other than the dumper operator, for manually moving boxes. Individual firms may weigh the cost of additional labor for manually moving boxes against the cost for a powered conveyor installation in making decisions on the dumping arrangements.

The box dumper may be arranged to dump directly into a flume. With this arrangement, however, the dumper must be operated so as to regulate the flow of potatoes from the pallet box according to the rate of input to the packing line. Alternatives would be (a) to provide a water tank to receive potatoes from the box dumper and an inclined roller conveyor with variable speed drive for carrying the potatoes out of the tank and into the flume to the packing line, or (b) to provide a hopper with an adjustable gate through which potatoes would

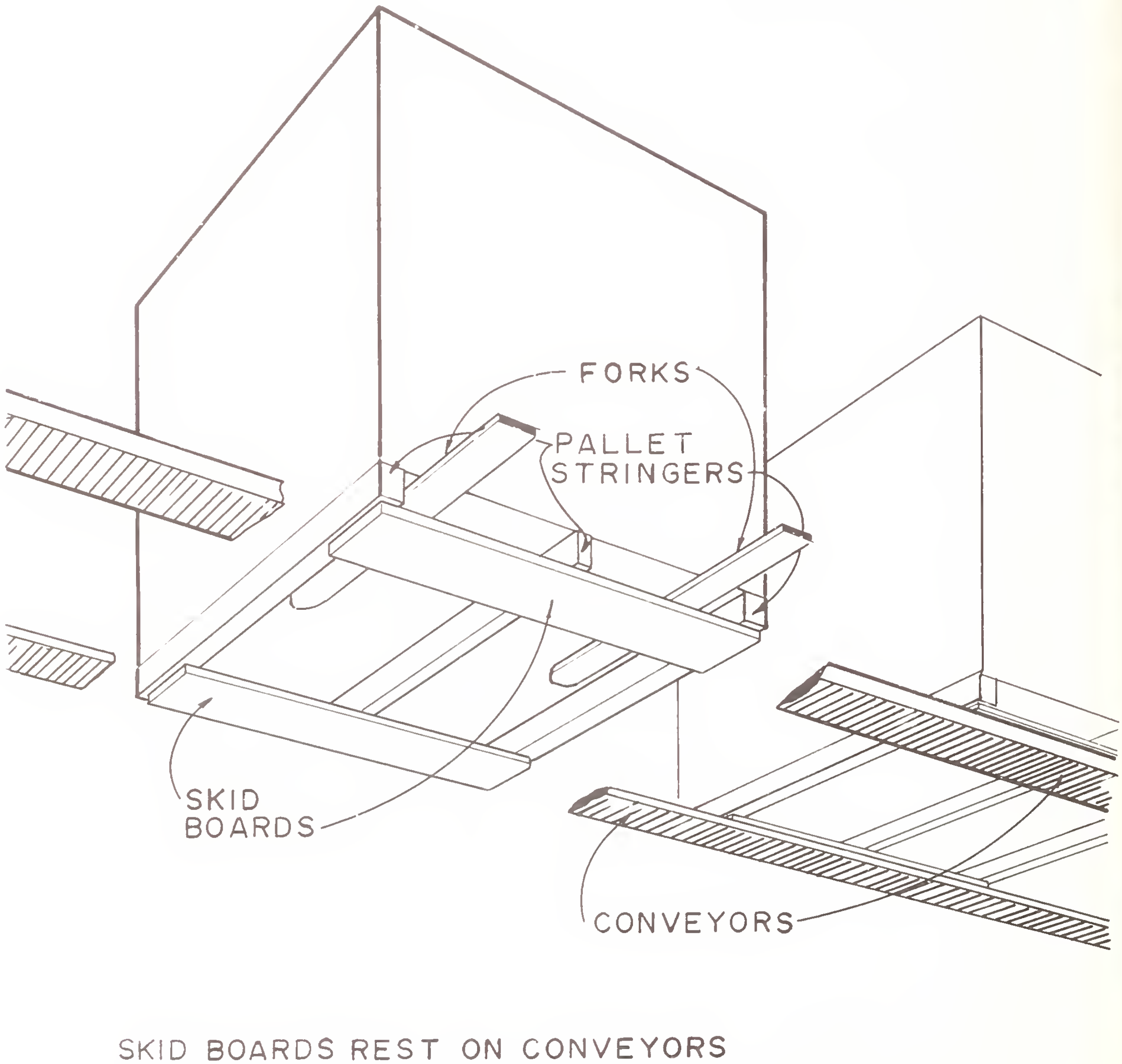


FIGURE 17.—View underneath pallet box, with gravity roller-conveyors cut away, showing position of skidboards relative to pallet box stringers and to roller conveyors.

flow by gravity onto an inclined roller conveyor with variable speed drive and thence into the flume or belt conveyor to the packing line.

A water tank or hopper can reduce the time for the dumper cycle and help to regulate the flow of product to the packing line. With either tank or hopper designed to hold at least one and one-half times the capacity of the pallet box which is being handled, product can move out of the pallet box en masse. Otherwise, the product must be removed at the rate of input to the packing line. The extra time this adds to the dumper cycle may range from ½ minute to more than 1 minute, depending on box capacity and the flow rate of the packing line.

Facility Requirements

The facility for temporarily holding potatoes at the packinghouse in the pallet box system can be a simple structure. It is essentially a roof over a level, paved floor and preferably clear of posts except around the perimeter. The roof should be made with an overhang of at least 30 inches to protect the tubers from direct sunlight.

It is important to have good accessibility for forklift equipment between the truck, the holding facility, and the dumper. In the day's operation, filled boxes will be moved from the truck to the temporary holding area before the packing line begins operation. While the packing line is operating, filled boxes will be moved both from the temporary holding area and from field trucks to the box dumper. During the first part of the day, empty boxes will be moved only from the temporary holding area to the empty field trucks. After the packing line starts operating, empty boxes will be loaded on field trucks directly from the dumper and occasionally from the temporary holding area.

