Marketing Research Report No. 916

POWERED BULK SCOOPING IN POTATO STORAGES

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

This report is one of several on the results of research conducted to minimize marketing costs for potatoes by developing modern and efficient methods, equipment, operating procedures, and facilities for preparing potatoes for market.

This study was conducted under the general supervision of Joseph F. Herrick, Jr., investigations leader, and Lewis A. Schaper, agricultural engineer, Handling and Facilities Research Branch, Transportation and Facilities Research Division, Agricultural Research Service.

The work was performed at the Red River Valley Potato Research Center, East Grand Forks, Minn.

The author wishes especially to thank Sheldon Preston of Preston Implement, East Grand Forks, Minn., for providing a bulk scoop for testing the experimental handling method.

The assistance of equipment suppliers who provided information on the various items of equipment is gratefully acknowledged.

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Washington, D.C. Issued March 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402—Price 25 cents

POWERED BULK SCOOPING IN POTATO STORAGES

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SUMMARY

Powered bulk scooping is the handling of potatoes with a self-propelled scoop from bulk piles to the packing or processing lines. Although industry has used this method to remove potatoes from storage for some time, little effort has been made to evaluate the factors affecting efficiency.

Volume and distances were determined mathematically to obtain the most desirable sizes of bins for particular storage sizes and types in this study. The location of the receiving hopper and its effect on haul distance were used as the determining factors. A graph and a table for selecting combinations of bin size, storage size, storage type, and receiving hopper locations are given.

Time study techniques were used to obtain elemental data concerning the performance of a typical bulk scoop. These data were synthesized to represent the output of the powered bulk scoop using three modes of transporting the potatoes to the grading line. The modes of transport were (1) the powered bulk scoop itself, (2) a central conveyor, and (3) a fully movable hopper. Curves illustrating the output rate for each method are given.

Data for determining annual costs for any combination of output rate and haul distance are given. Several combinations are developed and show that in all instances the fully movable hopper method is lower in cost than the hopper on a conveyor. The permanent hopper method is lower in cost than the fully movable hopper method only until a second bulk scoop is required.

INTRODUCTION

Powered bulk scooping of potatoes is a method of moving potatoes from bulk piles to packing or processing lines. Although earlier uses of this method are known, rapid acceptance did not occur in the potato industry until the 1963-64 shipping season. It is now a principal method of removing potatoes from storage.

The bulk-scooping method offers several advantages, but primarily its use results in lower costs and reduced labor requirements.[1]

Bulk scooping can be used successfully with all types of stored potatoes—seed, processing, and table stock. Potatoes can be delivered directly to either a washline or a dry-grading line.

The type of powered bulk scoop most commonly used is a highly maneuverable, four-wheel drive unit with an integral hydraulic system (fig. 1). It is basically a small agricultural-industrial loader and requires only minor modifications in its standard bucket for use with bulk potatoes. Figure 2 illustrates a typical potato bucket. The bucket has rounded edges and backrail to decrease damage to the potatoes during handling. Capacities of buckets range from 500 to 1,200 pounds of bulk potatoes.

A 15 to 30 horsepower (hp.) engine powers the

[1] Orr, P. H. handling potatoes from storage to packing line—methods and costs. U.S. Dept. Agr. Market. Res. Rpt. No. 890, 50 pp., illus. 1971. Hunter, J. H., Wilson, J. B., and Thibodeau, J. C. a fork-lift mounted scoop for bulk potatoes. Maine Agr. Expt. Sta. Misc. Pub. No. 662, 12 pp, illus. Nov. 1964.

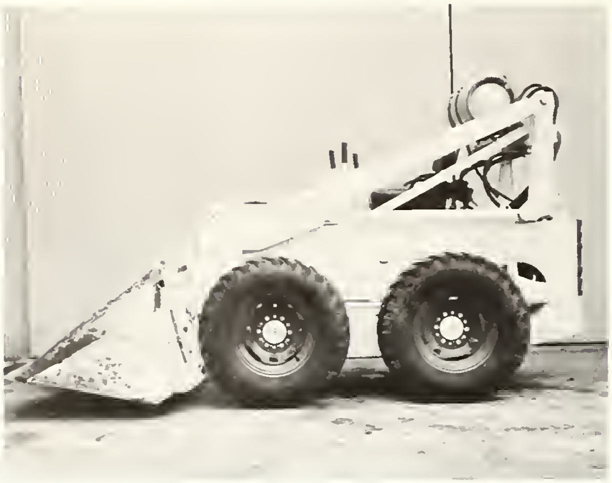


FIGURE 1.—A typical powered bulk scoop used in handling bulk potatoes.

FIGURE 2.—Typical potato bucket with rounded edges and a backrail.

four-wheel drive mechanism and the hydraulic system. Speed can be varied in either forward or reverse up to about 7 miles per hour. Steering is done with hand levers while boom and bucket are controlled by either foot pedals or hand levers. Figure 3 illustrates a typical set of controls on a powered bulk scoop.

The bucket is loaded by directing or forcing it into the face of the bulk potato pile at the floor and then raising the bucket off the floor. This load is then moved to the receiving hopper and dumped. The bulk scoop is then returnd empty to the bulk pile for another bucket full of potatoes. During the return trip to the pile, the bucket is kept on the floor to gather up any loose potatoes that may have been dropped from the loaded bucket. This cycle is repeated as required to maintain a supply of potatoes at the receiving hopper.

FIGURE 3.—Typical controls on a powered bulk scoop.

PURPOSE AND METHOD OF STUDY

Generally, the powered bulk scoop method of handling has been simply a replacement for previously used methods of supplying the grading line. Little or no earlier attempt was made to evaluate the effect of such factors as storage size, bin size, and receiving hopper location on the efficiency of bulk scoops. Combinations of these factors, together with capacities and speeds of scoops, were analyzed for the study reported here. Performance characteristics of methods, equipment, and layouts were identified. Annual costs for the various methods were determined.

Volumes and distances were determined mathematically to obtain the sizes of bins desirable for particular storage sizes and types. The location of the receiving hopper and its effect on haul distance were used as determining factors.

Time study techniques were used to obtain elemental performance data for a typical powered bulk scoop. These data were then synthesized to represent the performance of a scoop or several scoops within each selected method. The methods selected differed mainly in the mode of transporting the potatoes from the pile to the grading line.

Ownership, operating, and labor costs were developed for each item of equipment. These values were then further combined and presented as annual costs for each method over a wide range of output rates and hauling distances.

The information developed from these evaluations and studies are shown as (1) data for selecting bin size, storage size, and receiving hopper location combinations, (2) curves illustrating the output of a typical powered bulk scoop over a range of haul distances, and (3) annual cost data for comparing the methods in various handling situations.

VOLUMES AND DISTANCES IN CERTAIN STORAGE CONFIGURATIONS

Two arrangements of bins commonly found in above-ground storages were considered in determining combinations of storage size, bin size, and receiving hopper locations. The cross-alley layout has bins on each side and at right angles to the center alleyway. On the other hand, the end-alley layout has bins on only one side and at right angles to the alleyway. The two types of layouts are illustrated in figure 4.

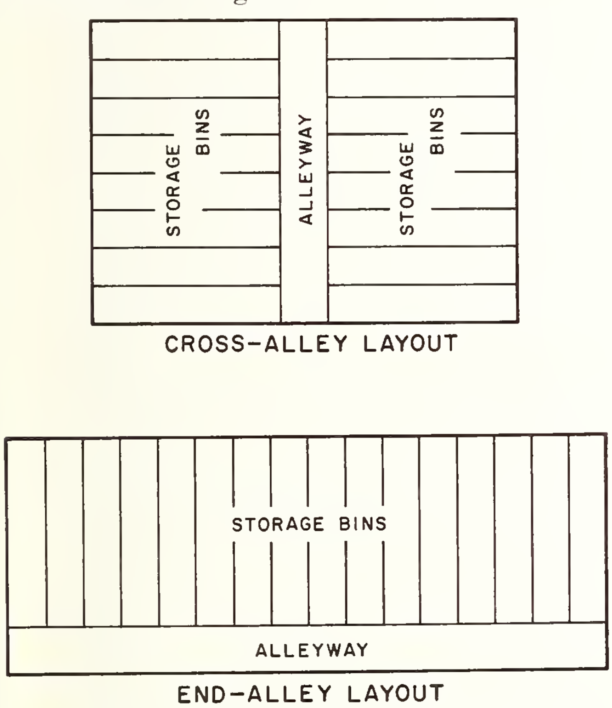


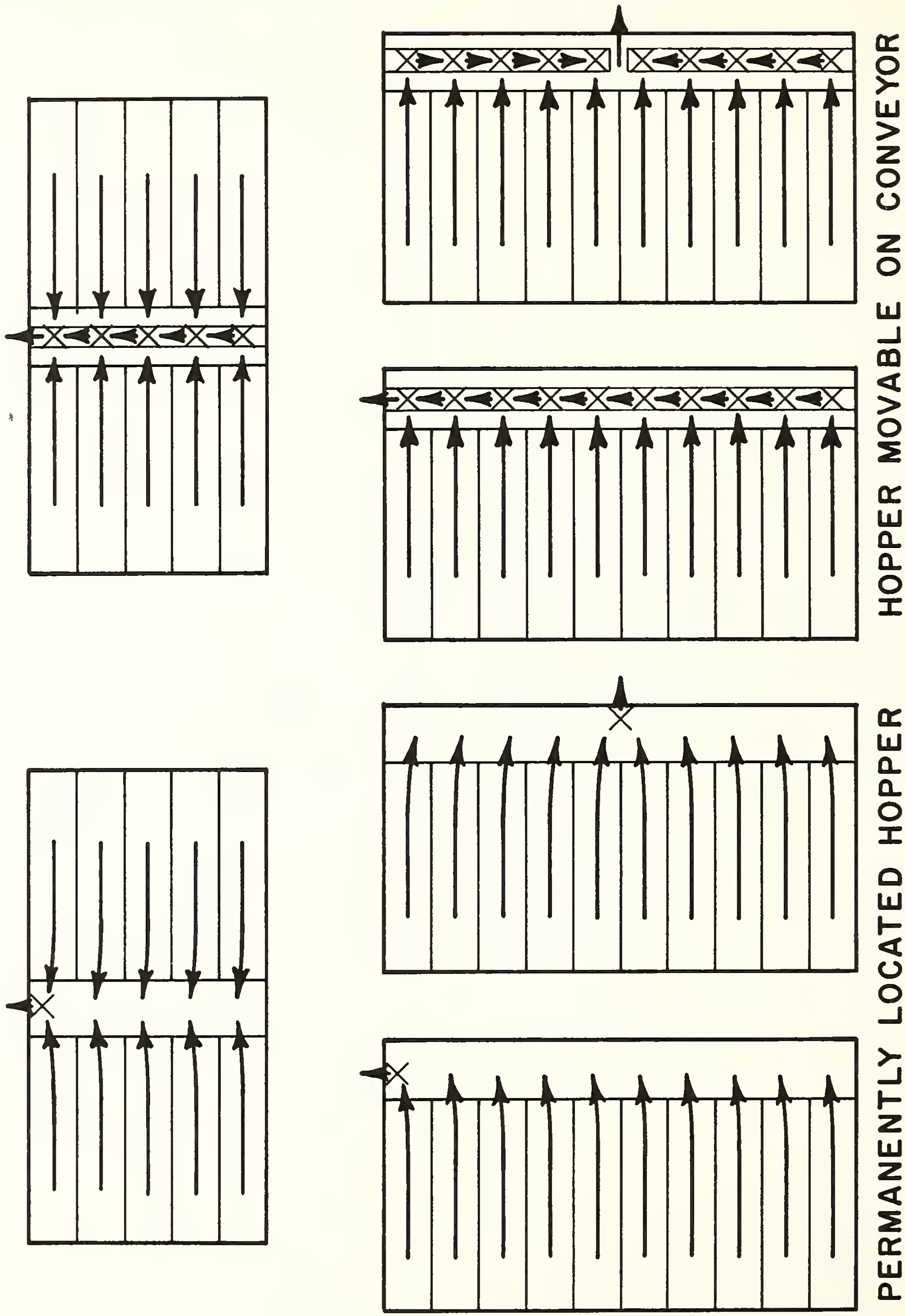
FIGURE 4.—Layouts of cross-alley and end-alley storages.

Location of the Receiving Hopper

The basis for the evaluation of storage and bin sizes in these storage layouts was the average haul distance involved in transferring the stored potatoes from the piles to the receiving hopper. Since the location of the stored potatoes is rigidly established by the layout, the location of the receiving hopper becomes important. Three applications of the receiving hopper selected were (1) permanently located (stationary), (2) movable on a conveyor, and (3) fully movable. Figure 5 illustrates the most practical possibilities for receiving hopper locations within the three selected applications. These locations are shown by the "X's" in figure 5.

