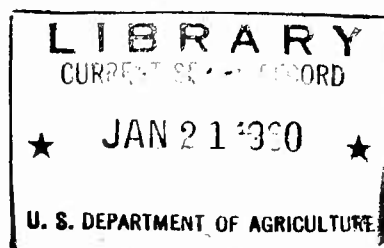


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Agriculture Handbook No. 171



Increasing Potato-Harvester Efficiency

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By A. H. Graves and G. W. French

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

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Increasing Potato-Harvester Efficiency

By A. H. GLAVES and G. W. FRENCH, *Agricultural Engineers, Agricultural Engineering Research Division,
Agricultural Research Service*

Mechanical potato harvesters have come into increasingly wide use since the late 1940's. An estimated 75 percent or more of the potatoes grown in Idaho and in the Red River Valley of Minnesota and North Dakota are harvested mechanically. Use of harvesters is increasing in other important producing areas as they are being improved and adapted to meet various difficult conditions.

Numerous models equipped with a variety of features and accessories are now commercially available to meet the wide range of requirements. The choice of a machine should be based on local conditions, including size of the individual operation, opportunity to do customwork, preferred method of operation, plans for marketing, manner of disposing of the crop, and ultimate utilization of the crop.

The decision to adopt mechanical harvesting involves more than the selection, purchase, and use of a single machine. The harvester alone is a major investment. If purchased new, a machine costs from about \$3,400 to about \$10,000.

For maximum efficiency of operation, the harvester should be equipped for bulk handling of the crop, and complementary companion equipment should be provided for hauling and rapid unloading. If the haul to packing plant or storage is short, two trucks with self-unloading boxes will be required to keep the harvester operating continuously. Three or four trucks may be required for longer hauls. Bulk-unloading facilities with high capacity help to reduce the number of trucks required.

The total investment in equipment, including harvester, trucks, boxes, and bin filler, may be more than twice that in the harvester alone. The investment amounting to several thousand dollars emphasizes the need for careful planning and maximum utilization. The factors affecting efficiency are complex and must be carefully considered to obtain maximum efficiency and most profitable use.

In spite of the large sums of money invested by potato growers in harvesting machines, little published information is available on the effective operation of this equipment. This is probably because the machines are frequently built by small manufacturers in limited quantities or custom built in local shops. Furthermore, the development of such equipment has been rapid in recent years and has involved rapidly changing features and specifications. The complexity of the machines themselves, as well as operating problems under diverse conditions, has made the preparation of comprehensive printed instructions difficult and costly.

This publication is based on research by the Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, conducted mainly during the 1950's. It includes suggestions based on field observations. Its purpose is to provide information for practical use by potato growers in the efficient operation of mechanical equipment, in both the direct and the indirect methods of harvesting.

MAIN OBJECTIVES

Certain main objectives should be borne in mind in all mechanical harvesting operations. The most important of these are discussed in the following paragraphs.

Complete Recovery of the Crop

The difference in cost between harvesting with 98-percent recovery and with 100-percent recovery may be much more than 2 percent of the value of the crop if complete recovery requires excessive depth of operation and results in inadequate sep-

aration of the potatoes and the hauling of much soil to the storage or packing house. A harvester with two 26-inch aprons, each lifting an average depth of 4 inches of soil and traveling at 2 miles per hour, would lift 8 to 10 tons of soil per minute. Operating one-half inch deeper than necessary would require the lifting of another ton or more of soil per minute and might recover only a few more potatoes, possibly with inadequate soil separation. Under adverse conditions, a skilled operator may be forced to harvest with less than 100-percent recovery.

Minimum Damage to the Potatoes

Mechanical injury can easily reduce the grade of 10 to 15 percent of the yield, or even jeopardize the salability of an entire lot. The seriousness of all mechanical damage tends to increase with time while the potatoes are in storage or are being handled in trade channels. Although potential loss from damage is difficult or impossible to estimate accurately, much can be done to minimize damage. Proper precautions before harvest and careful operation of harvesting and handling equipment should limit immediately detectable damage losses to 5 percent or less.

Clean Sample

Potatoes should be free from tare materials—clods, adhering soil, stones, weeds, and vines—that add to the cost of hauling, subsequent handling, and tare disposal. “Clean sample” means potatoes that are free from such materials. Subsequent handling operations are more easily accomplished with a minimum of injury to the tubers if the tare materials are removed first. Hauling operations have been observed where tare materials constituted from 20 to 25 percent of the weight of the load. Percentage of tare varies with local conditions, care in machine operation, and amount of hand sorting. Tare should generally be held below 5 percent and can often be as low as 2 or 3 percent.

Low Harvesting Costs

The three objectives just discussed (complete recovery of the crop, minimum damage to the potatoes, and clean sample) can be attained without increasing the cost of harvesting. Harvesting

costs can be reduced to a minimum only by full-season use of equipment and the sustained high-capacity operation that is made possible by good machine maintenance. Care is required to preserve the dependability of the original machinery. Unplanned interruptions are costly in proportion to the number of people made idle in the coordinated operations. By full mechanization, labor costs can be reduced as much as 80 percent. Mechanical harvesting and bulk handling eliminate arduous labor and can reduce harvesting and handling costs as much as 50 to 65 percent as compared with older hand methods.

Mechanical harvesting costs vary with field conditions; hauling costs vary with the distance hauled. With favorable field conditions and a haul of 4 miles or less, costs as low as 15 cents per hundredweight for harvesting and hauling are possible.¹ The goal of minimum damage to the potatoes should not be overshadowed by undue emphasis on low unit costs attained with rough handling at higher speeds.

¹ Additional information on handling costs may be obtained from the following publications:

DOWNING, LEWIS J., HEMPHILL, PERRY V., and SCHICKELE, RAINER. OBSERVATIONS ON POTATO HARVESTING COST BY HAND AND BY MACHINE IN THE RED RIVER VALLEY. 20 pp., illus. N. Dak. Agr. Col., Agr. Expt. Sta., and Red River Val. Res. Cen. Agr. Econ. Rpt. 7. Apr. 1953. [Processed.]