Labor Requirements and Work Methods

Labor requirements per 1,000 cwt. of potatoes are given in table 11. It is expected that truck drivers coming from the field will position trucks for unloading at the packinghouse and change to another truck which is already loaded

TABLE 11.—*Labor required per 1,000 cwt. of potatoes for specified crew to haul, receive, and supply the packing line using a pallet box system* [1]

Activity	4 truck drivers [2]	1 forklift operator [3]	1 dumper operator	1 dumper helper	Total, 7 workers
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*
Productive labor:					
Haul potatoes	13.02	—	—	—	13.02
Receive potatoes into temporary holding area (packing line not operating at start of day)	—	0.38	—	—	.38
Receive potatoes and serve dumper directly from field truck	—	1.10	—	—	1.10
Serve dumper from temporary holding area when trucks not in	—	.39	—	—	.39
Dump potatoes	—	—	1.35	0.41	1.76
Set up and clean up	.74	—	—	—	.74
Unavoidable delay	—	—	[4] .13	[4] .13	.26
Total productive labor	13.76	1.87	1.48	.54	17.65
Unproductive labor:					
Coordinate with harvesting operation	.32	[5] 1.46	—	—	1.78
Coordinate with packing operation	—	—	[6] 1.11	[7] 2.05	3.16
Total unproductive labor	.32	1.46	1.11	2.05	4.94
Total labor	14.08	3.33	2.59	2.59	22.59
	Hours	*Hours*	*Hours*	*Hours*	
Elapsed time	3.52	3.33	2.59	2.59	

[1] Truck loads of 110 packed hundredweight equivalents; six 1-ton capacity pallet boxes per load; round trip distance of 10½ miles between packinghouse and harvester.
[2] Truck drivers haul potatoes from 2 mechanical harvesters.
[3] Moves 1 pallet box at a time on tractor forklift.
[4] Based upon packing line down for delays 5 percent of time.
[5] Includes coordination with packing line also.
[6] May be less, depending upon amount of time given to regulating flow with the dumper.
[7] Includes cleanup work as needed during this time.

with empty boxes for return to the field. Frequently, no additional moving of a truck would be required at the packinghouse since positioning does not have to be as exact as for a hopper-body truck which must deliver potatoes into the hopper of a bin loader. The dumper helper will position trucks when occasional need arises.

The forklift operator performs his work so as to supply the dumper according to needs and to unload filled boxes from trucks and reload them with empty boxes also as needed.

Labor requirements are based on the handling of one box per trip with forklift equipment. This was done mainly because: (1) Boxes are required to be in one layer on the truck when they are filled directly from a mechanical harvester; and (2) at the packinghouse, the layout as shown involves only relatively short travel distances.

In considering other situations, particularly those involving greater travel distances, the relationship of travel time and the time required to stack and unstack the boxes for moving them two at a time is of prime importance.

Generally, the time per box for travel will be less if two boxes are moved together rather than one at a time. Stacking and unstacking of boxes for the 2-high stacks needed generally require more time than the simple pickup and release operations for handling one box at a time. Thus, there is what might be termed a break-even distance. For greater distances, the moving of two boxes per trip should mean less total time for forklift handling than if two boxes were moved one at a time between the same points. The break-even distance is influenced by factors which usually will vary from one firm to another. Additional information is given in appendix A.

The dumper operator controls the box dumper so as to supply the packing line with potatoes as needed. He may assist the dumper helper in moving boxes into and out of the dumper where a powered conveyor is not provided for the unit.

The dumper helper, in addition to moving boxes into and out of the dumper, performs miscellaneous work in the box-dumping operation. For example, he may rake potatoes out of a box in raised position in the dumper, when dirt interferes with complete emptying of the box by gravity.

Costs for System

Estimated equipment and facilities needed for hauling and handling potatoes from the harvester to the packing line would consist of six trucks with flat-bed bodies, tractor forklift, box dumper, conveyor, 108 pallet boxes, shed, pump, and flume. The estimated cost new of these items is $37,802 (table 12). Since it is assumed that the shed would serve for other purposes except during the potato harvesting season and only a part of its cost would be charged to potato handling, and that only 80 percent of the cost of the tractor forklift and

TABLE 12.—*Estimated required investment in equipment and facilities for handling potatoes in the pallet box system*

Item	Units	Estimated purchase price or replacement cost [1]	Investment		
			Total	Charged to potatoes	
				Proportion	Amount
	Number	*Dollars*	*Dollars*	*Percent*	*Dollars*
Truck	[2]2	3,500	7,000	40	2,800
Truck	4	3,500	14,000	100	14,000
Flat bed body	[2]2	300	600	40	240
Flat bed body	4	300	1,200	100	1,200
Tractor forklift	[2]1	6,200	6,200	80	4,960
Box dumper	1	1,800	1,800	100	1,800
Conveyor	1	500	500	100	500
Pallet box	108	20	2,160	100	2,160
Shed	[2]1	3,331	3,331	35	1,166
Flume	1	286	286	100	286
Pump	1	725	725	100	725
Total			37,802		29,837

[1] At 1964 prices.
[2] Used both for handling potatoes and other farm work.

40 percent of the cost of two of the trucks would be charged to potato handling, the charge to potatoes would be decreased to $29,837. This amount is almost $6,200 more than the bulk-dumping and flat-bottom bin system, and $1,200 more than the hopper-body and sloping-bottom bin system. The cost of the tractor forklift was estimated at $6,200, which is an important item of investment in this system.

The estimated cost of handling potatoes from the field to the packing line is $106.59 per 1,000 cwt. (table 13). This is $18.45 more than the estimated cost for the bulk-dumping flat-bottom bin system, but only $3.88 more than the estimated cost per 1,000 cwt. for the hopper-body and sloping-bottom bin system.

TABLE 13.—*Estimated annual labor, equipment and facilities cost, and cost per 1,000 cwt., for hauling and handling potatoes using the pallet box system.*

[Based on an annual volume of 78,750 cwt. of potatoes (packed equivalents)]

Item	Annual costs	Cost per 1,000 cwt.
	Dollars	*Dollars*
Labor [1]	2,224	28.24
Equipment and facilities [2]	6,170	78.35
Total	8,394	106.59

[1] Based on 22.59 man-hours per 1,000 cwt. (table 11) and a wage rate of $1.25 per hour.
[2] Based on appendix tables 15, 16, and 17.

CONCLUSIONS AND RECOMMENDATIONS

Experiments with the two bulk systems showed that the bulk dumping offered the lower cost. This cost was also lower than that for the hopper-body and sloping-bottom bin system, which represented the conventional bulk system for the area. Annually, the savings for the bulk-dumping system over the conventional bulk system would be about $1,100 on a volume of 78,750 cwt. (table 14).

Tuber injury was found to be in the same range as for the conventional bulk system.

The bulk-dumping system offers more simplicity in equipment requirements and a greater freedom to use the equipment and facilities for other purposes throughout the year. Trucks are basically flat-bed trucks. The dump body is made up of sideboards and endgate which may be easily removed. Thus, these trucks are easily adaptable for many uses whenever they are not needed for potato handling. Since potatoes are dumped from the truck directly into the bin, there is the unique advantage that no additional equipment is required to transfer the potatoes into the holding facility. The bin may be used for storage of equipment or other items for a large part of the year, when it is not needed for potatoes.