The stationary location of the receiving hopper could possibly be anywhere in the alleyway, but generally would be as shown at one end of the alleyway in the cross-alley storage and either at one end or at the center of the end-alley storage. The powered bulk scoop would transport the potatoes from the bins to this hopper at the grading line.

When the receiving hopper is made movable on a central conveyor, it may be located anywhere along the length of the conveyor, but generally will be placed as shown—at the end of each individual bin in both types of storage. The full length conveyor moves the potatoes from this hopper to the grading line after the powered bulk scoop has transported them from the bin to the hopper.


HOPPER MOVABLE ON CONVEYOR
PERMANENTLY LOCATED HOPPER

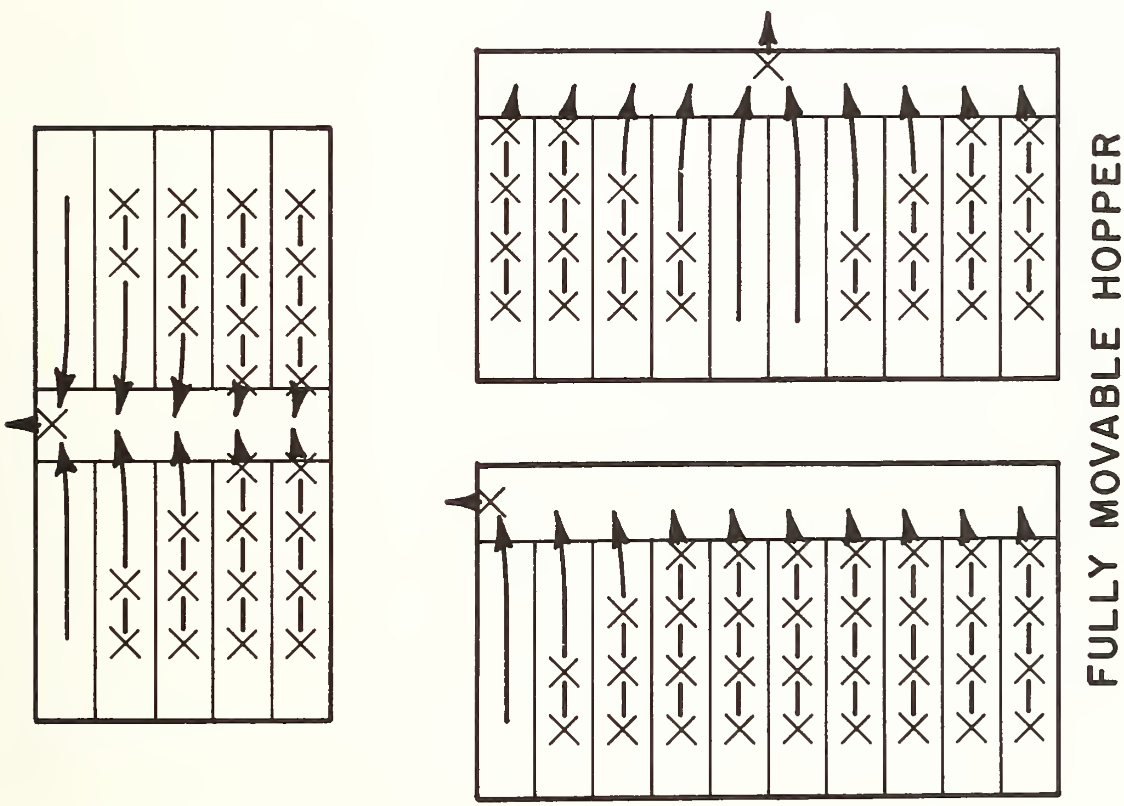


FIGURE 5.—Selected applications and locations (X) of the receiving hopper in layouts of cross-alley and end-alley storages.

Fully movable hoppers would be located as shown—near the potato pile in the bin during loading and at the grading line during unloading. The powered bulk scoop would be used to load the hopper and then transfer it to the grading line. When the distance from the bin to the grading line is very short, the scoop can be used to transport the potatoes directly to the grading line.

Criteria for Sizes of Storage and Bin

Before haul distances from the bins to the selected receiving hopper locations were evaluated, a usable range of sizes of bin and storage was established. Individual bin and total storage capacities included those which may possibly come into use as well as those that are now representative of the industry. Generally, this involved increasing the present sizes of bins and storages.

Capacities of bins selected were 5,000, 6,000, 7,500, 10,000, 12,000, and 15,000 hundredweight (cwt.). These capacities, and ultimately the total storage capacities, were based on these criteria: (1) The inside width of each bin is 20 feet; (2) the depth of the potato pile in each bin is 14.3 feet; and (3) the specific weight of bulk potatoes is 42 pounds per cubic foot. With these criteria, the volume of potatoes per foot of bin length is 120 cwt. and the required interior bin lengths are (1) 5,000 cwt.—41 feet 8 inches, (2) 6,000 cwt.—50 feet, (3) 7,500 cwt.—62 feet 6 inches, (4) 10,000 cwt.—83 feet 4 inches, (5) 12,000 cwt.—100 feet, and (6) 15,000 cwt.—125 feet. Bins having these dimensions were included in cross-alley and end-alley floor plans along a 24-foot-wide alleyway. Walls of the bins require 1 foot of space.

From these layouts, average haul distances for transporting the potatoes from the bulk piles to the receiving hopper were calculated for each of the three locations of the hopper. Sample illustrations of "average haul distances" are shown in figure 6. The average haul distance refers only to the travel of the powered bulk scoop when the hopper is being *filled* within each method. It *does not* include transferring filled hoppers or transporting the potatoes on conveyors. The resulting values are given in figure 7 and table 1.

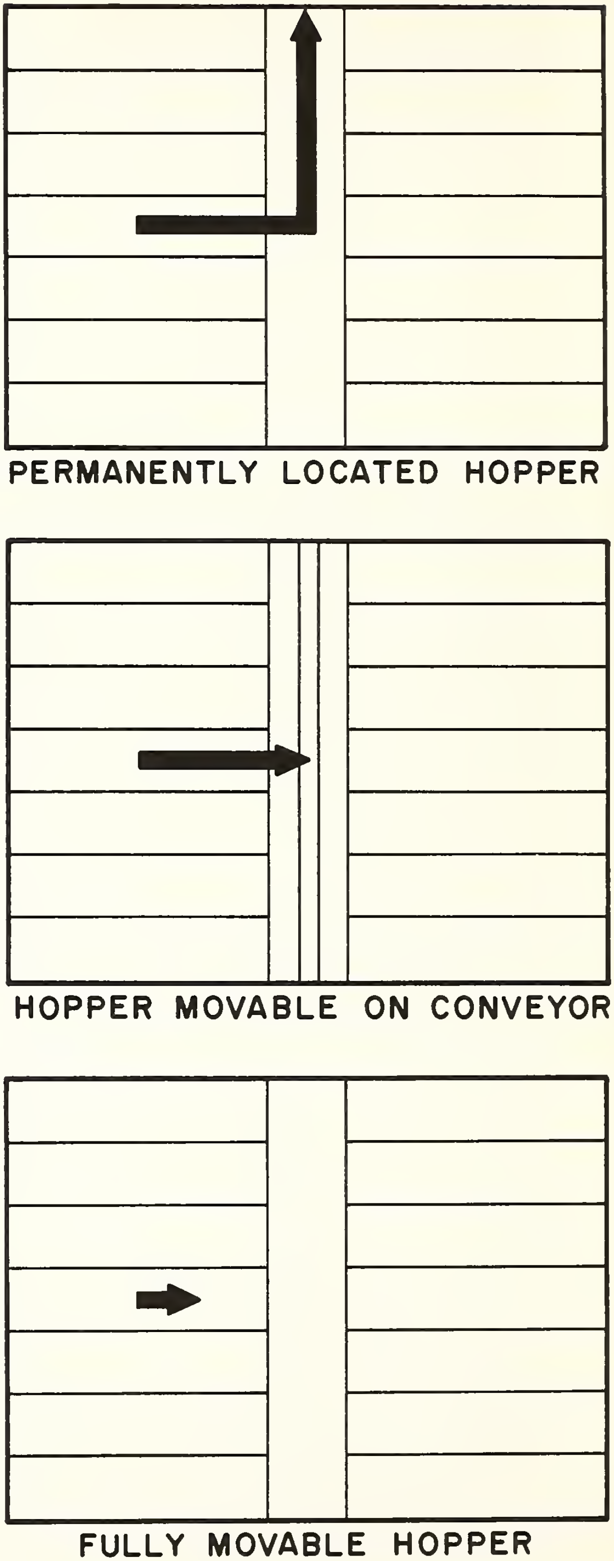


FIGURE 6.—Sample illustrations of average haul distances in storage layouts.

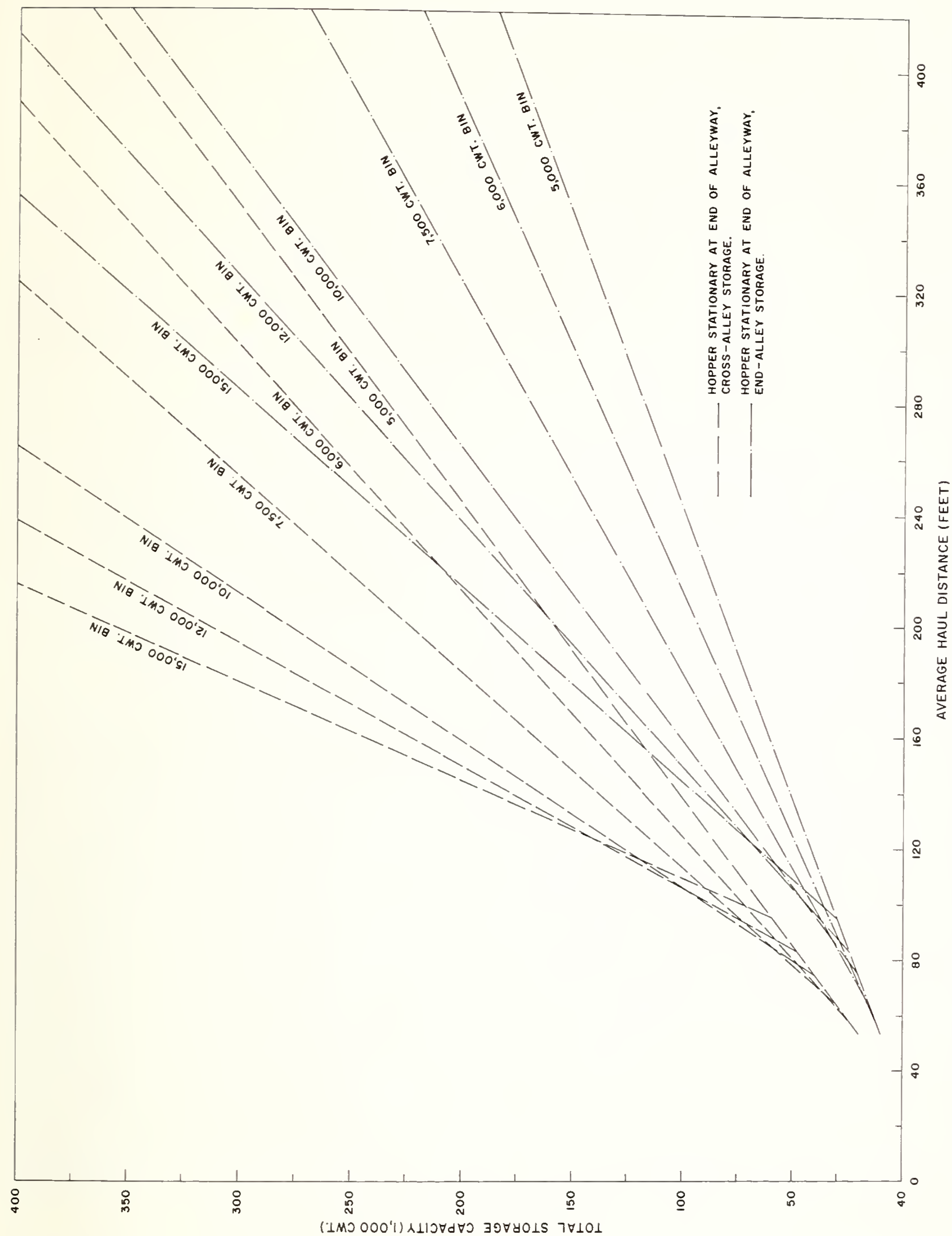


FIGURE 7.—Average haul distances of the bulk scoop for certain combinations of size and type of storage and size of bin when moving potatoes to a hopper at a *stationary* location.