GREENE, R. E. L., KUSHMAN, L. J., NORTON, J. S., and SPURLOCK, H. C. MECHANICAL HARVESTING AND BULK HANDLING OF POTATOES IN FLORIDA AND ALABAMA. 47 pp., illus. Fla. Agr. Expt. Sta., Agr. Econ. Ser. 54-10, 47 pp., Jan. 1954. [Processed.]

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



FIGURE 1.—Typical Red River Valley scene showing 2-row direct harvester with crew of 6 workers for hand sorting.

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GENERAL DIRECTIONS

Choice of Method

It is important to choose the method of operation best adapted to the particular conditions and objectives. Either the direct or the indirect method of harvest can be used. There are advantages and disadvantages in each.

In the direct method, the potatoes are dug, elevated, and transferred into containers or bulk trucks in one operation (fig. 1).

In the indirect method, the potatoes are dug and generally windrowed (fig. 2). After an adequate lapse of time, generally between 20 minutes and 2 hours, the harvester with suitable accessories picks up, separates, and transfers the potatoes into containers or trucks for transportation to storage or packing plant. The indirect method can be used to obtain high harvesting capacity from a lighter and more simple machine than the two-row direct harvester. Another advantage of the indirect method is the ability to "open up" a field without driving the truck on rows of undug potatoes (see fig. 2).

A previously used two-row digger can be equipped with windrowing accessories and continued in service for indirect harvesting (fig. 3). This permits the change to mechanized harvesting with smaller capital investment in new equipment. The following types of windrowing accessories have been used for this purpose. Most of them have been custom made to individual specifications.

1. Single-apron, cross-conveyor type, which deposits potatoes in a windrow approximately where one row grew.
2. Twin-apron, center-delivery type, which deposits potatoes from two rows about midway between the positions of the rows.
3. Resilient rubber-covered, multiple-roller type, which deposits potatoes in a pattern similar to that laid down by the single-apron, cross-conveyor type.
4. Padded rectangular-funnel type.
5. Twin-funnel type, which deposits potatoes from two rows in two individual bands, to be picked up by a two-row harvester equipped with pickup accessories.



FIGURE 2.—A single-apron indirect harvester. This harvester with a single 26- or 30-inch primary apron has high capacity when used indirectly to pick up a two-row windrow.



FIGURE 3.—Standard two-row digger equipped with right-hand-delivery, single-apron windrower. Different windrow patterns can be laid down to suit different plans of pickup. In this view, the potatoes are laid down in pairs of windrows as the machine makes adjacent passes by alternate trips in opposite directions.

Other types of windrowing accessories having longer conveyors for depositing potatoes in four- and six-row patterns have also been used to a limited extent. Encouraging success has been achieved with these, which indicates the possibility of higher capacity operations becoming more general as further improvements are made.

"Single-apron" harvesters (harvesters designed for one-row direct operation) are most commonly used for harvesting potatoes by the indirect method. They are modified by removing the blade, adding a structural cross member inside the primary apron if necessary, and adding suitable windrow retainer plates. Harvesters designed for two-row direct operation are sometimes, but less frequently, used for indirect harvesting. Certain combinations of conditions during the drying interval between the first stage and the second stage (pickup operation) affect the capacity of the one-row machine for soil separation with reduced apron speed and a minimum of agitation. Among these conditions are: Soil type, stoniness, soil moisture, relative humidity, wind velocity (and even wind direction, where the field is near a large body of water) air temperature, cloudiness (or brightness of sunshine), stage of maturity of the potatoes, amount and nature of weed growth, sod-iness, and amount of vine material.

In muck soils and heavy soils with high moisture, greater soil-separating capacity can be realized without excessive agitation by indirect operation than by direct operation.

The indirect method is often preferred for its cleaner work under adverse weedy or wet heavy-soil conditions. Furthermore, it is sometimes preferred for potatoes that are to be sold without being washed, as when they are to be used for certified seed or unwashed table stock.

For indirect harvesting, the windrowing must be carefully done. Frequently, with the indirect method, the damage during windrowing far exceeds the total damage during subsequent operations—pickup, elevation, separation, loading, and unloading.

Improved windrowing equipment is becoming available. In numerous instances, two two-row digger-windrowers are used to keep one single-apron pickup harvester operating at full capacity. This allows slower travel speeds for the digger-windrowers.

The travel speed of the indirect harvester can generally be faster than optimum for the digger-windrower. Under certain conditions affecting ease of separation, as explained previously, indirect harvesting more than doubles the capacity of the single-apron harvester harvesting only one row direct, and it can greatly increase the capacity of a two-row machine beyond its capacity with direct operation.

Choice of Machine

It is essential to choose a machine that is suitable to the area, the chosen method, and the specific harvesting conditions—especially those conditions that cannot readily be changed, such as soil, topography, stones, and field size. Stone clearing is sometimes a prerequisite for satisfactory mechanical harvesting and may have to be included in a longtime plan.



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FIGURE 4.—This blade is much shorter than the common single-pointed blade. It is intended for use in heavy soils. Note also the bridge plate inside the apron and just to the rear of the cone rollers. This is used when needed to prevent excessive undersweep or "boiling."

Choice of Accessories and Specifications

The best choice of optional accessories or machine specifications depends on soil type, method of operation, and other factors already mentioned; also on such factors as tuber size range and intended use, including use for certified seed, washed table stock, dry table stock, chips, french fries, and special potato products.

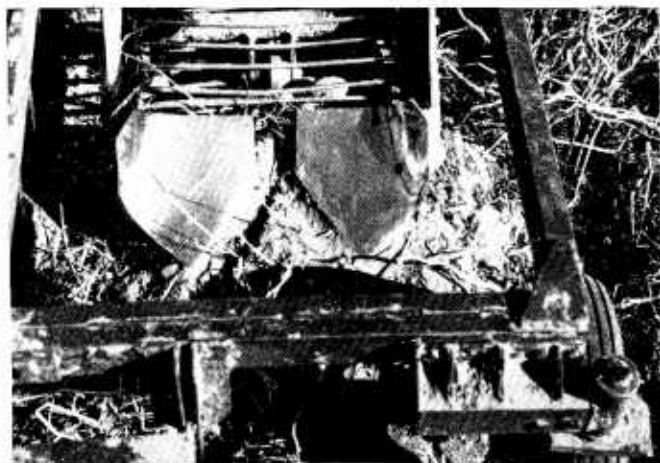
Efficiency of Operating Crew

Teamwork of the crew and the ability of the harvester operator are of utmost importance. One day's work of an unqualified operator may greatly reduce the net returns by lowering the grade and salability of the potatoes and increasing the amount of culls. The loss in quality, loss of operating time, and failure to care for the harvester may be two or three times as costly as the wages required to secure a good operator. The quality of the operator's work depends on his intelligence, aptitude, experience, skill, and incentive to do the best possible job.