The bulk-dumping system is recommended for commercial use as a system for hauling and receiving potatoes in bulk, and temporarily holding and moving them out for packing, in areas where flumes can be used.

Cost for the pallet box system was above that for the conventional system by $3.88 per 1,000 cwt. (table 14). This does not indicate lack of worthy features, however. Particular conditions could make the use of the pallet box system desirable.

Very small lots of potatoes can easily be kept separate and held temporarily in pallet boxes. There is great flexibility in location points where pallet boxes may be picked up or released. There is maximum opportunity for multiple use of trucks since they are of the flat-bed type which can serve many needs for agricultural enterprises. Also, the facility for temporarily holding pallet boxes filled with potatoes is simpler in construction than the holding facilities for the other systems considered in this report, and it is easily adaptable to other uses.

TABLE 14.—*Estimated labor and equipment costs per 1,000 cwt. and total annual costs for three methods for hauling and handling potaoes, based on an annual volume of 78,750 cwt.*

Method	Costs per 1,000 cwt.			Total cost per year
	Labor	Equipment	Total	
	Dollars	*Dollars*	*Dollars*	*Dollars*
Hopper-body and sloping-bottom bin	29.16	73.55	102.71	8,089
Bulk-dumping and flat-bottom bin	24.08	64.06	88.14	6,940
Pallet box	28.24	78.35	106.59	8,394

LITERATURE CITED

(1) BOWMAN, E. K., HOLMES, E. S., YOST, G. E., and GREENE, R. E. L.
1961. RESEARCH ON NEW METHODS FOR HANDLING POTATOES. Sunshine State Agr. Res. Rpt., v. 6, No. 2, 20 pp., illus. (Fla. Agr. Expt. Stas.)

(2) EDGAR, A. D., CLAYCOMB, R. S., and HANSEN, J. C.
1957. FLUME SYSTEMS FOR HANDLING BULK-STORED POTATOES. U.S. Dept. Agr. Mktg. Res. Rpt. 177, 16 pp., illus.

(3) GREENE, R. E. L., KUSHMAN, L. J., and SPURLOCK, H. C.
1959. AN ANALYSIS OF QUALITY AND COST OF HARVESTING AND HANDLING POTATOES WITH MECHANICAL EQUIPMENT. Fla. Agr. Expt Sta. Bul. 612, 72 pp., illus.

(4) GREENE, R. E. L.
1962. SOME ECONOMIC ASPECTS OF THE POTATO INDUSTRY IN FLORIDA. Fla. Agr. Expt. Sta., Dept. Agr. Econ. Mimeo Rpt. 62–16, 29 pp.

(5) HEEBINK, T. B.
1958. BIN PALLETS FOR AGRICULTURAL PRODUCTS. U.S. Dept. Agr., Forest Service Rpt. 2115, 34 pp., illus.

(6) JOHNSON, E. F., and BOWMAN, E. K.
1959. MECHANIZED METHODS OF RECEIVING POTATOES AT MAINE TRACKSIDE STORAGES. Maine Agr. Expt. Sta. Bul. 585, 75 pp., illus.

(7) NORTON, J. S., GREENE, R. E. L., and KUSHMAN, L. J.
1956. EQUIPMENT FOR MECHANICAL HARVESTING AND HANDLING OF IRISH POTATOES IN THE SOUTHEAST. Fla. Agr. Expt. Sta. Bul. 579, 32 pp., illus.

(8) NORTON, J. S., and GREENE, R. E. L.
1960. FLUME DESIGNS FOR RECEIVING AND HANDLING POTATOES IN PACKINGHOUSES. Fla. Agr. Exp. Sta. Cir. S–119, 8 pp., illus.

(9) PAWSKI, L.
1961. HANDLING POTATOES INTO RED RIVER VALLEY STORAGES—METHODS AND EQUIPMENT. U.S. Dept. Agr. Mktg. Res. Rpt. 471, 39 pp., illus.

APPENDIX A.—MEASUREMENTS USED IN THE RESEARCH

Calculation of Labor, Equipment, and Facility Costs

Estimates of cost of handling potatoes for each of three systems include cost of labor, equipment, and facilities involved in loading the potatoes from the mechanical harvesters in the field, hauling them to the packinghouse, and handling in the packinghouse until the tubers are placed on the conveyor which moves them to the washing, grading, and packing equipment.

Cost of Labor

Observations were made on number of men used and time required to perform various operations connected with handling potatoes. These values were reduced to time required per 1,000 cwt. and divided as to productive and unproductive labor. Total elapsed hours per man per 1,000 cwt. were calculated. This time was multiplied by the number of men to obtain total hours needed for each type of operation. Total hours were then multiplied by the wage rate per hour to calculate labor cost.

Cost for Equipment and Facilities

In calculating costs for equipment and facilities, estimates were first made of the type and number of units of equipment and facilities required. Costs were broken down into fixed, or ownership, cost and operating cost. Fixed costs were considered independent of hours operated during the season. For equipment used in both potato handling and other farm work, fixed costs were divided in proportion to the estimated time used in handling potatoes. Operating costs were calculated first on the estimated cost per hour. Total operating costs charged to potatoes were based on the number of hours used in potato handling. Both fixed and operating costs were calculated first for a unit of equipment and then multiplied by the number of units to obtain total cost.

Fixed Costs.—Fixed costs included charges for depreciation, interest, insurance, and taxes. The cost of a truck license was also included as a fixed cost. To express costs for all systems on the same basis, calculations of fixed costs were based on the cost of new equipment or facilities at 1964 prices. Estimates of the expected service life of equipment and facilities were based on the opinions of packinghouse owners who supervised their use. It is impossible to determine precise values for fixed costs because the disposal or trade-in value of equipment is unknown. It is also impossible to estimate with precision exact life because a machine may become obsolete before it is worn out.