TABLE 1.—*Average haul distances of the bulk scoop for selected sizes of bins when moving potatoes to movable hoppers in all sizes of cross-alley and end-alley storages*

Size of bin (cwt.)	Average haul distances	
	Hopper movable on a conveyor	Fully movable hopper
	Feet	*Feet*
5,000	33	25
6,000	37	25
7,500	43	25
10,000	54	25
12,000	62	25
15,000	74	25

Figure 8 is an enlargement of part of figure 7. This figure shows more clearly the distances involved in the smaller storages.

Some Relationships Within the Data

Location of Hopper

Figure 7 shows curves representing the condition "hopper *stationary* at end of alleyway" for the six sizes of bins in the end-alley layout and the cross-alley layout. The average haul distance increases as the total storage capacity increases for a given bin size. This occurs because the receiving hopper is located according to the *total storage* rather than to a bin within the storage or to the potato pile within a bin. Both size of bin and type of layout affect the average haul distance by influencing the dimensions of the layout.

The average haul distances for the condition "hopper *movable* on a conveyor" are shown in table 1. The average haul distance for the bulk scoop does not change as total storage capacity changes; it changes only when the bin size changes. This occurs because the receiving hopper is located according to *each bin* rather than to the storage itself or to the potato pile within the bin. The type of layout—either cross-alley or end-alley—does not affect the average haul distance since the hopper is located in the alleyway at the end of each bin.

Calculations for the average haul distance for the "hopper *fully movable*" condition yield only a single value (table 1), indicating that bin size, storage capacity, and type of layout have no effect on the average haul distance for the bulk scoop with this method. The lack of effect on the average haul distance is because the receiving hopper is located according to the *potato pile* within the bin rather than to the bin itself or to the total storage.

Type of Layout

The cross-alley storage provides an identical amount of storage on each side of the alleyway. The end-alley storage provides for storage on only one side of the alleyway. Thus, the set of curves (figs. 7 and 8) for the cross-alley storages shows double the total storage capacity of those for the end-alley storages at the same average haul distance.

When comparing the relationships on the graph for a given size of storage and bin, the end-alley storage does not show twice the average haul distance of the cross-alley. It is the *difference* in average haul distance which increases. As storage capacity doubles, the difference in average haul distance between the cross-alley and the end-alley set of curves doubles, because each additional pair of bins adds 42 feet of alleyway to the end-alley storage and only 21 feet to the cross-alley.

The slanting parallel lines in figure 7 are associated with: (1) 5,000 cwt. cross-alley—10,000 cwt. end-alley, (2) 6,000 cwt. cross-alley—12,000 cwt. end-alley, and (3) 7,500 cwt. cross-alley—15,000 cwt. end-alley. These lines indicate a constant difference in average haul distance as total storage capacity changes. Since these lines represent pairs of small and large bins, with the larger twice the capacity of the smaller, the resulting difference in average haul distance illustrates the effect of alleyway location; that is, cross-alley versus end-alley. The situation is analogous to dividing the larger bin into two halves by moving the alleyway from the end of the larger (end-alley) to separate the smaller ones (cross-alley). Storage capacity changes equally in both layouts for each change in the length of alleyway. The constant difference in average haul distance as shown in figure 7 for these particular pairs of lines is one-half the difference in bin length for the paired bins involved.

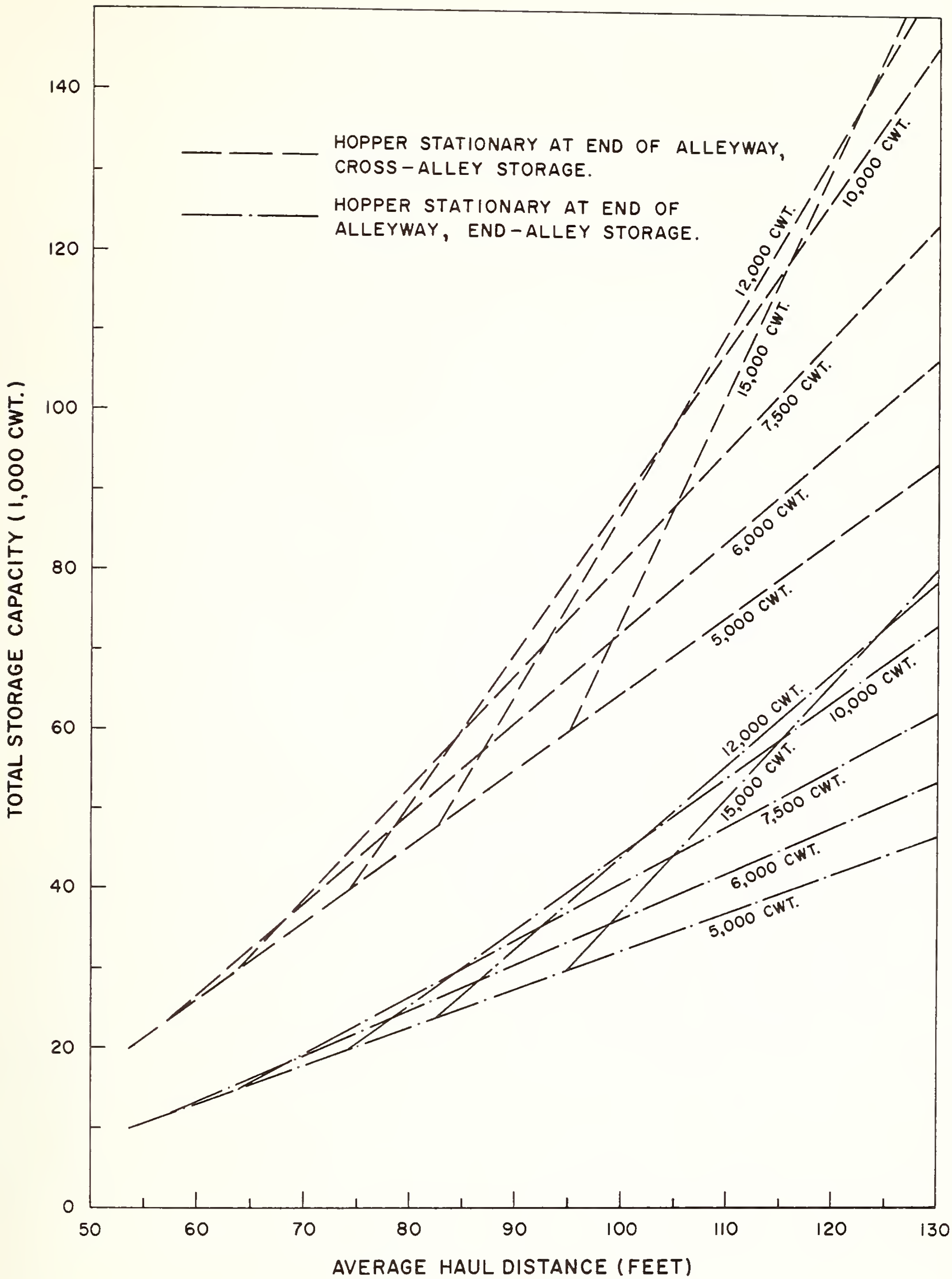


FIGURE 8.—Average haul distances of the bulk scoop for certain combinations of size and type of storage and size of bin when moving potatoes to a hopper at a *stationary* location. (Enlargement of part of figure 7.)

Size of Bin

The relationship between the individual curves (fig. 7) for each size of bin within each set of curves for stationary hopper location is one of constant *rate* of change in average haul distance as storage capacity changes. Since each bin has the same width regardless of its capacity and the difference in capacity of any two sizes of bins is constant, the rate of change would be expected to be constant. The fan-shaped sets of lines result from this relationship.

Use of the Data

The curves presented in figure 7 and its companion graph, figure 8, and the values listed in table 1 are generally useful for evaluating present storage layouts, planning new storages, planning a handling equipment layout or relayout, and determining material-handling requirements in present or proposed storages.

When evaluating present storage layouts for handling characteristics, the storage capacity, storage layout, bin size, and receiving hopper location are already established. With these data, average haul distance can be determined from figure 7 or table 1. Comparisons with other possible locations of the receiving hopper are easily made. Equipment requirements to provide a desired level of handling performance from the storage can be estimated. Possible performance levels of present equipment can also be estimated for the present layout.

Efficiency in material handling should be a prime criterion in new storage design. When used for planning new storages, the data can be used to determine the most efficient combinations of layout, bin size, and receiving point for a desired storage capacity. If other design criteria require that the layout be a specific type with the receiving hopper located or used in a given manner, then the graph can provide information for selecting the proper bin size for use with that set of conditions.

When used for planning a handling layout or relayout, the data can be used to determine the best arrangement of the equipment on the basis of average haul distance. The primary consideration is determining the location of the receiving point, but bin size and layout also are involved. For example, the bin size which gives the shortest average haul distance to the "hopper movable on a conveyor" will also require the longest conveyor belt for a given storage capacity. The end-alley storage will require a much longer conveyor than the cross-alley for the same storage capacity. Thus, a compromise must be arrived at in the design of a handling layout. These data can be helpful in effecting this compromise.

FACTORS AFFECTING OUTPUT OF A POWERED BULK SCOOP

The basic factors that affect the output of a powered bulk scoop are (1) speed, (2) bucket capacity, (3) haul distance, (4) maneuvers required, and (5) operator's performance. These factors were evaluated for a typical powered bulk scoop.

Measurements Used

Speed was determined by a stop-watch time study over a measured distance with the scoop loaded and then with the scoop empty. The elements "travel empty" and "travel full" were described on the basis of a straight line motion of the loader; a travel speed was calculated for each case.

Bucket capacity was determined by averaging the output of 60 bucketfuls of potatoes from a powered bulk scoop operating in a commercial handling situation.

Haul distance is unique to each storage layout. Several feet of haul distance are taken up by elements representing maneuvers for turning, loading, and emptying the bulk scoop; the rest is straight-line travel distance. Scoop travel distance was determined by combining the changing lengths of the straight travel elements with the premeasured unchanging lengths required for the various maneuver elements.

The required maneuvers depend largely on storage layout and location of the receiving hopper. Basic maneuvers required when handling potatoes from storage were determined, the distance required was measured, and the elemental time for performance was established. Such elements as "approach pile—load scoop—leave pile" and "approach hopper—empty scoop—leave hopper" are typical. These and other elements are described in the appendix.

The performance of the operator affects the time required to perform the elements of work with the bulk scoop. This effect was accounted for by the time-study technique of rating the operator's performance. Additional time requirements for fatigue and personal time for the operator were included when arriving at standard times for performing the various elements.

Once these elements of work were identified and measured, the data could be used to evaluate any storage handling situation involving a typical powered bulk scoop. This evaluation was done by synthesis—combining the elemental data into a value which represents the performance of the scoop in the handling situation under study.

Typical Bulk Scoop

A powered bulk scoop typical of that used in commercial potato handling operations was evaluated. The scoop, a 24.5-hp. propane-fueled, four-wheel drive loader (fig. 1), could move either forward or reverse at various speeds. Steering was done with hand levers operating clutch mechanisms with output to the drive wheels. Steering, speed, and bucket controls are shown in figure 3. Bucket capacity of the powered scoop was set at 7.42 cwt. The type of bucket and its modification is shown in figure 2.

Output Rate of Bulk Scoop Versus Haul Distance

The results from the elemental timings were synthesized to represent a powered bulk scooping operation in an actual storage situation. The output rate of the system versus haul distance was plotted.

The elements included in the storage handling situation were (1) load scoop at pile, (2) unload scoop at hopper, (3) make a 90° turn into and out of bin for each scoopful, and (4) travel empty and full the required distances. The time values for these elements, including personal and fatigue allowance, are given in the appendix.

When more than one scoop is operating in a storage, interference occurs and the output per scoop decreases. To represent this decrease, the output curve of multiple scoop operations was adjusted downward on this basis: 5 percent per additional scoop at 100-foot haul distance, 4 percent at 200, 3 percent at 300, 2 percent at 400, 1 percent at 500, and zero at 600. The bucket capacity was 7.42 cwt. for all scoops considered.

Figure 9 was plotted from the assembled data. For a given haul distance, part of which is used for the loading, turning, and unloading cycle, the output rate of the bulk scoop or scoops in hundredweight per hour is shown.