From two to seven workers may be needed for hand sorting to remove tare material including clods, stones, vines, culls, cut potatoes, and potatoes damaged by frost. Hand sorters should be nimble fingered; many operators prefer women because of their manual dexterity. As some work positions on the machine are more tiring than others, it is a good practice to rotate workers to different positions each time across the field or each round.

Capacity of Potato-Handling Equipment

The capacity of the handling equipment should be keyed to the anticipated harvesting rate with a very liberal margin. Unloading equipment should



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FIGURE 5.—Two-piece or open-center blades similar to these are often preferred for conditions where tough root material tends to accumulate uncut on one-piece blades.

have a capacity from 50 to 100 percent greater than the average harvesting rate because its operation is less continuous. High capacity for quick unloading can sometimes reduce by one the number of trucks required, without unduly delaying the operation of the harvester. Maximum efficiency and economy depend on coordination of operations as well as on efficiency of the individual operations.

Preventing Unplanned Interruptions

Systematic periodic inspection and general preventive maintenance, including lubrication, adjustment, and general care of the harvesting machinery, are especially important because of the interdependence of the different operations.

Interruptions of harvester operation caused by machine failures that require repairs result in idle time for the trucks, the harvester crew, and the storage-house crew. Such idle time may cost from \$10 to \$15 per hour. Excessive interruptions in harvester operation have caused even greater losses where they have resulted in significant

acreage left unharvested with the coming of freezing weather.

Maturity Acceleration and Other Preharvest Precautions

Preharvest precautions, including maturity acceleration by timely vine killing, can contribute substantially to harvesting success by making the work easier and the crop less vulnerable to damage. Growers should keep this in mind during planting, cultivating, and other production operations. They should avoid soil compaction when it would aggravate the clod problem.

When neither frost nor natural maturity is adequate, mechanical mutilation or a recommended chemical treatment should be used to kill the vines and accelerate maturity. The action should be taken early enough to allow for 2 to 3 weeks of warm weather before harvest. In irrigated areas, it is advisable to withhold irrigation about 3 weeks prior to the planned harvest date.²

SPECIFIC DETAILS OF OPERATION

Blade Control and Performance

The performance and depth control of the blade are of major importance in the operation of a potato harvester. For each half inch of average depth of the blade, about 75 tons of soil are lifted per acre of operation. In muck-type soils, the weight is less. An extra soil load of about 1 ton per minute, resulting from operating the blade one-half inch deeper than necessary, may overload the aprons beyond their operating capacity. When this occurs, it may be necessary to reduce either the travel speed or the depth until one of the following occurs: (1) An occasional potato is cut; (2) the separating capacity is adequate; or (3) the soil blanket on the primary aprons becomes inadequate for protection against damage.

The blade should be polished enough to permit it to scour freely. Failure of the blade to scour freely, especially in certain types of soil, is a common problem. This failure may be caused by paint, rust, inadequate polish, too steep an angle with respect to horizontal, loose soil condition, or uncut material accumulated over the cutting edge. (See later discussion under "Reducing Spill-Out Losses.")

If unsatisfactory scouring persists, one or more of the following should be tried: (1) Deeper operation; (2) blades with smaller surface area (see fig. 4); (3) faster travel speed of harvester and truck; (4) open-center or two-piece blades (figs. 5 and 6); (5) a blade substitute—either driven rotary rod, undriven rotary rod, stationary round rod, or 1/2-inch pipe slotted on one side and slipped

over the cutting edge of a narrow blade (figs. 7 and 8).

In very heavy soil, uniform accurate depth control at the ideal depth is sometimes difficult to attain. This situation can be corrected by equipping the machine either with rubber-tired wheels or with spool rollers located just ahead of the blades. Without these and with the suction of the blades carried on the end of a long tractor drawbar, the total deflection in the drawbar itself, in the tractor tires, and in the machine frame may vary enough to make accurate depth regulation unattainable.

Factors Affecting Separation

Separation of potatoes from extraneous matter is a complex problem because of the extremely variable nature of the tare material and the widely assorted sizes and shapes of potatoes. Constantly changing soil conditions, temperatures, and crop characteristics produce problems requiring alert-

²For further details on maturity acceleration, the following references on vine killing are suggested:

HOUGHLAND, G. V. C. POTATO VINE KILLING. Div. Veg. Crops and Diseases, Bur. Plant Ind. and Agr. Engin., Agr. Res. Admin. unnumbered rpt., 5 pp. [Mimeographed.] 1952.

KUNKEL, R., EDMUNDSON, W. C., and BINKLEY, A. M. RESULTS WITH POTATO VINE KILLERS IN COLORADO. Colo. Agr. Expt. Sta. Tech. Bul. 46, 36 pp., illus. 1952.

SCHOENEMANN, JOHN A. BETTER QUALITY POTATOES THROUGH TIMELY VINE KILLING. In *Potato Handbook*, Machinery and Equipment Issue 3: 51-52. Potato Assoc. Amer. 1958.



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FIGURE 6.—These two-piece blades have a modified middle-buster design. The outer moldboard on each unit is intended to reduce the clod problem by deflecting packed soil from the shoulders of the ridge outward so that fewer clods are delivered onto the aprons.

ness and keen judgment on the part of the harvester operator.

The operator has several choices of combinations to meet the specific situation. Damp soil on apron rods may build up to a diameter of three-fourths to 1 inch, which greatly reduces the soil-separating capacity of the apron. At the same time, this provides excellent padding to reduce damage to the tubers. It may be practical to use higher apron speeds to offset partially the loss of separating capacity resulting from the reduced space between the heavily coated rods. Aprons with wider pitch and sprockets to match may be needed; or aprons with smaller rod size (three-eighths instead of seven-sixteenths inch) can be substituted advantageously until drier soil conditions prevail.