Table 15 shows type of equipment and facilities used in each system, estimated service life, annual fixed costs per unit of equipment by items of cost, number of units of equipment or facilities, total annual costs, and percentage and

TABLE 15.—*Estimated replacement cost, service life, and annual fixed or ownership costs of equipment and facilities for specified potato handling systems, based on an annual volume of 78,750 cwt. of potatoes (packed equivalent)*

System and equipment	Estimated purchase price or replacement cost (1964 prices)	Estimated service life	Annual fixed or ownership cost: Cost per unit of equipment: Depreciation [1]	Interest [2]	Insurance and taxes [3]	Licenses	Total	Units of equipment	Total annual cost: Amount	Charge to potatoes: Proportion	Charge to potatoes: Amount
	Dollars	*Years*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Number*	*Dollars*	*Percent*	*Dollars*
Hopper-body and sloping-bottom bins:											
Truck [4]	3,500	[5] 5	[5] 480.00	127.00	140.00	75.00	822.00	2	1,644.00	40	657.60
Truck [6]	3,500	10	350.00	96.25	70.00	5.00	521.25	4	2,085.00	100	2,085.00
Hopper body	800	10	80.00	22.00	16.00	---	118.00	6	708.00	100	708.00
Electric motor	45	5	9.00	1.35	.90	---	11.25	2	22.50	100	22.50
Bin loader	2,500	10	250.00	68.75	50.00	---	368.75	1	368.75	100	368.75
Shed and bins	3,295	20	164.75	86.49	65.90	---	317.14	1	317.14	100	317.14
Flume	451	20	22.55	11.84	9.02	---	43.41	1	43.41	100	43.41
Pump	725	20	36.25	19.03	14.50	---	69.78	1	69.78	100	69.78
Total	--------	--------	--------	--------	--------	--------	--------	--------	5,258.58	--------	4,272.18
Bulk-dumping and flat-bottom bins:											
Truck [4]	3,500	[5] 5	[5] 480.00	127.00	140.00	75.00	822.00	2	1,644.00	40	657.60
Truck [6]	3,500	10	350.00	96.25	70.00	5.00	521.25	4	2,085.00	100	2,085.00
Flat-bed body [4]	300	10	30.00	8.25	6.00	---	44.25	2	88.50	40	35.40
Flat-bed body [6]	300	10	30.00	8.25	6.00	---	44.25	4	177.00	100	177.00
Hydraulic lift for body	500	10	50.00	13.75	10.00	---	73.75	6	442.50	100	442.50
Shed and bins [8]	4,834	20	241.70	126.89	96.68	---	465.27	1	465.27	25	116.32
Pump	925	20	46.25	24.28	18.50	---	89.03	1	89.03	100	89.03
Pipe and valves	180	20	9.00	4.72	3.60	---	17.32	1	17.32	100	17.32
Hose	120	5	24.00	3.60	2.40	---	30.00	1	30.00	100	30.00
Total	--------	--------	--------	--------	--------	--------	--------	--------	5,038.62	--------	3,650.17
Pallet box system:											
Truck [4]	3,500	[5] 5	[5] 480.00	127.00	140.00	75.00	822.00	2	1,644.00	40	657.60
Truck [6]	3,500	10	350.00	96.25	70.00	5.00	521.25	4	2,085.00	100	2,085.00
Flat-bed body [4]	300	10	30.00	8.25	6.00	---	44.25	2	88.50	40	35.40
Flat-bed body [6]	300	10	30.00	8.25	6.00	---	44.25	4	177.00	100	177.00
Tractor forklift	6,200	[7] 10	[7] 440.00	211.00	124.00	---	775.00	1	775.00	80	620.00
Box dumper	1,800	10	180.00	49.50	36.00	---	265.50	1	265.50	100	265.50
Conveyor gravity roller	500	10	50.00	13.75	10.00	---	73.75	1	73.75	100	73.75
Pallet box	20	7	2.86	.57	.40	---	3.83	108	413.64	100	413.64
Shed [8]	3,331	20	166.55	87.44	66.62	---	320.61	1	320.61	35	112.21
Flume	286	20	14.30	7.51	5.72	---	27.53	1	27.53	100	27.53
Pump	725	20	36.25	19.03	14.50	---	69.78	1	69.78	100	69.78
Total	--------	--------	--------	--------	--------	--------	--------	--------	5,940.31		4,537.41

[1] Depreciation is calculated by the straight line method based on the estimated service life. Adjusted for salvage value where indicated.
[2] Interest is calculated at 5 percent of the average of the values at the beginning of the first and last years of estimated life.
[3] Insurance and taxes calculated at 4 percent of estimated purchase price or replacement cost for trucks used full time and for other items at 2 percent.
[4] Used both for hauling potatoes and for other farm operations.
[5] Salvage value estimated at $1,100.
[6] Used only for hauling potatoes.
[7] Salvage value estimated at $1,800.
[8] Shed will be available for storage of equipment or other use the rest of the year.

amount of fixed cost charged to potato handling.

Depreciation was calculated by the straight line method, based on estimated new cost and service life. No salvage value was considered at the end of the use period except for the tractor forklift and the trucks used full time. The interest cost was calculated at 5 percent of the average of the values at the beginning of the first and last year of estimated life. The insurance and taxes charge was calculated at 2 percent of the replacement cost, except 4 percent was used for the trucks used full time. The license charge was the cost of licenses for trucks of the size used. Trucks used only for hauling potatoes had a low charge of only $5. A special provision of the Florida law makes the license charge only $5 per year for trucks used mainly on the farm and seldom run on highways.

The total annual fixed costs for all equipment and facilities charged to potatoes were estimated at $4,272.18 for the hopper-body and sloping-bottom bin system, $3,650.17 for the bulk-dumping and flat-bottom bin system, and $4,537.41 for the pallet box system. In the bulk-dumping and flat-bottom bin system and the pallet box system, it was assumed that the buildings would be used for other purposes except during the potato harvesting season. Therefore, only 25 and 35 percent of the fixed costs for buildings for these two systems, respectively, was charged to potato handling.

Operating costs.—Operating costs included those costs directly associated with operating equipment and facilities such as (1) maintenance and (2) fuel, electricity, grease, and oil. Operating costs were estimated for a unit of each type of equipment and facility used and expressed on the basis of cost per hour (table 16). Maintenance was first expressed in terms of cost per 100 hours of operation, based on stated percentages of the estimated purchase or replacement cost. This figure was multiplied by the number of hours used for potato handling to get cost of maintenance to be charged to potatoes. Maintenance was then expressed on the basis of cost per hour of use. The estimated cost per hour for fuel or electricity and for grease and oil was added to maintenance to give total operating cost per hour. Annual operating costs equal hourly unit cost times number of units times the hours used for potatoes.

Total ownership and operating costs.—Table 17 shows the total fixed and operating costs, per year and per 1,000 cwt., for the three systems of handling potatoes.

Development of Time Values

All operations except those in the hopper-body and sloping-bottom bin system were necessarily on an experimental basis. The time values for the experimental operations, while valid for the comparative relationships presented in this report, are not necessarily the same as values developed from the study of stable commercially operating systems. Time values for the hopper-body and sloping-bottom bin system were developed mainly from studies at one packinghouse where the experimental bulk-dumping system was installed for the final season. Facilities, equipment, and methods were representative.