Given a required input at the grading line, the number of scoops needed to supply it may be found. The haul distance at which an additional scoop will be required is also available.

The efficiency or utilization of the scoop-handling system may be determined with the aid of the graph. For example, if the rate of supply to the grading line cannot exceed a certain value and that value is lower than the bulk-scoop system can provide, the utilization of the scoop or scoops is less than maximum. The most serious condition is at a point where the needs of the packing line exceed slightly the capability of one scoop and a second scoop must be used. At this point the second scoop is barely working or if the workload is balanced between the two scoops they are both working at just above 50 percent capacity. Supply rates should be selected that utilize the scoop or scoops to the greatest advantage over the entire range of storage distances.

The graph also illustrates how rapidly bulk scoop performance, in output rate, drops off as haul distance increases. The high rate of output is available only at short distances. At these distances, the scoop is essentially loading, unloading, and maneuvering, not traveling. The need is for a method of bulk scooping which maximizes the amount of short hauls and minimizes extra travel distances.

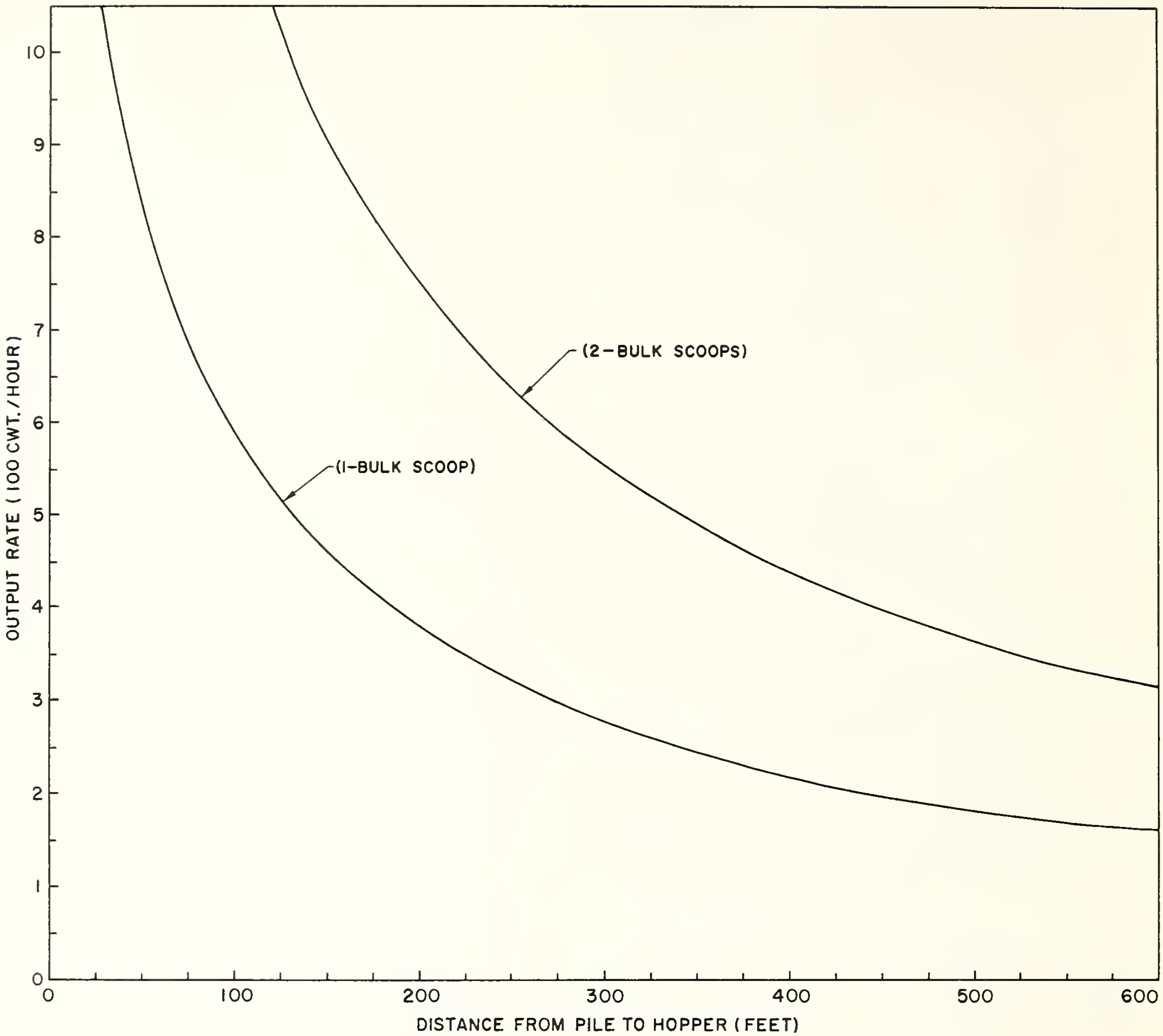


Figure 9.—Output rate versus haul distance in bulk scooping.

Description of Operations and Equipment

Stationary Hopper at Grading Line

Figure 10 shows a receiving hopper, commonly used with powered bulk scooping, that is permanently located at the grading line. The capacity of the unit is about 30 cwt. The hopper converts the intermittent flow provided by the bulk scoop to the uniform flow needed at the grading line. It does this conversion through the use of an inverted "V"-panel over the draper chain conveyor in the hopper bottom. The conveyor is powered by an electric motor through a variable speed drive, making the hopper self-contained.

The other unit of equipment in the system is the bulk scoop. One or more may be used with the stationary hopper.

In operation, the bulk scoop or scoops load and transport the potatoes from the bins to the hopper. The scoop travels the full distance from pile to hopper with each bucketful of potatoes, whether the distance is short or long. The operator's primary concern is to keep the hopper properly supplied with potatoes.

FIGURE 10.—Typical receiving hopper for a stationary location.

Movable Hopper on a Conveyor

This handling system requires more equipment than the stationary hopper system. Figure 11 shows a typical setup of the equipment in the alleyway of a potato storage. The storage itself has a trench running the length of the alleyway to receive the conveyor. The conveyor consists of the necessary drive system, framing, support rollers, and belt. The receiving hopper is mounted above the conveyor belt on rollers. It is generally a smaller hopper than that used in stationary locations, but otherwise it is the same. The belt transfers the potatoes from the receiving hopper to the grading line. Removable covers over the trench provide for passage of surface equipment across the alleyway. The bulk scoop is the other necessary item of equipment.

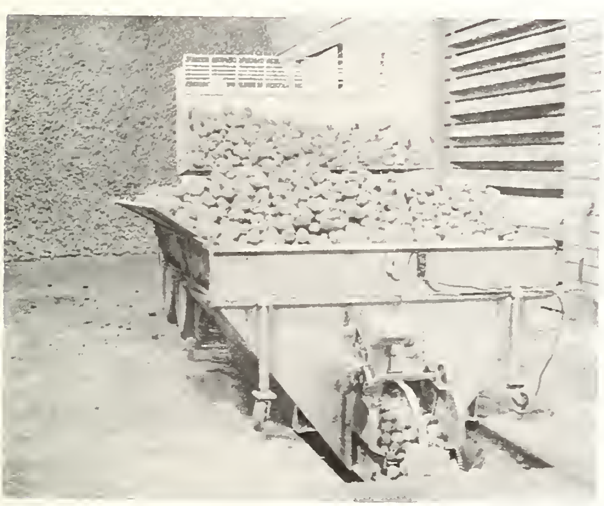


FIGURE 11.—Typical setup of a movable hopper on a conveyor for bulk scooping.

In operation, the bulk scoop is used to load the potatoes at the pile in the bin, transport them out of the bin, and deposit them in the hopper. The haul distance varies from a few feet when the bin is first opened to the length of the bin when it is almost empty. The operator's main function is to keep the hopper properly supplied with potatoes. The hopper is moved from bin to bin along the conveyor as the emptying of the storage progresses.

Fully Movable Hopper

Equipment needed with this method of handling is much like that of the stationary receiving hopper. The requirement for the hopper is the same except for the need for larger capacity and two units in place of one. The capacity of the hopper should be about 80 cwt. for use with the bulk scoop described in this report. The undercarriage must be substantial enough to support the load, and the hopper must be maneuverable enough to be turned easily in the bins and alleyway. The hopper feed and conveying mechanisms are essentially the same as that described in the other two systems. A draper chain or belt conveyor is needed to transfer the potatoes from the movable hoppers to the grading line. Figure 12 illustrates an arrangement of the hoppers and the conveyor during unloading operations.

With this system, the bulk scoop operator hooks the scoop to one of the movable hoppers and transfers it to the bulk pile in the bin. The hopper is placed in a position in the bin that gives the operator enough room to maneuver the scoop but keeps travel to a minimum. He unhooks the bulk scoop and loads the hopper. After filling is completed, the scoop is hooked again to the movable hopper and used to transfer the loaded hopper to the conveyor at the grading line. The hopper is moved into position at the conveyor and unloaded. While one hopper is being unloaded, the bulk scoop is unhitched from it and used to transport the other hopper to the pile for filling. This cycle of filling and emptying hoppers is repeated. With this method, the bulk scoop is used to transport a hopper full of potatoes rather than each bucketful. The usual method of

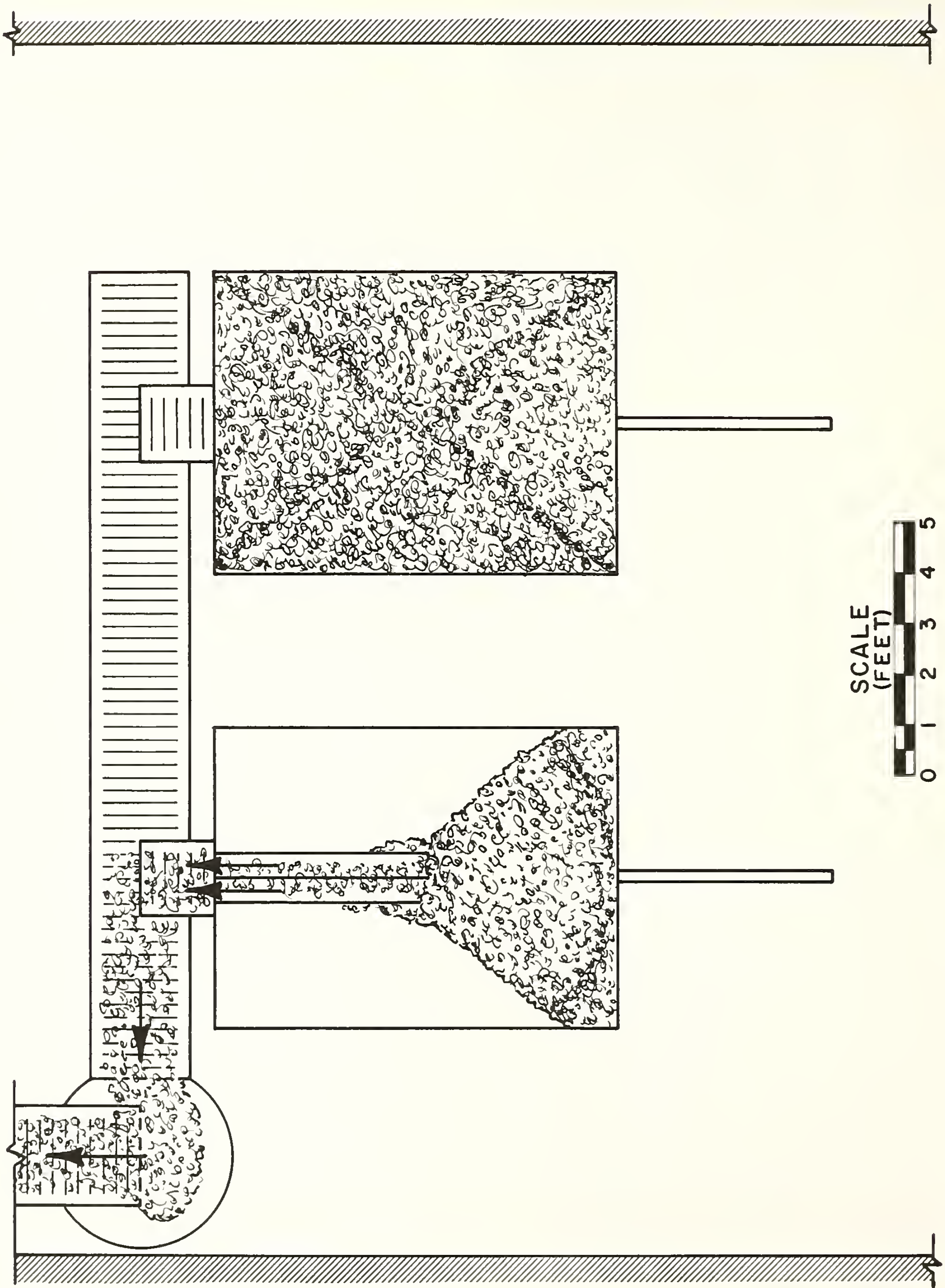


FIGURE 12.—Arrangement of hoppers and conveyor during unloading.

transport by scoop would be used when the travel and haul distance is short enough.