Pitch of Aprons

Pitch is the length of each individual link from hinge point to hinge point. Average pitch is the total length of an apron in inches, divided by the number of links. (Net distance between apron rods is sometimes erroneously referred to as "pitch.") Aprons with 1.56-inch pitch have been most common.

Use of aprons having wider pitch is often the best means of increasing separation. Pitches of 1.63, 1.76, 1.88, or even 2 inches, with suitable sprockets, may be used instead of 1.56-inch pitch. An apron of wider pitch, with sprockets to match, is recommended for use in adversely wet conditions (fig. 9).

When drier conditions prevail and reduce soil buildup, too many of the small potatoes are likely

to fall through the apron. When this occurs, these small potatoes can be saved by applying rubber digger tubing to the apron rods. This also protects the tubers from damage. Aprons with wide pitch are more suitable for round varieties than for long or flat types.

Magnitude and Frequency of Agitation

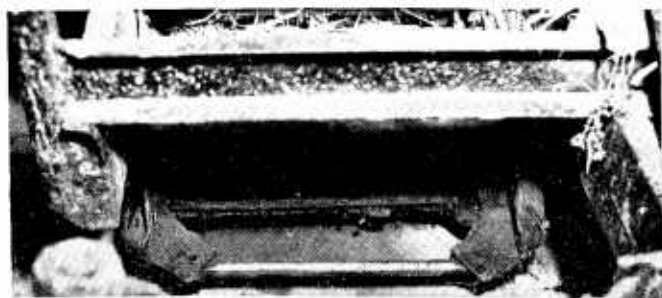
Agitation of the apron can be expensive when it is too severe. Its severity depends on its magnitude and also on apron speed and the amount of soil padding on the apron at the point of agitation.

The term "magnitude" as used here refers to the distance the apron rods are lifted in passing over a pair of idler rollers or a pair of agitator sprockets. The term "frequency" as used here indicates the number of times per minute the apron is lifted by any given pair of idler rollers or agitator sprockets. Frequency depends on the number of links passing for each lifting action, the apron operating speed (generally in terms of feet per minute), and the pitch of the apron. The frequency over round idlers is equal to the number of links passing per minute; thus, aprons with wide pitch have slower frequency than those with narrower pitch operating at the same number of feet per minute. This change in relationship is often an advantage for the apron with the wider pitch because the same frequency of agitation is reached at slightly higher apron speeds, which produces more thinning action in a given volume of soil. (See also the discussion under "Thinning the Flow and Increasing the Scatter.")

Agitator sprockets with varying magnitude and frequency are shown in figure 10.

All smooth idler rollers give the same frequency with a given apron speed and pitch. The smaller the roller with respect to the chain pitch, the greater the magnitude of agitation.

Plain round idler rollers under aprons may be considered as mild agitators of low magnitude and high frequency. Their frequency is equal to the



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FIGURE 7.—Under unfavorable soil conditions, a stationary 1-inch round rod with flattened ends bolted under the regular blade brackets, as shown here, has sometimes been more satisfactory than conventional blades. This unit is subject to further improvement in method of mounting.



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FIGURE 8.—The rotary rod blade-substitute shown here is power-takeoff driven at very low speed, as in rod weeders. Basically similar units have been produced by five or more manufacturers. Research, testing, and development are being continued.

number of chain links passing per unit of time. Their magnitude and degree of agitation depend on the material of which they are made and the relation between their diameter and the pitch of the apron. Large-diameter rubber idlers under a closely pitched apron would give the softest type of agitation. Idlers as small as 2 inches in diameter have been used. These require special mounting brackets. (See fig. 10.)

Rubber Covering for Apron Rods

Rubber covering should be used on apron rods to reduce damage to the potatoes if they are to be dropped from a height of 6 inches or more. This covering may be applied in the form of tubing, or it may be applied by dipping or by molding.

The tubing used for this purpose is often called "potato-digger tubing." It is manufactured in solid-wall type for rod diameters of $\frac{5}{16}$, $\frac{3}{8}$, and $\frac{7}{16}$ inch. The respective outside diameters of this tubing are $1\frac{1}{32}$, $1\frac{9}{32}$, and $2\frac{1}{32}$ inch.

Sponge-rubber tubing with $\frac{3}{8}$ -inch inside diameter and with outside diameters of three-quar-

ters and 1 inch are also used in some harvesters, but this type is less readily available at present.

Applications of rubber coating to apron rods by dipping and molding processes require special manufacturing facilities.

Relation of Pitch to Rubber Covering

A wide-pitch apron with rubber covering can be used for gentle handling of tubers without the loss of soil-separating capacity that would result from the application of rubber covering to a standard-pitch apron. Sprockets of matched specifications are required.

"Undersweep" and "Boiling"

"Undersweep" is a term used to describe the soil action of that part which is sifted through the front of the harvester apron and dragged forward by the lower side of the apron. (This soil is actually *recirculated* over the front of the apron.) It is important to understand this action and to take full advantage of it in the operation of both digger and harvester. This action makes possible



FIGURE 9.—Severe soil buildup on aprons, as shown here, greatly reduces separating capacity when heavy soil is very damp. Aprons with wider pitch are suggested for use in such conditions; they can be aprons whose pitch has been increased significantly by wear. There is need for development of a good apron cleaner.

the gentle lifting of potatoes onto the primary apron of an indirect harvester. It is also useful in the performance of diggers or direct harvesters.

The amount of undersweep varies with soil conditions, depth of operation, apron design (dimensional specification), accumulated wear (which has increased the pitch), apron adjustment (which determines the amount of sag behind the front idler rollers), and the location of lower apron-return idlers with respect to the front pair. Either the height or the distance of span between the front pair and the next pair of apron-return idlers to the rear may affect the amount of undersweep.