Recognized time study techniques were used to obtain time study data. Through analysis of this data, values were established for each of the various activities making up the different operations. A rating factor was applied to each of the time values derived from the time study data to obtain a base time in which an average qualified worker working at a normal pace could satisfactorily accomplish the work. Allowances were then added to compensate for fatigue effects and personal requirements of workers. The resulting values were termed productive time values.

The labor requirement tables in the body of this report primarily show the crew organization and the labor per 1,000 cwt. of potatoes. Additional detail concerning activities in the three systems and productive time values per truckload of 110 cwt. of potatoes are given in table 18.

Allowances of 5 percent for personal needs and 5 percent for fatigue were used in developing the productive times shown in table 18, except for the fatigue allowances as follows:

	Percent
Hopper-body and sloping-bottom bin system:	
Set up, clean up, insert board, bin	10
Move bin loader to next bin	20
Bulk-dumping system:	
Raise stopboard for travel	10

Forklift Time for One and Two Boxes per Trip

A break-even distance for given conditions of forklift travel speed with given times for stacking, unstacking, pickup, and release of boxes may be considered. For distances greater

TABLE 16.—*Estimated hourly and annual operating cost for equipment used in 3 potato handling systems, based on an annual volume of 78,750 cwt. of potatoes (packed equivalent)*

System and equipment	Estimated purchase price or replacement cost (1964 prices)	Maintenance cost per 100 hours of operation: Percentage of estimated purchase price or replacement cost	Maintenance cost per 100 hours of operation: Amount	Estimated time used for potatoes	Total maintenance cost	Operating cost per hour per unit: Maintenance	Operating cost per hour per unit: Electricity, fuel, grease, and oil	Operating cost per hour per unit: Total	Units of equipment	Total annual operating cost
	Dollars	*Percent*	*Dollars*	*Hours*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Number*	*Dollars*
Hopper-body and sloping-bottom bins:										
Truck[1]	3,500	2.0	70.00	172	120.40	0.700	0.50	1.200	2	412.80
Truck[2]	3,500	2.0	70.00	172	120.40	.700	.50	1.200	4	825.60
Hopper body	800	.5	4.00	307	12.28	.040	--	.040	6	73.68
Electric motor	45	10.0	4.50	67	3.02	.045	.02	.065	2	8.72
Bin loader	2.500	1.5	37.50	135	50.62	.375	.03	.405	1	54.68
Shed and bins	3,295	3.0	[3]98.85	204	98.85	.484	--	.484	1	98.74
Flume	451	.5	2.26	204	4.61	.022	--	.022	1	4.49
Pump	725	.75	5.44	204	11.10	.054	.15	.204	1	41.62
Total	--	--	--	--	--	--	--	--	--	1,520.33
Bulk-dumping and flat-bottom bins:										
Truck[1]	3,500	2.0	70.00	175	122.50	0.700	0.50	1.200	2	420.00
Truck[2]	3,500	2.0	70.00	175	122.50	.700	.50	1.200	4	840.00
Flat-bed body[1]	300	1.0	3.00	175	5.22	.030	--	.030	2	10.50
Flat-bed body[2]	300	1.0	3.00	175	5.22	.030	--	.030	4	21.00
Hydraulic lift for body	500	50.0	250.00	2	5.00	2.500	--	2.500	6	30.00
Shed and bins	4,834	2.0	[4]100.28	204	25.07	.123	--	.123	1	25.09
Hose, pipe, and valves	300	.5	1.50	204	3.06	.015	--	.015	1	3.06
Pump	925	.75	6.94	204	14.16	.069	.15	.219	1	44.68
Total	--	--	--	--	--	--	--	--	--	1,394.33
Pallet box system:										
Truck[1]	3,500	2.0	70.00	171	119.70	0.700	0.50	1.200	2	410.40
Truck[2]	3,500	2.0	70.00	171	119.70	.700	.50	1.200	4	820.80
Flat-bed body[1]	300	1.0	3.00	171	5.13	.030	--	.030	2	10.26
Flat-bed body[2]	300	1.0	3.00	171	5.13	.030	--	.030	4	20.52
Tractor forklift[1]	6,200	1.5	93.00	147	136.71	.930	.50	1.430	1	210.21
Box dumper	1,800	1.5	27.00	204	55.08	.270	.05	.320	1	65.28
Pallet box	20	.5	.10	204	.20	.001	--	.001	108	22.03
Conveyor gravity roller	500	.5	2.50	204	5.10	.025	--	.025	1	5.10
Shed	3,331	2.0	[5]66.62	204	23.32	.114	--	.114	1	23.26
Flume	286	.5	1.43	204	2.92	.014	--	.014	1	2.86
Pump	725	.75	5.44	204	11.10	.054	.15	.204	1	41.62
Total	--	--	--	--	--	--	--	--	--	1,632.34

[1] Used both for hauling potatoes and for other farm work. [2] Used only for hauling potatoes. [3] Estimated total maintenance cost for the year.
[4] Estimated total maintenance cost for the year; only 25 per cent of maintenance cost charged to potato handling.
[5] Estimated total maintenance cost for the year; only 35 percent of maintenance cost charged to potatoes.

than this, forklift time will be less by moving two boxes per trip, while for shorter distances, one box per trip will require less forklift time to move an equivalent amount of product in like quantities per box. A formula for the relationship is given below:

$$\frac{[S_2 + P_2 + (CD)(N) \quad + R_2 + DS_2] - [2P + (CD)\ (2N) + 2R]}{V} = K$$

where:

S_2 = stacking boxes 2-high (min. per stack)
P_2 = pick up 2-high stack (min. per stack)
CD = change direction in travel (min. per occurrence).
N = number of changes of direction in travel.
R_2 = release 2-high stack (min. per stack)
DS_2 = unstack 2-high stack (min. per stack)
P = pick up one box (min. per box)
R = release one box (min. per box)
V = travel speed for forklift (min. per foot)
K = round trip break-even distance (feet)

To apply the formula, a cycle of activity must be used. Illustrating this, in the moving of boxes between a truck and box dumper, time values for the following activities are used:

Make 2-high stack of filled boxes on truck when moving two boxes per trip;

Pick up filled box(es) from truck;

TABLE 17.—*Estimated annual ownership and operating costs of equipment and facilities for three potato handling systems, for an annual volume of 78,750 cwt. of potatoes, and cost per 1,000 cwt. (packed equivalents)*