Figure 13 illustrates the effect that this method has on the output rates of the bulk scoop. Note that the output of the system remains uniformly high for these haul distances. "Travel empty" and "travel full" with the bulk scoop has virtually been eliminated through the use of movable hoppers.

When the bulk scoop is handling potatoes from the bin to a central conveyor, the output rate would closely approximate the curve representing one bulk scoop. However, the distances involved would be from only a few feet to the length of one bin.

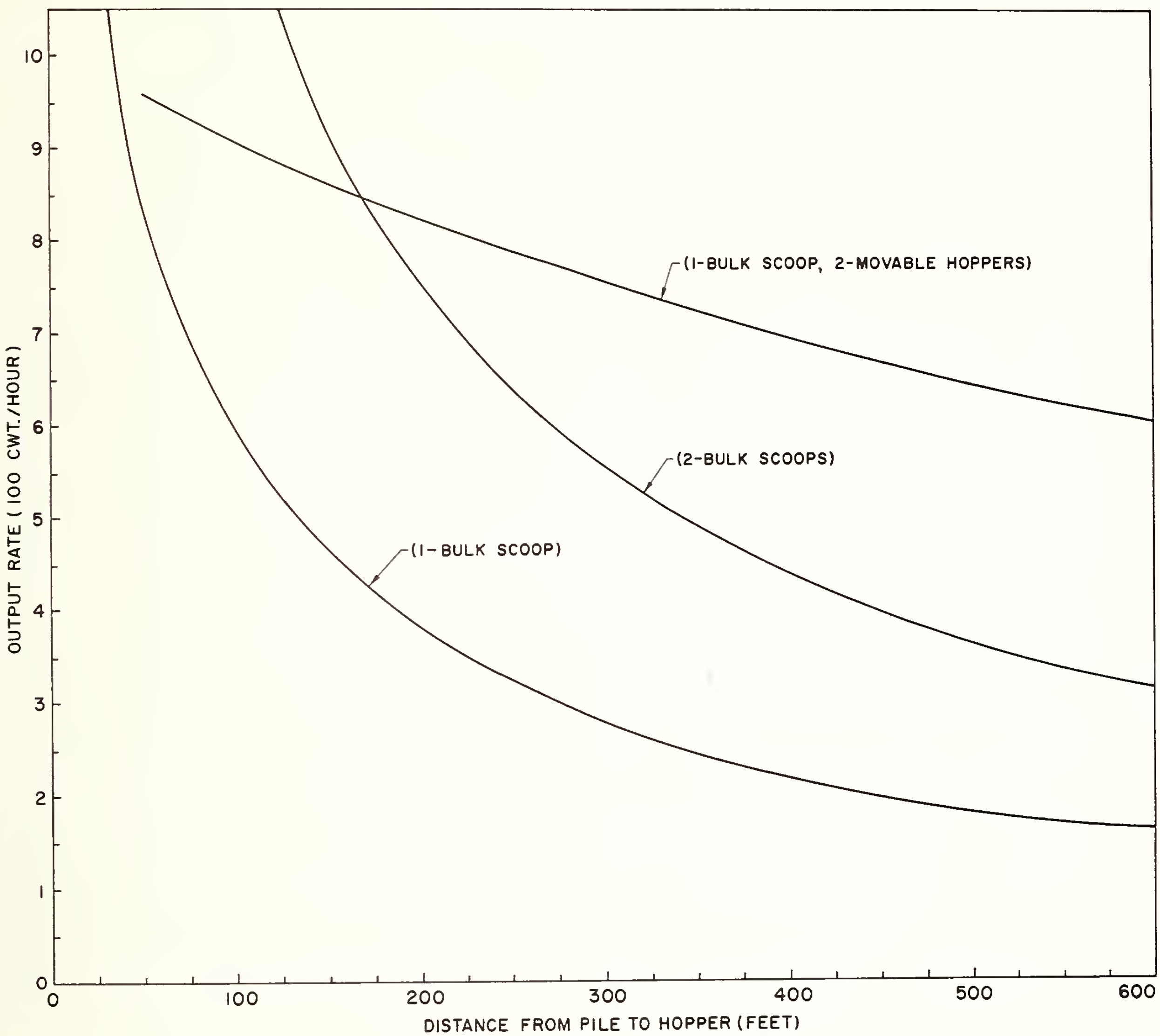


FIGURE 13.—Comparison of output rates of methods of bulk scoop operation.

COST COMPARISONS OF THE METHODS

To establish the costs of each method, the correct type, size, and amount of equipment required by each system were determined for the entire range of output rates and haul distances used in this analysis. Practical considerations and nominal values were applied so that the data could be presented in graphic form and be as universally useful as possible.

Annual costs were determined for (1) ownership, (2) operating, and (3) labor. Table 2 lists the ownership and operating costs for the various items of equipment. Labor cost was a single item set at $2 per hour.

Ownership costs were independent of the hours of operation and included charges for depreciation, interest, taxes, and insurance. The cost for all items was based on 1969 charges. Depreciation was calculated by the straight-line method. Estimated life and salvage value were established using available data on the equipment, data on comparable items of equipment, and opinions of packinghouse operators and equipment suppliers. Interest on the investment was set at 6.5 percent of the average value. Insurance was calculated at 1 percent of the average value and taxes at 2 percent. All costs were charged fully to potato handling.

Annual operating costs were dependent on the hours of operation and included charges for power, fuel, and maintenance. The costs were based on 1969 charges.

Total electric power costs for the plant were estimated and used as a basis for the average rate per kilowatt-hour. This average rate was then used to calculate the power costs for each handling system. The average rate schedule used was as follows:

Stationary or movable
  hopper systems .... 3¢ per kw.-hr.
Conveyor systems:
  Up to 200 feet .... 2.5¢ per kw.-hr.
  From 200 to 500 feet .... 2.75¢ per kw.-hr.

Fuel costs for the powered bulk scoop were based on 5 hours of operating time per tank of propane at $2.50 per tank.

Maintenance charges include repair, inspection, servicing, and maintenance. The charges were applied on the basis of percentage of the initial cost per 100 hours of operation. The percentages used were as follows:

	Percent
Powered bulk scoop	1.0
Stationary bulk hopper	1.0
Movable bulk hopper	1.0
Hopper on conveyor	1.0
Draper chain conveyor	1.5
Conveyor system	.5

TABLE 2.—*Annual ownership and operating costs for bulk scooping equipment*

Equipment	Initial cost (1969 prices)	Estimated life	Ownership costs: Depreciation	Ownership costs: Interest	Ownership costs: Taxes and insurance	Ownership costs: Total	Operating costs: Maintenance	Operating costs: Power and fuel	Operating costs: Total
	Dollars	*Years*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Powered bulk scoop[1]	4,645	[2] 5	689.00	189.96	87.68	966.64	232.25	250.00	482.25
Stationary bulk hopper	810	15	54.00	26.32	12.15	92.47	40.50	8.39	48.89
Movable bulk hopper[3]	1,485	15	99.00	48.26	22.28	169.54	74.25	8.39	82.64
Hopper for conveyor	800	15	53.33	26.00	12.00	91.33	40.00	7.27	47.27
Draper chain conveyor	1,000	15	66.67	32.50	15.00	114.17	75.00	8.39	83.39
Conveyor system:[4]									
100 foot	6,300	20	315.00	204.75	94.50	614.25	157.50	30.76	188.26
200 foot	10,300	20	515.00	334.75	154.50	1,004.25	257.50	51.27	308.77
300 foot	14,700	20	735.00	477.75	220.50	1,433.25	367.50	69.91	437.41
400 foot	19,100	20	955.00	620.75	286.50	1,862.25	477.50	93.21	570.71
500 foot	23,500	20	1,175.00	763.75	352.50	2,291.25	587.50	116.52	704.02

[1] Includes potato bucket and extra liquified petroleum (LP) tank f.o.b. East Grand Forks, Minn.
[2] $1,200 salvage value.
[3] Includes snap hitch.
[4] All conveyor systems include trench and covers at $10 per lineal foot.

To present the material in a form usable over a wide range of output rates and haul distances, 500 annual operating hours were selected and maintenance, fuel, and power charges were applied on that basis.

Ownership Costs

Appropriate items of equipment and their respective ownership costs were combined to represent the equipment needs of each of the three handling systems. These costs are presented as curves and tables from which annual ownership costs for each system may be obtained for a range of output rates and haul distances.

Figures 14 and 15 and table 3 present the ownership costs for the three methods of bulk scooping potatoes. Figure 14 refers to the stationary hopper method. A combination of output rate

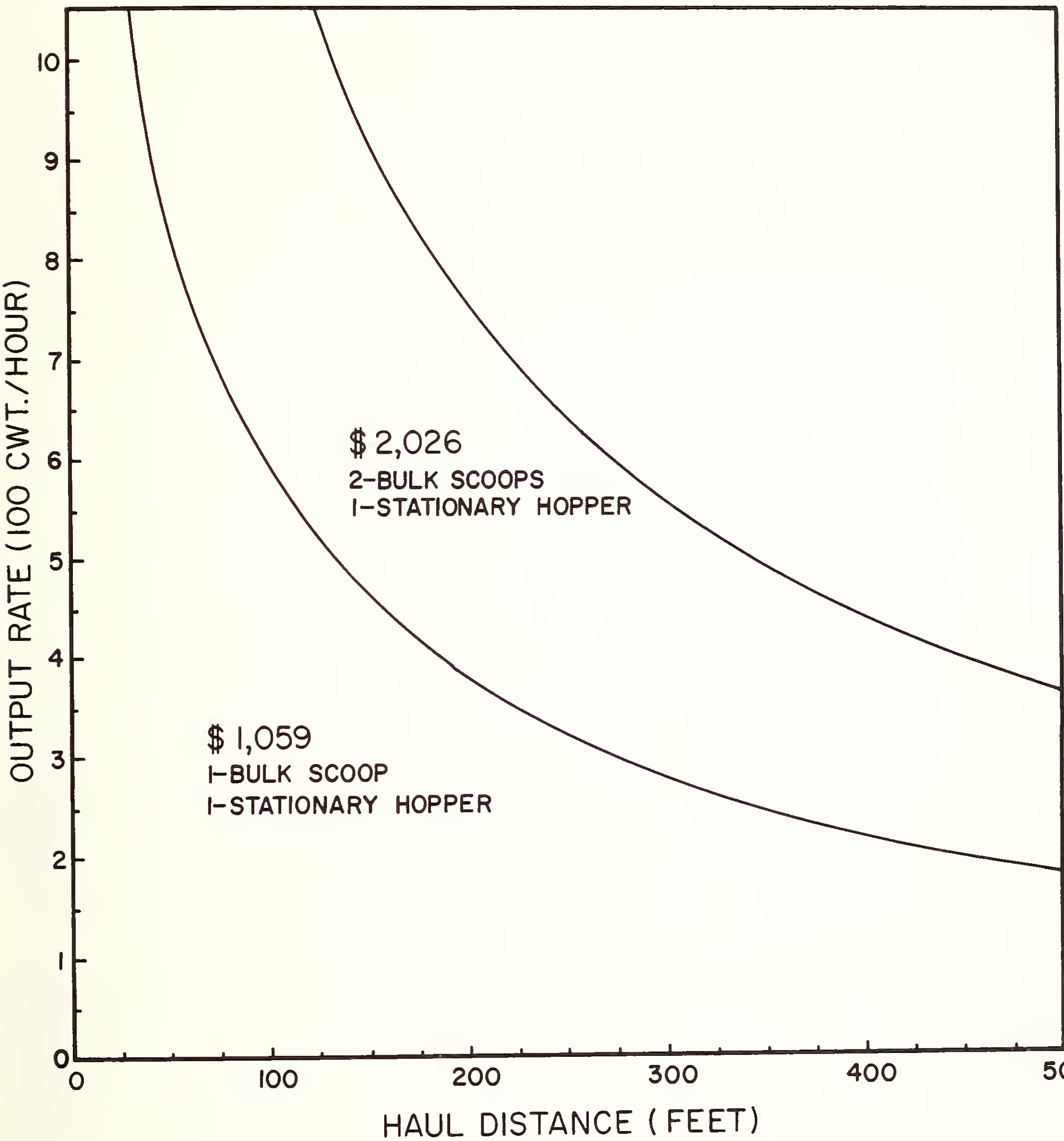


FIGURE 14.—Ownership costs for equipment required with the stationary hopper method.