When undersweep action is excessive to the extent of being troublesome, it is often referred to as "boiling." This may be reduced by one or more of the following measures:

1. Removing one or more apron-chain links to reduce slackness of apron.
2. Relocating one or two pairs of apron-return idlers to change their height, length of span, or length of contact where underside of the apron drags soil forward.
3. Changing the position of the front idler rollers (cone rollers or cylindrical face type) vertically with respect to the blade.
4. Changing the spacing between rear edge of the blade and the front of the apron by fore-and-aft positioning of front idler rollers (same rollers as in suggestion 2 above but in different direction).
5. Changing the tilt of the blade in combination with suggestion 2 or without other change.
6. Increasing the depth of operation.
7. Inserting a bridge plate 10 to 18 inches wide close under the apron and just behind the cone rollers. (See fig. 4.) This reduces the amount of soil that falls through the front part of the apron.

Means for readily adjusting undersweep have been used experimentally, but manufacturers have not provided for such adjustment except by the means just listed.

Thinning the Flow and Increasing the Scatter

Thinning the flow or increasing the scatter of the potatoes and soil reduces bridging of the soil and increases the capacity for sifting material through the aprons. With pulled-type harvesters that have independent power units, or potato-harvesting machines with variable-speed drives, the depth of material carried on aprons and conveyor belts can be reduced by increasing apron speeds or by reducing travel speeds of the harvesters. Two advantages can be gained by these means. On tilted conveyor belts or aprons where separation is accomplished by lateral rolling—that is, crosswise to the direction of conveying—adequate scatter is a prerequisite to the most effective separation. This principle of increasing or decreasing scatter by changing relative speeds should be utilized to full advantage to increase separation under some conditions (wet, heavy soil; weedy fields; heavy vine growth) and to facilitate gentleness of handling and reduce rollback under intermediate and drier conditions.

With some harvesters, it is optional either to use a long, continuous primary apron, or to use ac-

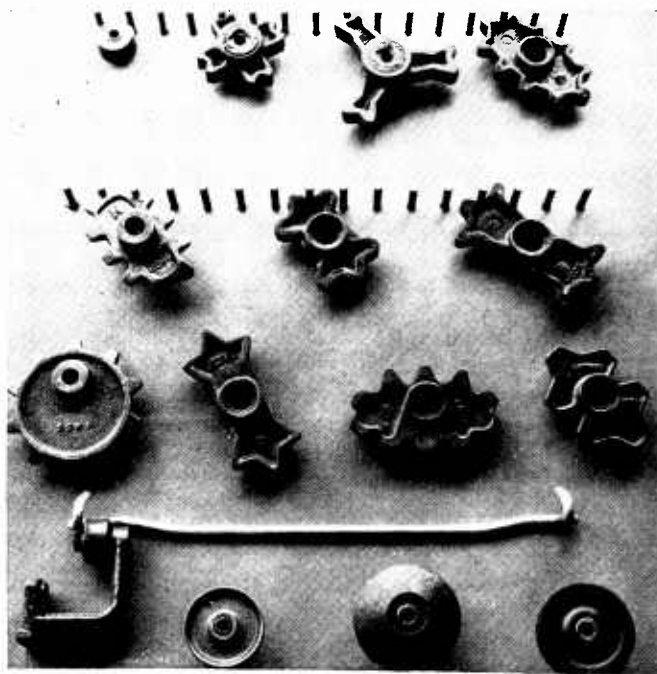
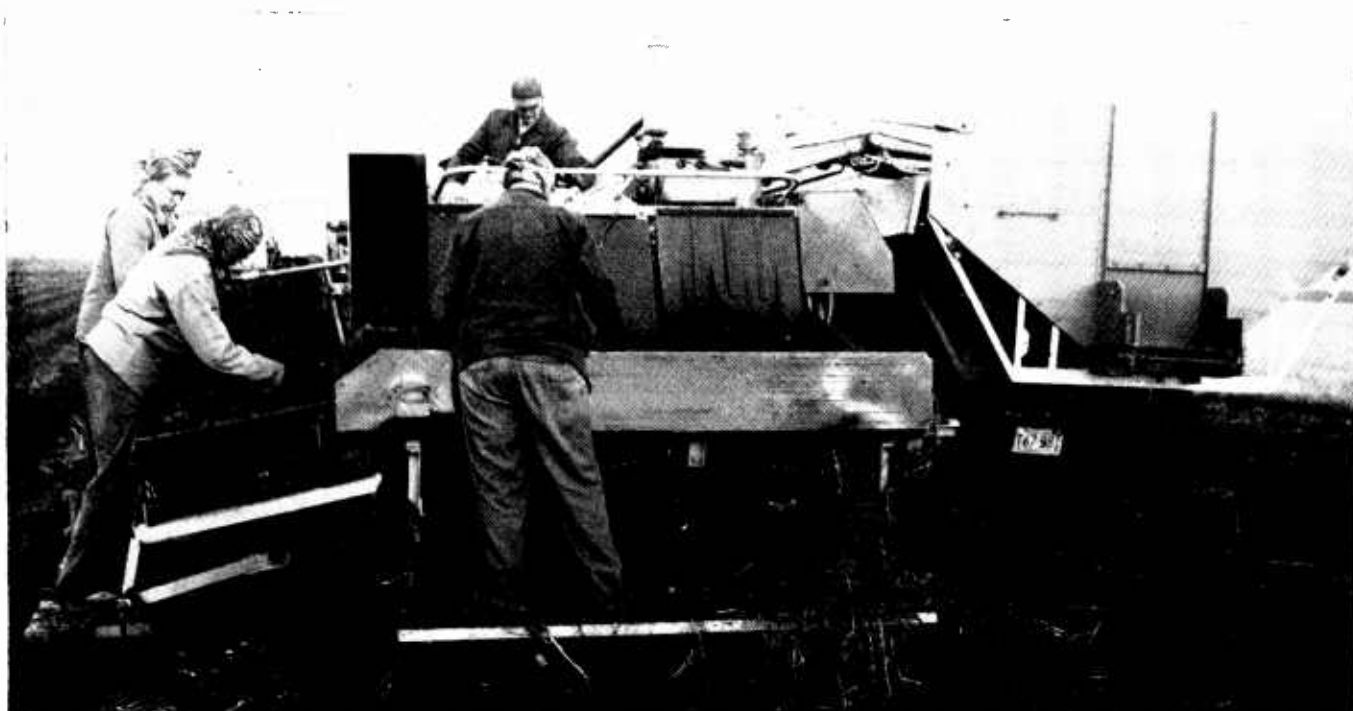


FIGURE 10.—A wide assortment of apron idler rollers and agitator sprockets offers a choice of different magnitudes and frequencies of agitation. The small 2-inch roller at the upper left requires a special mounting bracket, as shown at the lower left. The 4-inch roller at the lower right gives very soft, high-frequency agitation with approximately $\frac{1}{8}$ -inch magnitude. The second roller from the left in the top row gives a frequency half that of a round idler roller. Others shown give frequencies $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{1}{10}$ of plain-roller frequency. The agitator sprockets in the top row are represented in mesh with 1.56-inch chain pitch and in the second row with 1.63-inch pitch.