System	Annual costs			Cost per 1,000 cwt.
	Ownership	Operating	Total	
	Dollars	*Dollars*	*Dollars*	*Dollars*
Hopper-body and sloping-bottom bins	4,272.18	1,520.33	5,792.51	73.55
Bulk-dumping and flat-bottom bins	3,650.17	1,394.33	5,044.50	64.06
Pallet box	4,537.41	1,632.34	6,169.75	78.35

TABLE 18.—*Labor requirements per load of 110 cwt., 3 potato handling systems*

System and activity	Crew size	Elapsed time	Total labor
	Workers	*Minutes*	*Man-hours*
HOPPER-BODY AND SLOPING-BOTTOM BIN SYSTEM			
Load and haul potatoes	1	85.95	1.432
Begins as driver starts trip to field with empty truck. Includes: Change from loaded truck to empty truck at packinghouse; load truck from mechanical harvester (44.0 elapsed min.); travel between packinghouse and harvester (round trip distance, 10 miles on road, ½ mile in field, average speed of 20 m.p.h. and 5 m.p.h. respectively). Ends as driver starts next trip to field with empty truck.			
Unload potatoes into bin	2	13.89	.463
Begins as driver starts to back loaded truck to position at bin loader. Includes: Position truck; set up to unload; unload potatoes; clean up; move bin loader; insert bin board; prepare to position next truck. Ends as driver starts to position next truck.			
Supply packing line	1	16.25	.271
Begins as potatoes start to flow from bin to conveyor or flume. Includes: Continuous attention and necessary movement of bin door to provide rate of flow needed by packing line; move between bins as required. Ends as one load is supplied to packing line (not necessarily actual cutoff of flow at end of load).			
Unavoidable delay:			
Unloading	2	.37	.012
Begins when unloading is stopped because cover boards on hopper-body conveyor are stuck or bin-loader conveyor belt is slipping. Ends when unloading is resumed.			
Line supply	1	.85	.014
Begins when packing line operation is interrupted for causes not the responsibility of the supply operation. Ends when packing line operation is resumed.			

TABLE 18.—*Labor requirements per load of 110 cwt., 3 potato handling systems*—Continued

System and activity	Crew size	Elapsed time	Total labor
BULK-DUMPING SYSTEM			
Load and haul potatoes	1	85.37	1.423
Begins as driver starts trip to field with empty truck. Includes: Loading truck (44.0 elapsed min.); travel between packinghouse and harvester (round trip distance, 10 miles on road, ½ mile in field, average speed of 20 m.p.h. and 5 m.p.h., respectively). Ends as driver starts to back truck into bin.			
Unload potatoes into bins	1	2.63	.044
Begins as driver starts to back loaded truck into bin. Includes: Back truck to unloading position; lower stopboard, release endgate, raise dump body, and move truck so as to empty all potatoes from the body; drive truck out of bin, lower dump body, raise stopboard and close endgate. Ends as driver starts to drive empty truck away.			
Supply packing line	2	16.25	.542
Begins as potatoes start to flow from bin to main flume. Includes: Continuous attention, move hose, and employ waterflow as necessary to flush potatoes from the bin at rate of flow needed by the packing line; move between bins as required; direct trucks in backing into bins; clean up, and perform miscellaneous duties in bin operation. Ends as one load is supplied to packing line (not necessarily actual cutoff of flow at end of load).			
Unavoidable delay	2	.85	.028
Begins when packing line operation is interrupted for causes not the responsibility of the supply operation. Ends when packing line operation is resumed.			
PALLET BOX SYSTEM			
Load and haul potatoes	1	85.95	1.432
Same as for hopper-body and sloping-bottom bin system.			
Unload potatoes and supply the dumper	1	12.37	.206
Begins as tractor forklift operator starts pickup of first filled box from truck. Includes: Handling six filled and empty boxes between truck, dumper, and temporary holding area in proportions as in a full day at assumed conditions (75.5 percent directly between truck and dumper; remainder into and out of temporary holding area).[1] Ends as last empty box to reload truck is released on truck. Tractor forklift travels at 3 m.p.h. and one box is moved at a time.			
Dump potatoes:			
Operator	1	8.92	.149
Helper	1	2.69	.045
Begins when workers start to move first box of load into dumper cradle. Includes: Manually pushing boxes into and out of the dumper, and raising and lowering dumper to empty potatoes from boxes to conveyor belt or flume. Ends as last box of load is emptied and pushed out of dumper cradle.			
Unavoidable delay	2	.85	.028
Begins when packing line operation is interrupted for causes not the responsibility of the supply operation. Ends when packing line operation is resumed.			
ALL SYSTEMS			
Set up	1	[2] 15.00	.041
Begins as truck driver starts preparatory activity for the day. Includes: Refueling, checking of truck, and minor adjustments; driving truck to field in advance of start of harvesting. Ends when truck is in position at mechanical harvester.			
Clean up	1	[2] 15.00	.041
Begins as truck driver starts end-of-day activity. Includes: Driving truck to packinghouse after harvesting ends; checking truck for repairs or adjustments needing attention of maintenance personnel. Ends when driver has disposed of truck for the day.			

[1] Elapsed time values included in weighted average, per load of six boxes are: (1) Handle filled and empty boxes directly between truck and dumper (approximately 150 feet travel for each box)—9.60 minutes; and (2) handle filled and empty boxes between truck and temporary holding area (approximately 175 feet travel for each box)—10.30 minutes, and between temporary holding area and dumper (approximately 175 feet travel for each box)—10.53 minutes.

[2] Provides 15.00 minutes per day for each of four drivers hauling 24.545 truckloads per day.

Release filled box (es) on dumper conveyor;
Unstack 2-high stack of boxes;
Make 2-high stack of empty boxes, when moving two boxes per trip;
Pick up empty box (es) from dumper conveyor;
Release empty box (es) on truck;
Unstack 2-high stack of empty boxes on truck.

In the formula, time values for handling two boxes per trip are in the first set of brackets and time values for equivalent product handled one box per trip are in the set of brackets after the minus sign.

Example:

Cycle: Filled boxes from truck to dumper and empty boxes from dumper to truck on return trip.