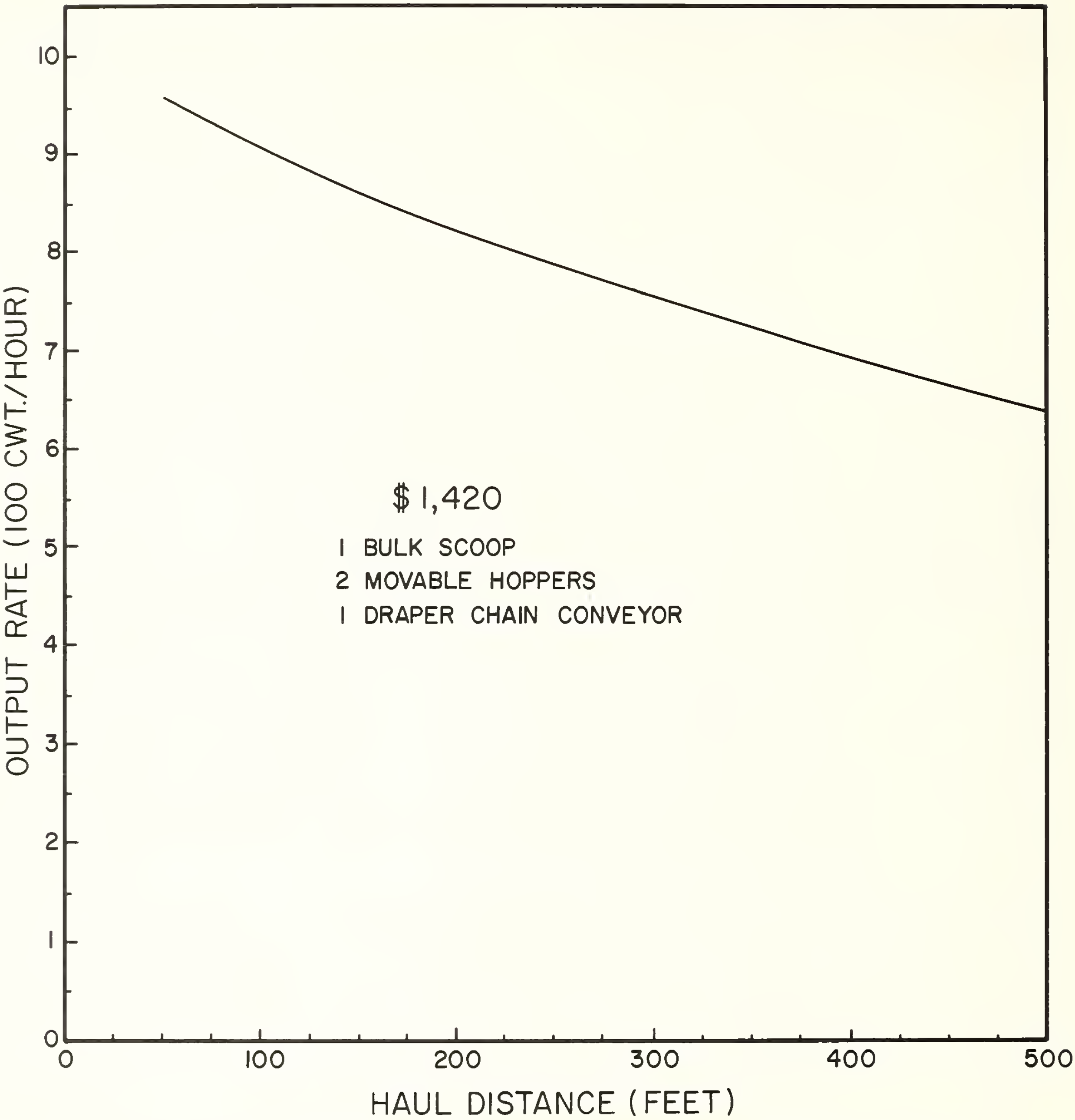


Figure 15.—Ownership costs for equipment required with the fully movable hopper method.

and longest haul distance that intersects below the lower curve requires equipment that has an annual ownership cost of $1,059. If the combination intersects between the two curves, a second bulk scoop is required and the total annual ownership cost is $2,026. Requirements beyond two scoops are not practical and are not given. The haul distance used should be the *longest* haul distance since that determines the equipment requirement and thus the ownership cost. Once the equipment requirements are established, the ownership cost is the same whether the system is operating at low or maximum output.

TABLE 3.—*Ownership costs for equipment required with the movable hopper on a conveyor method*

Length of conveyor (feet)	Ownership costs[1]
	Dollars
100	1,672
150	1,867
200	2,062
250	2,276
300	2,491
350	2,705
400	2,920
450	3,134
500	3,349

[1] Based on equipment consisting of 1 bulk scoop, 1 hopper, and a conveyor system of the length shown and having the capability of handling potatoes at an output rate up to 800 cwt. per hour.

Figure 15 refers to the fully movable hopper system. Again, a combination of output rate and *longest* haul distance is used to determine the annual ownership cost. For all practical purposes, with the fully movable hopper method, a single scoop can provide output rates that are sufficient at these distances. Thus, a single ownership cost of $1,420 is given.

Table 3 refers to the system utilizing the movable hopper on a conveyor. Ownership costs increase as the *length* of *the conveyor* increases. The data are only for 50-foot increments, but other values can be determined by interpolation. In general, requirements for equipment do not increase greatly as rate of output increases at a given distance. Any change in rate of output is accomplished by changing the operating speed of the conveying equipment rather than by changing the quantity or size of the equipment. This procedure is common practice. Thus, the ownership cost shown as a single value at each 50-foot increment in the table applies for all rates of output from zero to about 800 cwt. per hour.

Operating Costs

Figures 16, 17, and 18 are used to determine the operating costs for each method of handling. Figure 16 refers to the method using the stationary hopper. A combination of rate of output and *average* haul distance will result in an average hourly operating cost from the curves. Interpolation should be used for points not falling on the given curves. The average hourly operating cost is then multiplied by the total annual hours of operation for the particular storage situation being investigated. Over the given ranges of output and haul distance, many combinations are possible. Although the operating costs may be checked for any haul distance over the entire range, the average distance should be used to determine the average hourly operating cost.

Figure 17 is the same type of curve for the fully movable hopper method. Since operating costs include transporting the hoppers as well as filling them, the haul distances refer to those in the entire storage from potato pile to hopper unloading point. Again, the *average* haul distance is used to determine the average hourly operating cost. This cost is then multiplied by the annual hours of operation required to empty the storage.

Figure 18 refers to the movable hopper on a conveyor system and gives the average hourly operating costs based on rate of output and length of conveyor. Again, this hourly cost must be multiplied by the annual hours of operation to obtain annual operating costs.

Labor Costs

The base rate for labor was set at $2 per hour for the bulk scoop operator. No other type of labor is involved with any of the methods. Figure 19 gives the hourly labor costs for the stationary hopper and figure 20, for the fully movable hopper method.

The movable hopper on a conveyor method requires a single hourly labor cost of $2 for all lengths of conveyor up to 500 feet and all output capacities up to 800 cwt. per hour.

When using figure 19, the average hourly labor cost should be determined by calculating the total haul distance that requires one operator and the total that requires two operators. This calculation is easily done by noting on figure 19 the haul distance at which the output rate intersects the curve; that is, the point at which the change from one to two operators is made. This figure divided by the total haul distance gives the percentage of the total annual operating hours to be calculated at the $2 rate. The remaining percentage of the total annual hours is cal-

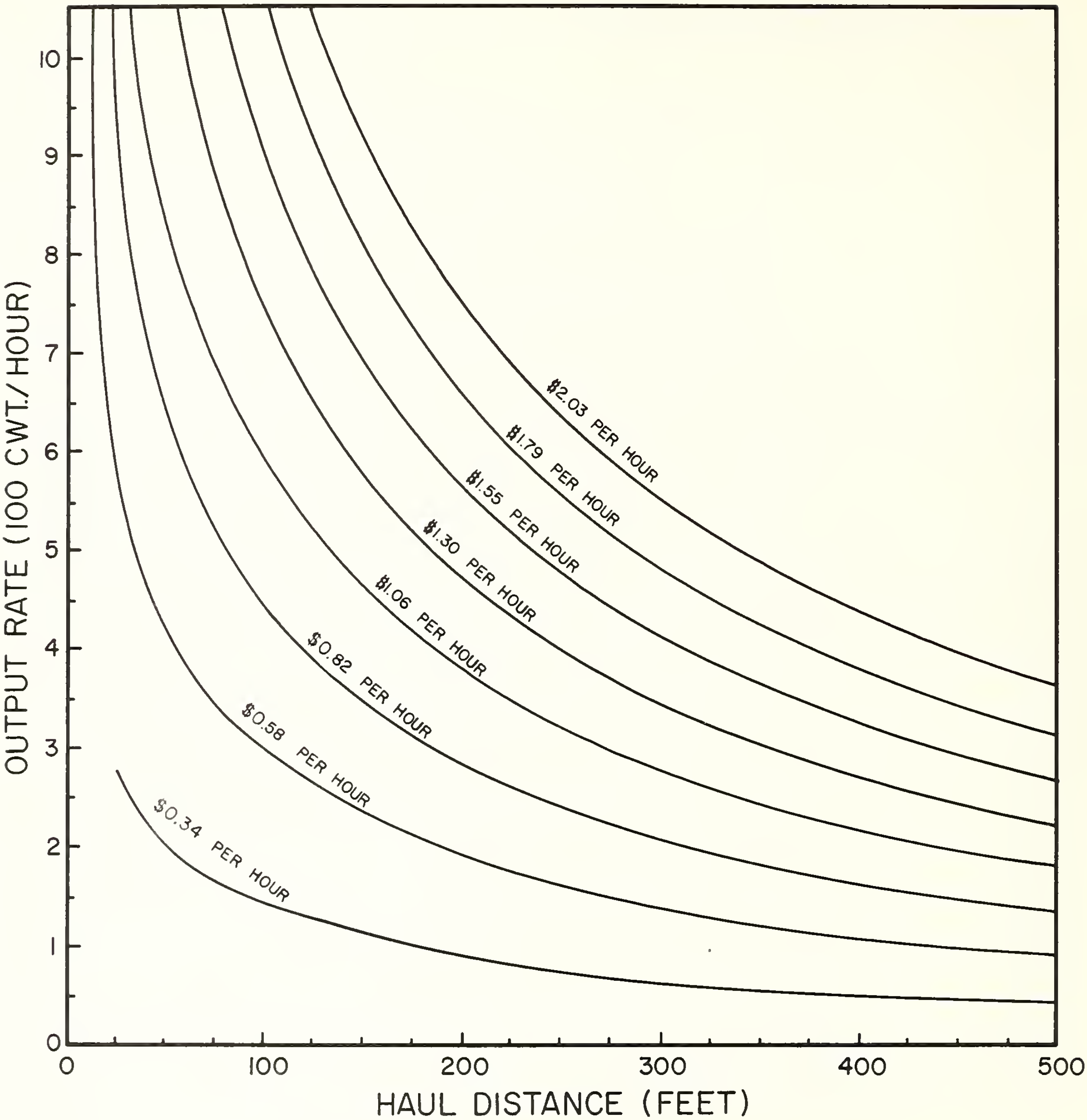


FIGURE 16.—Operating costs for equipment required with the stationary hopper method.