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FIGURE 11.—In the two-row direct harvester shown here, tilted-apron separation is featured in both the rear cross conveyor and the long double-lane conveyor on the left where most of the hand sorting is done. The right (upper) side of the conveyor on the left delivers tare material back onto the ground. Double lateral-roll fractionization, of which this machine provides an example, is now featured in several makes of harvesters popular in the Red River Valley.

cessories to convert this to the split-apron arrangement by dividing the long apron into two. In the latter alternative, the drop from the first section to the second is a partial substitute for agitation. This arrangement increases soil separation to meet wet conditions; but under dry conditions, increased depth of operation (undesirably deep) may be required in order to supply enough soil padding to protect the potatoes against the drop. The split-apron arrangement is not recommended for indirect operation because of the extra drop, generally without adequate soil padding on the apron.

Tilted-conveyor separation is probably the most widely used method of separating stones and clods larger than the smallest potatoes to be saved. (See fig. 11.) The degree of tilt in most of these is adjustable.

Belts and rubberized rod aprons are both used in these units. Belts require from 8° to 12° of tilt. Aprons require more tilt than do belts to produce an equivalent rolling action. Their tilt may range from 10° to nearly 30° . It is necessary to maintain scatter and avoid overloading these elements in order for them to operate effectively. If rod-type conveyors are used, it is important to keep them well rubberized. (See fig. 12.)

Rubber-roller table separators, which are most highly developed in Idaho (fig. 12), have a very high soil-separating capacity and are adapted to

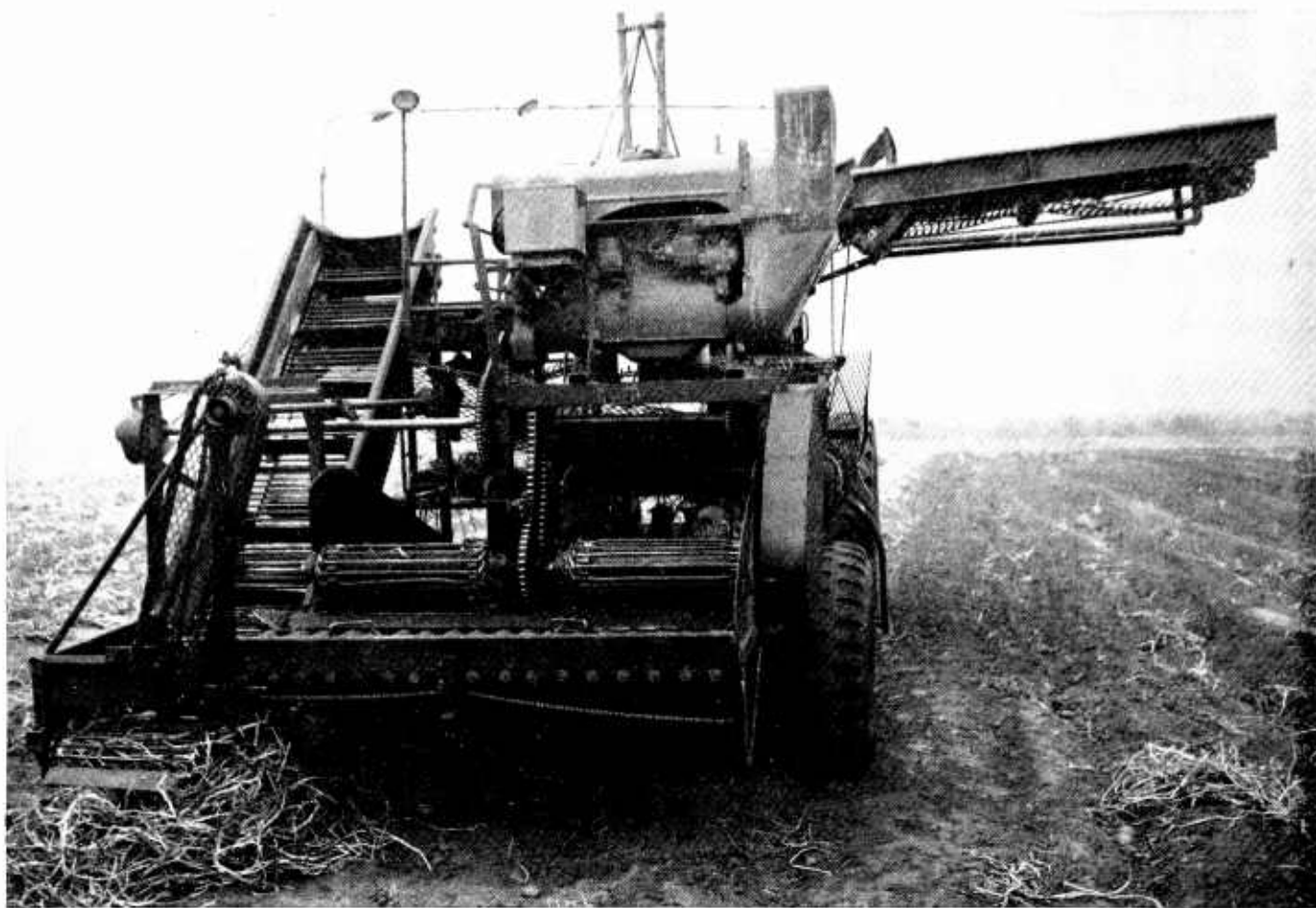
certain conditions. Their successful use has been limited to lighter soils and to soil conditions dry enough so that soil buildup on the rollers is not too troublesome. A full-capacity flow of potatoes over the rollers should be maintained to avoid continuous rolling without forward movement of individual potatoes, as this tends to increase skinning.