Time values:

S_2 = .85 min. (filled boxes on truck)
P_2 = .25 min. (filled boxes on truck)
CD = .03 min.
N = 4 occurrences.
R_2 = .34 min. (filled boxes on dumper conveyor — side approach)
DS_2 = .50 min. (filled boxes on dumper conveyor — side approach)
S_2 = .49 min. (empty boxes on dumper conveyor — side approach)
P_2 = .18 min. (empty boxes on dumper conveyor — side approach)
R_2 = .24 min. (empty boxes on truck)
DS_2 = .50 min. (empty boxes on truck)
P = .25 min. (filled box on truck)
R = .20 min. (filled box on dumper conveyor — side approach)
P = .15 min. (empty box on dumper conveyor — side approach)
R = .16 min. (empty box on truck)
V = .004167 min. per foot (3 miles per hour)

Substituting in formula:

S_2 = .85 + .49 = 1.34 min. (Sum of values for symbol)
P_2 = .25 + .18 = .43 min. (Sum of values for symbol)
R_2 = .34 + .24 = .58 min. (Sum of values for symbol)
DS_2 = .50 + .50 = 1.00 min. (Sum of values for symbol)
P = .25 + .15 = .40 min. (Sum of values for symbol)
R = .20 + .16 = .36 min. (Sum of values for symbol)

The answer obtained, for the specified cycle, indicates that if round trip travel distance in the cycle is less than 410 feet, moving one box per trip will require less time for the forklift operator and equipment than moving two boxes per trip, for a given amount of product.

Table 19 shows the time for the break-even distance for moving one and two boxes per trip and the times for shorter and longer distances.

TABLE 19.—*Time required to move 1 and 2 pallet boxes per trip by forklift truck, by length of trip*

Trip length and activity in cycle	2 boxes per trip	1 box per trip
	Minutes	*Minutes*
Break-even distance—410-ft. round trip:		
Loading and unloading[1]	3.46	1.76
Travel:		
410 ft. at 0.004167 min. per ft.	1.71	----
410 ft. x 2 trips at 0.004167 min. per ft.	----	3.42
Total for cycle	5.17	5.18
Shorter distance—200-ft. round trip:		
Loading and unloading[1]	3.46	1.76
Travel:		
200 ft. at 0.004167 min. per ft.	.83	----
200 ft. x 2 trips at 0.004167 min. per ft.	----	1.67
Total for cycle	4.29	3.43
Longer distance—600 ft. round trip:		
Loading and unloading[1]	3.46	1.76
Travel:		
600 ft. at 0.004167 min. per ft.	2.50	----
600 ft. x 2 trips at 0.004167 min. per ft.	----	5.00
Total for cycle	5.96	6.76

[1] Refer to formula solution.

The following time values are provided so that the formula may be used for other cycles:

Activity	Time per occurrence — Two boxes per trip *Minutes*	Time per occurrence — One box per trip *Minutes*
Release filled box (es) on ground	0.28	0.19
Pick up filled box (es) from ground	.22	.17
Release empty box (es) on ground	.16	.16
Pick up empty box (es) from ground	.18	.13

$$\frac{[1.34. + .43 + (.03 \times 4) + .58 + 1.00] - [(2 \times .40) + (.03 \times 4 \times 2) + (2 \times .36)]}{.004167}$$

$$= \frac{3.47 - 1.76}{.004167} = \frac{1.71}{.004167} = 410 \text{ feet}$$

APPENDIX B.—SYSTEMS FOR BULK HANDLING IN DADE COUNTY, FLORIDA

During virtually all of the time when the research was underway in the Hastings-Elkton area, mechanical harvesters and related bulk-handling systems were not accepted in the Dade County area. That situation began to change during the 1963 season, and by the next season, the majority of growers and packers had converted to use of mechanical harvesters and bulk handling. In most cases, however, the bulk handling involved only the adoption of hopper-body trucks and a means, either flume or belt conveyor, at the packinghouse for moving the potatoes directly from hopper-body truck to packing line; facilities for temporarily holding potatoes usually were not included.

In exceptional cases, however, means for temporarily holding potatoes were provided. Two systems are discussed briefly to assist in interpreting these commercial installations in respect to the research results.

Hopper-Body and Drive-In Bin System

Description of System

Hopper-body trucks, as described earlier, are used. Potatoes are unloaded into bins by means of a movable conveyor unit, generally called a bin loader, which is moved to the desired point in the bin for piling the potatoes (fig. 18). The conveyor boom may be positioned for different heights to pile potatoes at least 14 feet deep, and horizontally so as to distribute potatoes over the width of a bin, usually 14 to 16 feet. Length of these bins may vary over a considerable range. Some which were observed were about 100 feet long and 14 feet wide, and held about 7,500 cwt. when potatoes were piled 14 feet deep.

For moving potatoes out to the packing line, a 24-inch belt conveyor was built into the bottom of each bin. Wooden cover boards were used in the same manner as in a hopper-body truck; a false floor of wooden boards sloped about 30 degrees from each sidewall to the edge of the conveyor (fig. 19). The boards of the floor on each side of the conveyor were also removable to provide clear width for the wheels when trucks were backing into the bin for unloading.

The commercial installation observed in Dade County was basically similar to one of the systems used in the Red River Valley area of Minnesota. A research report from that area designates the system as "Above-ground multiple-door storage—cleated belt bin loader" (*9*).

Comparison With Hastings-Elkton Area Research

Limited studies were conducted to compare the given commercial system and those involved in the research effort.

A summary of information bearing upon comparative relationships follows:

1. *Facilities.*—Those observed in the Homestead area comprised four bins with a total capacity of about 25,000 packed cwt. Providing this capacity requires a major investment. Moreover, the need for large capacity for temporarily holding potatoes, in Florida, requires justification by the packer on the basis of particular circumstances and plan. It cannot be taken for granted. For moving potatoes out of

BN–26712

FIGURE 18.—Drive-in bin structure, front view. Each door opens into a bin approximately 100 feet long. A bin loader is in doorway of bin at right.

the bins, a belt conveyor in the bin floor as observed, may cost more than flumes. "When considering equipment costs alone, conveyors will probably be cheaper than flumes up to about 100 feet, because the cost of sump, pump, and allied equipment would be about the same as for that length of suitable conveyor. Beyond that distance the cost of flume and pipe at about $5 a foot has a distinct advantage over conveyor cost of about $20 a foot" (*2*).

2. *Time.*—The elapsed time per load for receiving potatoes into bins is about the same as given for the hopper-body and sloping-bottom bin system, for equivalent equipment and load size.

3. *Crew.*—The crew for receiving potatoes into bins and for moving them out of bins is about the same size as in the hopper-body and sloping-bottom bin system.

4. *Equipment.*—Cost for equipment is about the same as for the hopper-body and sloping-bottom bin system.

5. *Injury to potatoes.*—Sampling and statistical analysis of data on mechanical injury to potatoes showed no significant difference between the observed system and a field box system generally used in the area.