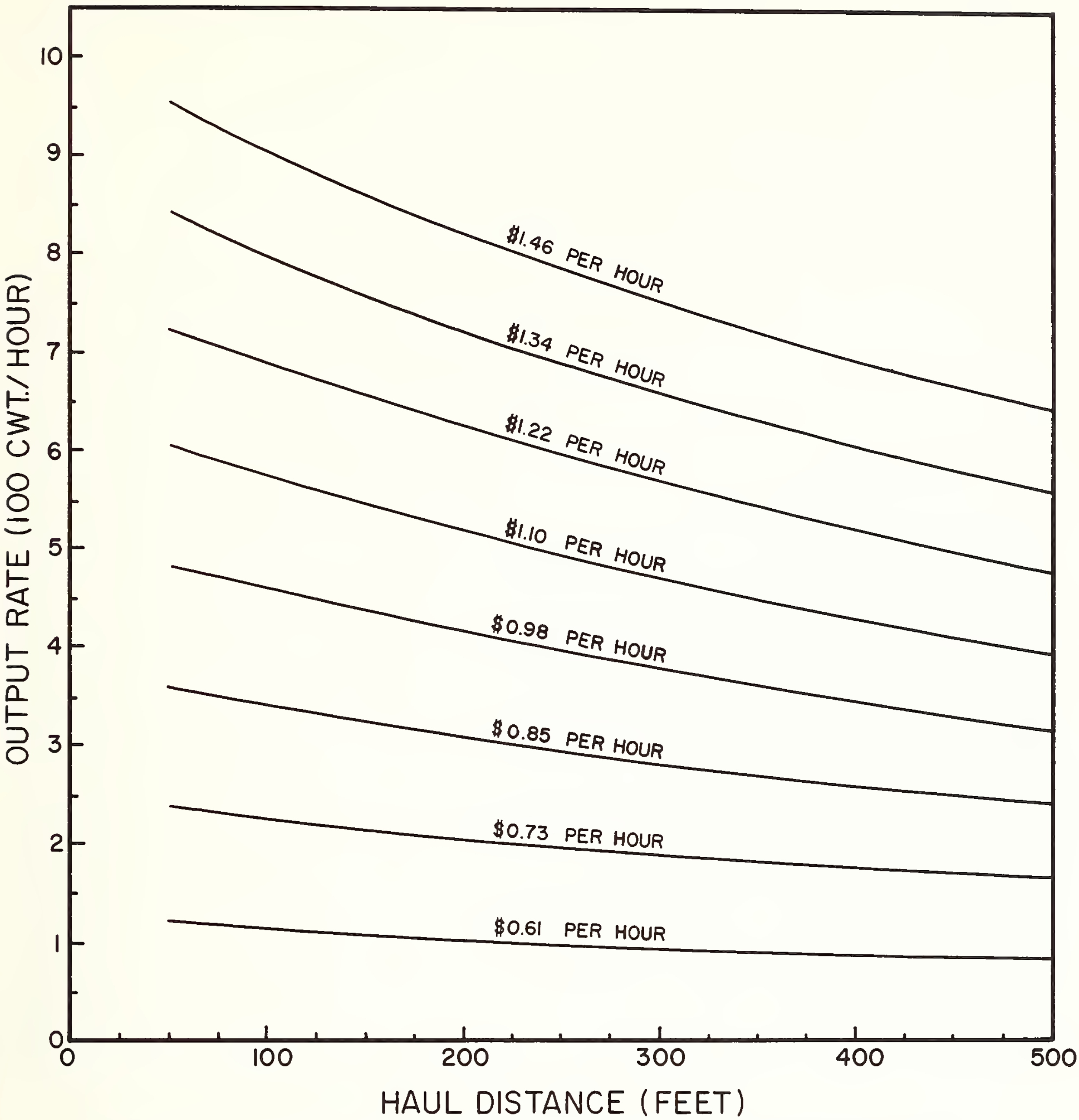


FIGURE 17.—Operating costs for equipment required with the fully movable hopper method.

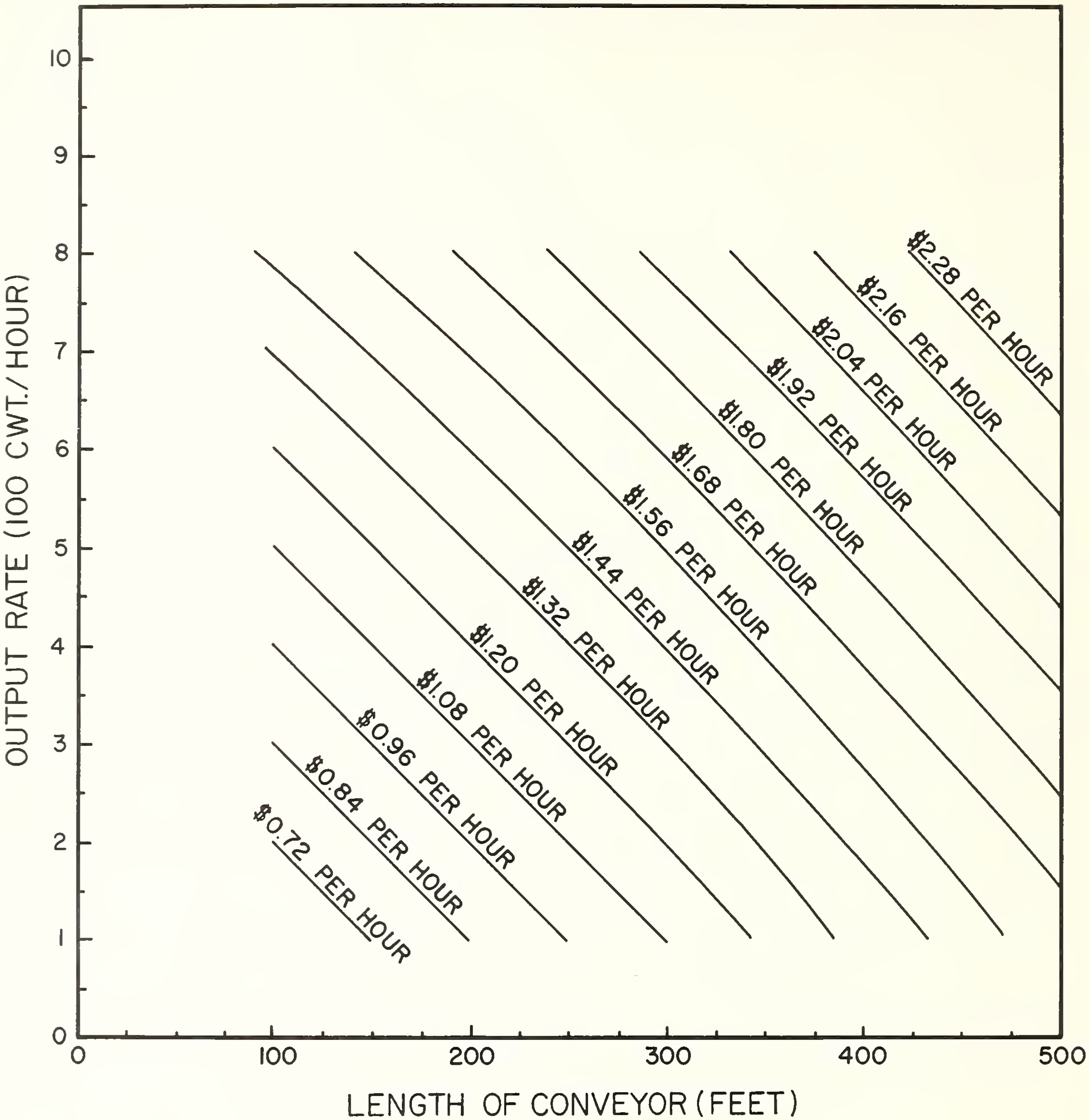


Figure 18.—Operating costs for equipment required with the movable hopper on a conveyor method.

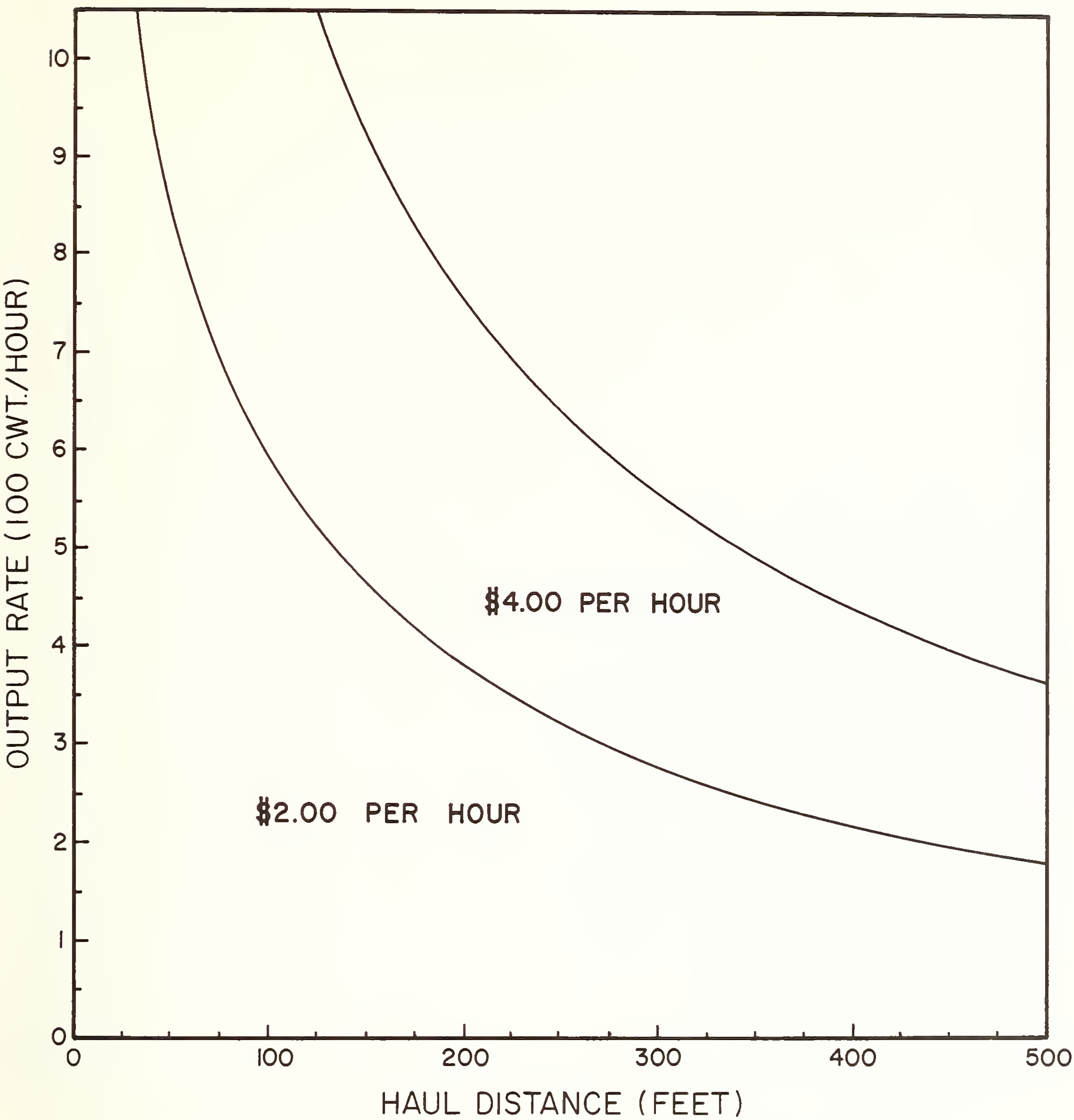


FIGURE 19.—Costs for labor with the stationary hopper method.