Vine Elimination

Vine removers, often called deviners, differ widely in design. Most of them can be classified under four general types: (1) Double wringer-roller with belts; (2) single-roller type, operating against the underside of an apron at delivery end; (3) wide-mesh apron (or strainer) type, some of which have stripper rollers; (4) airblast type. Each type has limited adaptation to specific conditions. The two most widely used are types 1 and 3. (See figs. 11, 13, and 14.)

Vine elimination by the use of an airblast is featured in machines employed where vines are likely to be completely dead and dry at harvest-time. The airblast type has become popular enough for use on dry vines to be considered a standard feature on some harvesters built chiefly for local distribution in Idaho.

Other types of mechanical vine removers that are still in the experimental stage do not fall under any of the classifications just mentioned.



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FIGURE 12.—This two-row direct harvester, built in Idaho, is representative of those featuring multiple rubber-roller separation. The resilient rubber rollers are usually about 3 inches in diameter and all turn in the same direction. They are most popular where harvest conditions are dry and soil buildup on rollers is not troublesome.

Recommendations applicable to all vine removers, or deviners, are to keep protective shields and safety devices in good condition, to avoid overloading, to keep drives and tension springs correctly adjusted, and to clean off accumulations of vines frequently.

Reducing Spill-Out Losses

It is essential to watch for spill-out losses that are only partly visible. Losses of this type are frequent, variable, and difficult to measure accurately. Losses of 15 bushels per acre are not uncommon, and losses up to 50 bushels per acre have been observed in some soils when blades were not scouring freely. Corrective measures include the following:

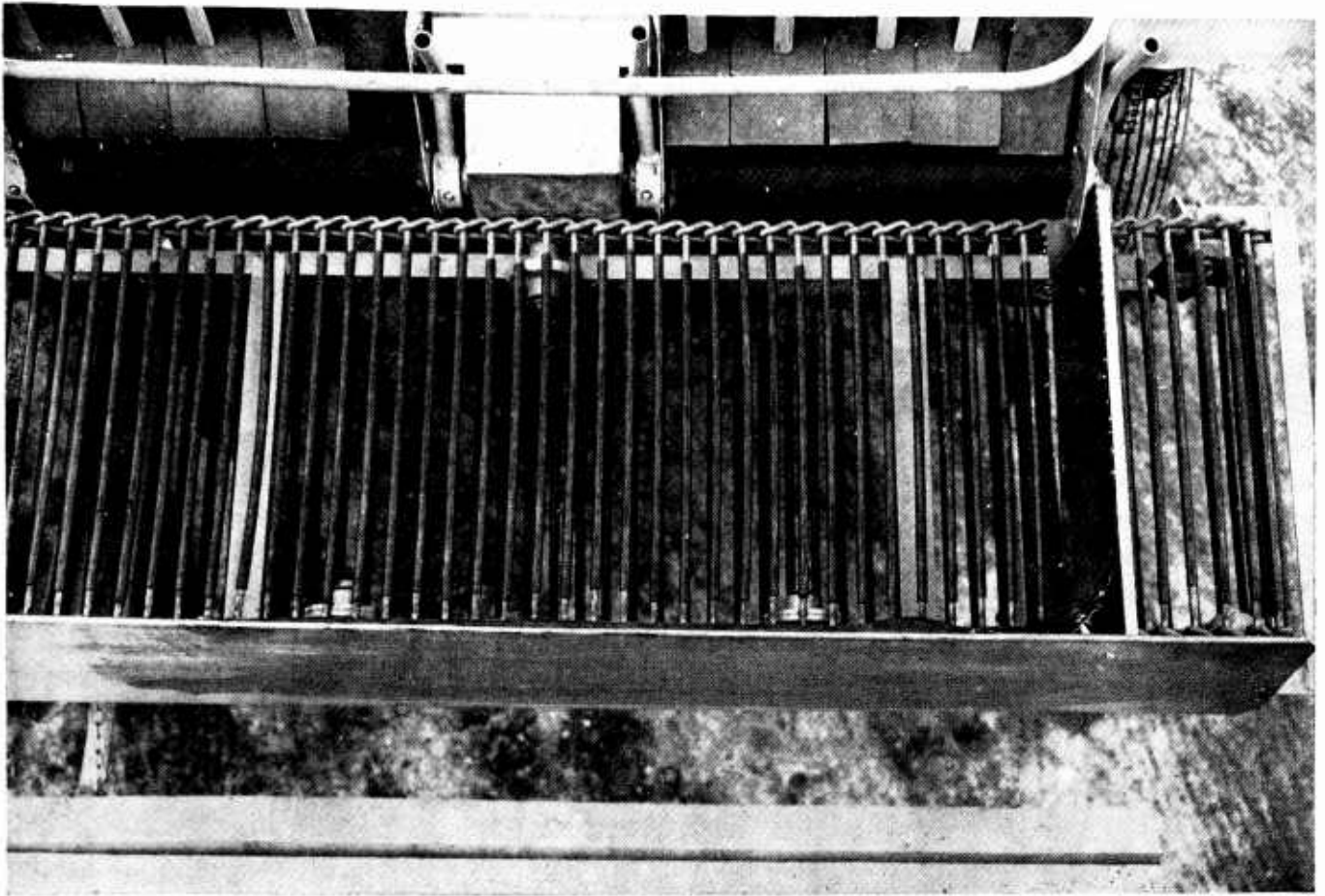
1. Cleaning and repolishing the blade.
2. Changing to different blade style or shape, or to a blade of smaller soil-contact area.
3. Substituting open-center or two-piece blade for single blade. (See figs. 5 and 6.)
4. Sharpening the blades if they fail to cut root material satisfactorily.
5. Increasing the operating depth of the blade.

6. Trying one of the blade substitutes—a stationary round rod (see fig. 7); a rotary rod weeder (see fig. 8); or a round-edged bar or a length of $\frac{1}{2}$ -inch pipe, slit on one side and slipped over the cutting edge of a narrow-type blade. In many instances, a positively driven, slowly rotating rod has been the most satisfactory accessory for handling old alfalfa roots or other material too tough to be effectively cut by blades. This accessory has been produced by three or more manufacturers of potato harvesters. It is well suited for use in muck or peat soils.