Pallet Box System (Boxes Filled at Packinghouse)

The commercial pallet box installation observed in the Homestead area was basically similar to a pallet box system covered in research in the Red River Valley area (*9*).

Description of System

Potatoes are hauled to the packinghouse in hopper-body trucks, which are the same as those already mentioned in connection with other bulk-handling systems. Potatoes are unloaded from the hopper body by a box-tipping unit (fig. 20) into 2,000-pound-capacity pallet boxes. Filled boxes are moved with forklift equipment to a temporary holding area and stacked. They are moved from this area to the box dumper with forklift equipment when it is desired to put them through the packing line. Boxes are manually moved into and out of the box dumper on gravity roller conveyors.

Comparison With Hastings-Elkton Area Research

Studies were conducted on a limited basis to provide comparison of this commercial system with a pallet box system included in the research in the Hastings, Fla., area and one included in research at the Red River Valley Potato Research Center.

The following relationships were indicated by these studies.

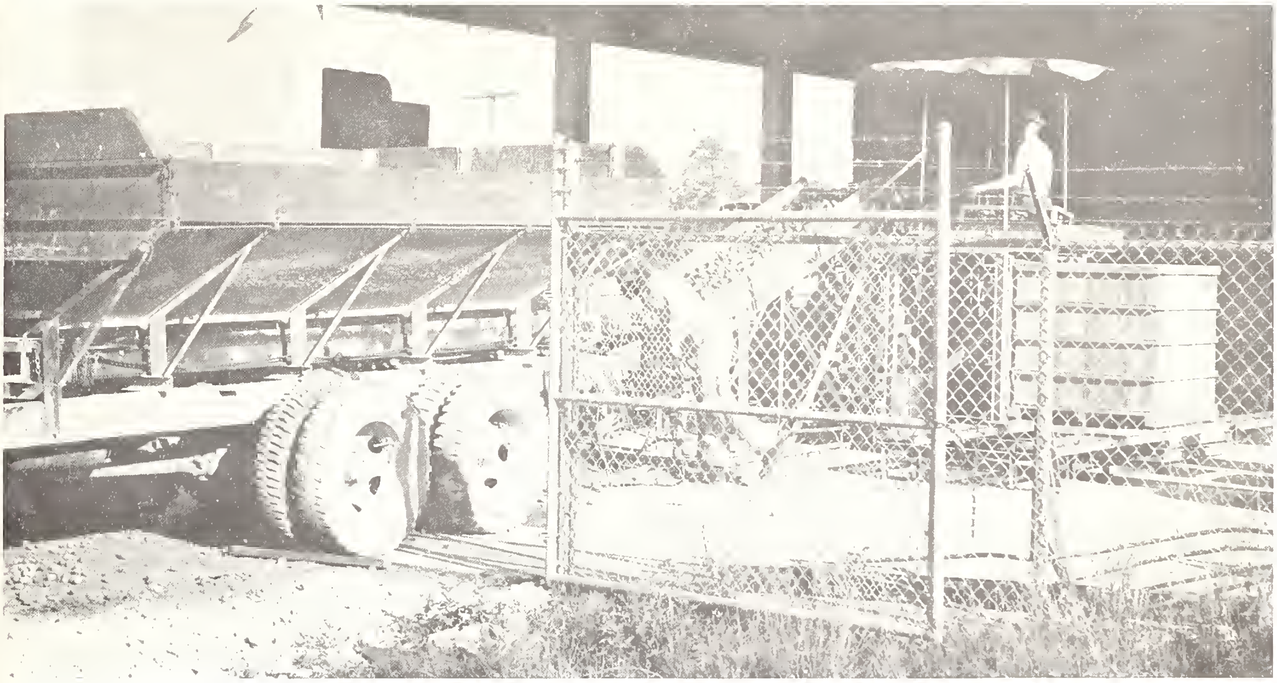
1. *Injury to potatoes.*—Sampling and statistical analysis of results showed no significant difference in mechanical injury to potatoes between the observed system and a field box system generally used in the area that was displaced where bulk handling had been adopted.

2. *Time.*—Elapsed time requirements for hauling and receiving potatoes are about the same for the observed system, the system in Red River Valley research, and that in Florida research, given similar box capacity, truck loads, and forklift handling.

3. *Crew.*—For the system observed at Homestead, Fla., or that covered in Red River Valley

BN-26713

FIGURE 19.—At right, bin loader extends into doorway. Endboard of bin is in place. At left, underfloor conveyor is covered and boards of sloping false floor of bin are lying flat so that bin filler and truck can enter bin to start filling.



BN–26714

FIGURE 20.—Box-tipper unit in right background with box in down position. Potatoes are flowing to box in other cradle, not visible, on opposite side of unit.

research, a crew of three to five workers is needed for receiving the potatoes at the packinghouse. Unloading potatoes from hopper-body trucks into pallet boxes, a part of each of these systems, is largely the basis for this manpower need. One worker operates the hopper body, one the box tipper, one the forklift equipment, and one or two more are needed to manually move pallet boxes in and out of the box tipper on gravity roller conveyors.

For the system covered by the Hastings, Fla., area research, only one worker, operating the forklift equipment, receives potatoes, which are already in pallet boxes on arrival at the packinghouse. It is assumed that there would be no differences, among the respective systems, in crew used for dumping the potatoes from boxes to packing line.

4. *Equipment.*—Additional equipment is required for a pallet box system in which the potatoes are not loaded directly into the boxes from a mechanical harvester. Both the system observed at Homestead and that covered in the Red River Valley research are in that category. A box tipper with belt conveyors for receiving the potatoes and roller conveyors on which boxes are moved into and out of the tipper is the major unit. Equipment cost for a box-tipping unit may range from $2,000 to $5,000.

Hopper-body trucks are needed to move potatoes from the harvester to the box tipper. Flatbed trucks are used between harvester and packinghouse where potatoes are placed in boxes directly from the mechanical harvester as in the system covered in the Hastings research. The entire value of hopper-body trucks must be allocated to a firm's potato operations. Versatility of flat-bed trucks permits allocation of part of their value to other operations, which tends to lower equipment cost per unit of product.

Other equipment required is essentially the same: pallet boxes, forklift equipment, and box dumper.

5. *Facilities.*—Additional space may be provided under roof for the box tipper and activities incident to its use in a system like that observed at Homestead. Otherwise, the facility requirement can be essentially the same as for the system covered in the Hastings research.

For an open, pole-type building with construction similar to that in figure 16, the estimated cost per square foot of space is $1.82.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1966—0 222-690