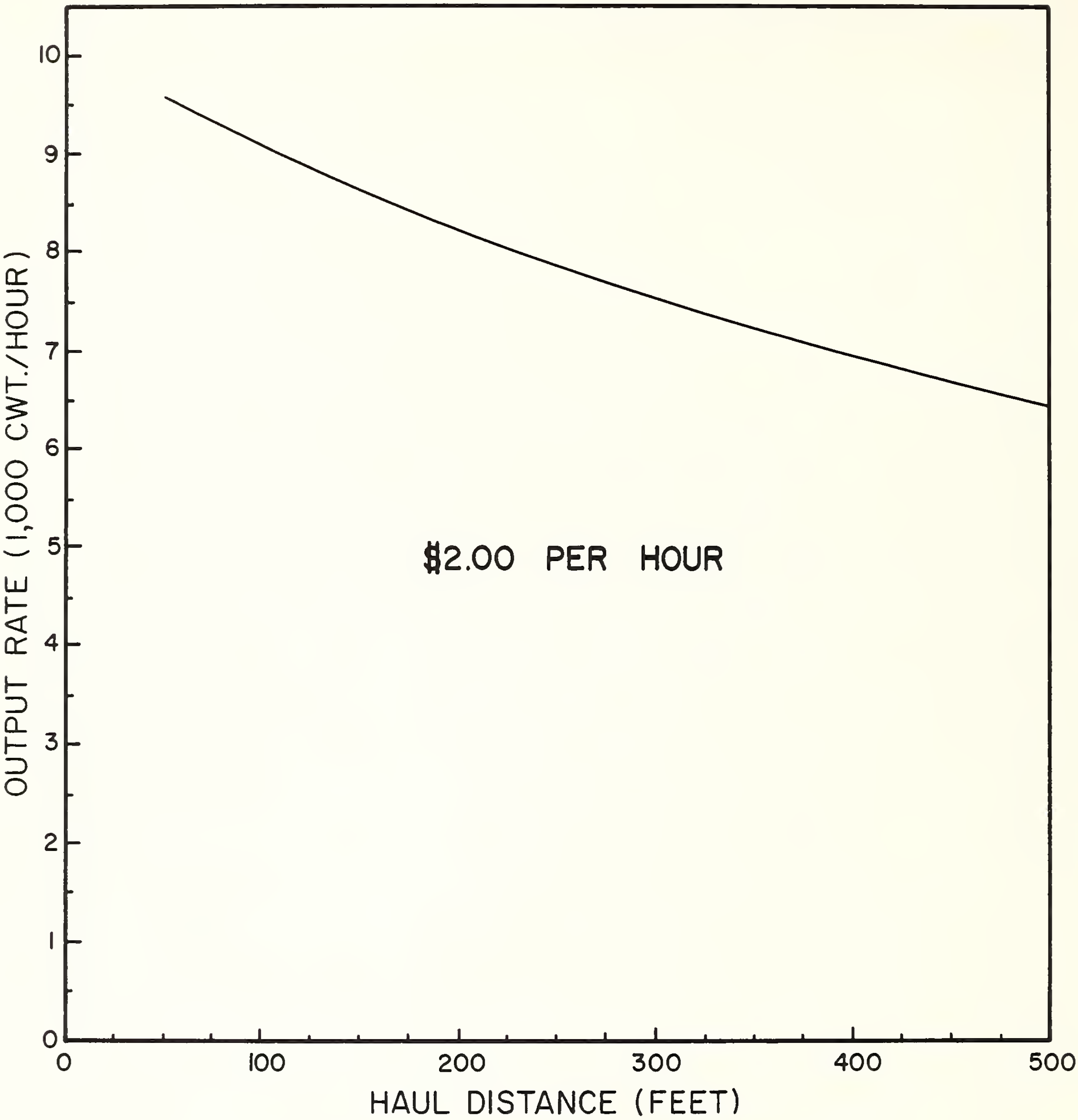


FIGURE 20.—Costs for labor with the fully movable hopper method.

culated at the $4 rate. The total annual hours are the same as were used for determining operating costs and is an individual situation depending on the storage capacity and the rate of output.

Figure 20 indicates that at $2 per hour labor cost is appropriate for all practical ranges of output and haul distance with the fully movable hopper method. The $2 per hour cost is also appropriate for all practical instances of the movable hopper on a conveyor method, and no curve is given for that method.

Examples of Annual Costs

An example of determining annual costs follows: Given that a storage has a capacity of 100,000 cwt. contained in ten 10,000 cwt. bins with an inside width of 20 feet arranged in a cross-alley configuration. Interior walls each require 1 foot of space. The desired output rate is 500 cwt. per hour. The hopper unloading point is at one end of the alleyway.

The longest haul distance for both the stationary hopper and fully movable hopper methods is 200 feet. The conveyor length required, if the movable hopper on a conveyor method is used, is 105 feet. With these values, ownership costs determined from figures 14 and 15 and table 3 are $2,026 for the stationary hopper method, $1,420 for the fully movable hopper method, and $1,692 for the movable hopper on conveyor method.

To determine operating and labor costs, first compute the annual hours of operation by dividing 100,000 cwt. by 500 cwt. per hour. The result is 200 hours. Then, from figures 16, 17, and 18 determine the operating costs of $0.94 per hour for the stationary hopper method and $1.02 per hour for the fully movable hopper method, using 106 feet for the average haul distance. The movable hopper on a conveyor method has an operating cost of $1.09 per hour for the 105-foot conveyor from figure 18. Each of these hourly costs is multiplied by the 200 hours of operation giving total annual operating costs of $188 for the stationary hopper method, $204 for the fully movable hopper method, and $218 for the movable hopper on a conveyor method.

If figure 19 is entered at 500 cwt. per hour, the curve representing the change from $2 to $4 per hour is reached at a haul distance of 134 feet. This distance divided by the longest distance of 200 feet yields 0.67. Converted to percentage, this means that for 67 percent of the 200 hours, or for 134 hours, required to empty the storage only one scoop operator at $2 per hour is necessary. The rest of the time, 33 percent or 66 hours, requires two scoops and two operators whose labor cost is $4 per hour. Multiplying 134 hours by $2 equals $268 and 66 hours by $4 equals $264 for a total labor cost of $532 for the stationary hopper method. Figure 20 shows that at 500 cwt. per hour, only one scoop operator is required by the fully movable hopper method. Since the movable hopper on conveyor method also requires only one operator, the cost amounts to $400 for 200 hours of labor for each method. Summarizing these data, annual costs amount to $2,746 for the stationary hopper method, $2,024 for the fully movable hopper method, and $2,310 for the movable hopper on conveyor method. Converting these costs to a cost per hundredweight basis yields 2.7¢, 2.0¢, and 2.3¢ per hundredweight, respectively.

Table 4 summarizes the annual costs for various haul distances and rates of output. However, any other combinations of rates of output and haul distances may be evaluated by using the curves and data as explained in the example.

TABLE 4.—Total annual costs and costs per hundredweight for 3 methods of bulk scooping from various storages at various rates of output.

Rate of output and method	Storage capacity (cwt.)[1] 60,000 Total costs	60,000 Per cwt.	100,000 Total costs	100,000 Per cwt.	160,000 Total costs	160,000 Per cwt.	200,000 Total costs	200,000 Per cwt.	240,000 Total costs	240,000 Per cwt.	360,000 Total costs	360,000 Per cwt.	450,000 Total costs	450,000 Per cwt.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
200 cwt. per hour														
Stationary hopper	1,779	3.0	---	---	---	---	---	---	---	---	---	---	---	---
Fully movable hopper	2,227	3.7	2,770	2.8	---	---	---	---	---	---	---	---	---	---
Movable Hopper on conveyor	---	---	3,057	3.1	---	---	---	---	---	---	---	---	---	---
300 cwt. per hour														
Stationary hopper	1,569	2.6	1,925	1.9	2,482	1.6	3,385	2.0	---	---	---	---	---	---
Fully movable hopper	1,980	3.3	2,356	2.4	2,923	1.8	3,301	1.6	---	---	---	---	---	---
Movable Hopper on conveyor	---	---	2,641	2.6	3,536	2.2	4,179	2.1	---	---	---	---	---	---
400 cwt. per hour														
Stationary hopper	1,464	2.4	1,789	[2] 1.8	3,409	2.1	3,893	2.0	4,328	1.8	---	---	---	---
Fully movable hopper	1,855	3.1	2,148	2.2	2,588	1.6	2,890	1.4	3,190	1.3	---	---	---	---
Movable Hopper on conveyor	---	---	2,434	2.4	3,185	2.0	3,715	1.9	4,037	1.7	---	---	---	---
500 cwt. per hour														
Stationary hopper	2,408	4.0	2,746	2.7	3,326	2.1	3,739	1.9	4,125	1.7	---	---	---	---
Fully movable hopper	1,781	3.0	2,024	2.0	2,393	1.5	2,640	1.3	2,889	1.2	3,644	1.0	---	---
Movable Hopper on conveyor	---	---	2,310	2.3	2,974	1.9	3,441	1.7	3,713	1.6	5,154	1.4	---	---
600 cwt. per hour														
Stationary hopper	---	---	---	---	3,227	2.0	---	---	---	---	---	---	---	---
Fully movable hopper	---	---	---	---	2,261	1.4	2,472	1.2	2,688	1.1	3,340	0.9	3,828	0.8
Movable Hopper on conveyor	---	---	---	---	2,834	1.8	3,261	1.6	3,493	1.5	4,799	1.3	---	---
700 cwt. per hour														
Stationary hopper	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Fully movable hopper	---	---	---	---	---	---	---	---	2,545	1.1	3,131	0.9	---	---
Movable Hopper on conveyor	---	---	---	---	---	---	---	---	3,340	1.4	---	---	---	---

[1] Characteristics of specified storages by storage capacity:

Storage capacity (cwt.)	Bins No.	Bins Capacity of each (cwt.)	Layout configuration	Haul distance (ft.) Longest	Haul distance (ft.) Average	Length of conveyor (ft.)
60,000	8	7,500	Cross alley	158	85	84
100,000	10	10,000	do.	200	106	105
160,000	16	10,000	do.	263	137	168
200,000	20	10,000	do.	305	158	210
240,000	20	12,000	do.	322	166	210
360,000	30	12,000	do.	427	218	315
450,000	30	15,000	do.	452	231	315

[2] Slightly above the capacity of 1 scoop, but only a single scoop was considered.

ADDITIONAL FACTORS FOR COMPARISON

Each method of bulk scooping should be examined on the basis of the time value of money—generally annual cost. Such an analysis involving ownership, operating, and labor costs generally determines which method will be used. However, material handling is never static and expansion, relayout, and increased output are desired frequently. Factors such as simplicity, flexibility, and adaptability of the handling system must not be overlooked.

1. *Simplicity.*—With the fully movable hopper method, only a single bulk scoop, two movable hoppers, and a bulk unloading conveyor are needed and only one operator is required for all supply rates and haul distances. The stationary hopper method is simpler when rates and distances require only one bulk scoop, but additional scoops and operators complicate the system. The movable hopper on a conveyor method is more complex than either of the other two.

2. *Flexibility.*—With the fully movable hopper method, each item of equipment can be moved to another location or used for an entirely different purpose. The fully movable hoppers may well be farm trucks with hopper-bottom boxes, although their maneuverability is limited in a storage. With the other methods, only the bulk scoop is usable on other jobs. There is really no practical substitute operation for the movable hopper on a conveyor method, since the conveyor is an integral part of the storage. A bulk truck box may be used for the receiving hopper in the stationary hopper method.

3. *Adaptability.*—With the fully movable hopper method, the rate of handling can be either high or low as required. Haul distance may be short or long without a change in equipment or workers. The storage layout may be expanded or altered without requiring equipment changes. With the stationary hopper method, rate changes or distance changes may require changes in the number of scoops and operators. The movable hopper on a conveyor method cannot easily be adapted to altered or expanded storage unless such changes are anticipated in the original design of the conveyor.

4. *Economy.*—With the fully movable hopper system, additional equipment or workers are not required until a combined rate of 600 cwt. per hour and a distance of 600 feet are exceeded. The other two systems require either additional bulk scoops and operators or a larger conveyor system as distance or rate of supply increases.

CONCLUSIONS AND RECOMMENDATIONS

Average haul distance for the bulk scoop is at a minimum when the receiving hopper is located relative to the potato pile; it is next lowest when the hopper is located relative to the bin; and it is greatest when the hopper is located relative to the storage. These three conditions are met, respectively, by the fully movable hopper method, by the movable hopper on a conveyor method, and by the stationary hopper method. By utilizing two fully movable hoppers for transferring several scoopfuls of potatoes rather than an individual scoopful, the output of the bulk scoop is maintained well as haul distance increases. At the short distance needed to load the hopper at the pile, the bulk scoop is essentially loading, unloading, and maneuvering, and not traveling, which allows operating at the high end of the output curve for the scoop.

In all methods examined, the fully movable hopper method is lower in cost than the movable hopper on a conveyor method. The stationary hopper method is lower in cost than the fully movable hopper method only at rates and distances that do not require a second bulk scoop. In general, factors such as flexibility, adaptability, simplicity, and economy also tend to favor the fully movable hopper method.

APPENDIX

General descriptions of the work elements and their associated time values which were used in evaluating the rate of output of the powered bulk scoop are as follows:

Work elements	Unit	Time value[1]
Approach pile—load scoop—turn 180°—leave pile	Minutes	0.206
Approach hopper—dump bucket—turn 180°—leave hopper	Do.	.132
Turn 90° (loaded or empty)	Do.	.047
Leave hopper after filling—travel to hitch—hook up	Do.	[2].15
Maneuver loaded hopper at receiving point	Do.	[2].45
Unhook—travel to empty hopper—hook up	Do.	[2].12
Maneuver empty hopper at pile	Do.	[2].20
Unhook from empty hopper—travel to pile	Do.	[2].15
Travel with bucket empty	Feet/minute	476.10
Travel with bucket full (742 lbs.)	Do.	464.73
Travel pulling empty hopper	Do.	464.73
Travel pulling full hopper (80 cwt.)	Do.	300.28

[1] A fatigue allowance of 5 percent and a personal allowance of 5 percent included in the above time values.
[2] Estimates based on simulated conditions.

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Agricultural Research Service
Hyattsville, Maryland 20782

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