No satisfactory method has been found for keeping the aprons continually clean or for solving the problem of soil and root buildup which increases the working diameter of apron rods. (See fig. 9.)

Reducing Clod Problems

Clod problems resulting from wheel packing during seedbed preparation, cultivation, chemical application, or vine mutilation can best be reduced or minimized at their source. Surface clods resulting from hilling can be substantially reduced by the pressure of spool rollers ahead of the blade. Soft pneumatic rollers located on har-



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FIGURE 13.—This closeup view shows the double vine-remover belts in the machine illustrated in figure 11 and also the rubberized cross conveyor. Note that the location of the apron-supporting idler rollers is good. The single roller at the upper side of the apron is not directly under the point of delivery of the potatoes from the vine-remover belts to the apron. The delivery of potatoes onto the apron rods not directly supported by paired idler rollers tends to reduce the severity of impact.

vester aprons have been used with partial success where clods were not too hard, but they have not been satisfactory for severe clod conditions.

Clods from positions below the potatoes can be minimized at harvesttime by using shortened blades and operating as shallowly as feasible. Clods from shoulders of ridges can be minimized by more careful tractor driving during vine beating and by the use of harvester blades similar to those shown in figure 6.

For clods lifted by the harvester aprons and not readily reduced by agitation, there are three principal methods of elimination on the harvester: (1) lateral roll on tilted-belt or tilted-apron conveyors; (2) use of resilient rubber-roller tables; (3) hand sorting (as a supplement to mechanical separation). (See figs. 11 and 12.)

Efficient Hand Sorting

Efficiency in hand sorting can often be improved by proper coaching and practice. It has been demonstrated that hand sorting of materials carried

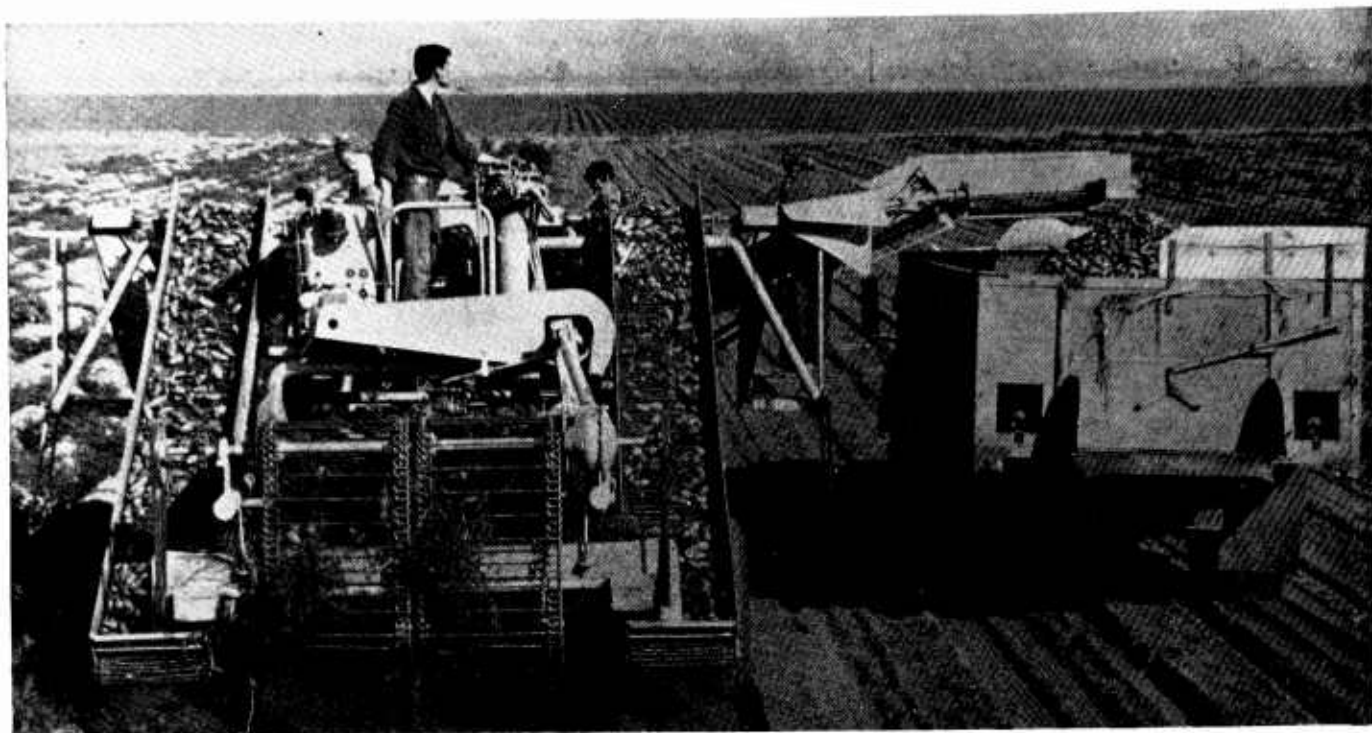
on a conveyor in front of the workers is more efficiently done when the workers toss the materials to the opposite side of the conveyor with a rotary arm movement than when they toss it behind them with a swinging arm movement.

When clods are soft enough to crush readily by hand, they can be eliminated more efficiently by pressing them through a rod apron than by grasping the clods and tossing them elsewhere.

Transferring the Potatoes Into Hauling Equipment

Careless transfer into hauling containers can cause considerable damage to the potatoes. However, little damage will occur if the bulk loader is continually adjusted so that the potatoes do not fall more than 4 to 6 inches.

Bulk handling from field to storage is adapted for very high capacity and maximum economy and requires no arduous labor. With power hydraulic controls on harvester bulk loaders, an alert operator can deliver potatoes very gently into self-unloading hopper truck boxes with almost negl-



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FIGURE 14.—The wide-mesh apron (or strainer) type of vine remover is shown in this machine. This illustrates an idea that has been widely used since about 1948. It is best adapted for use on unmutilated vines (vines that have not been partly destroyed with mechanical shredders), especially where the potatoes are mature enough so that they are not still clinging too tightly.

ble damage. The chief requirements are an alert and conscientious harvester operator, who should be reasonably experienced and skilled, and a similar qualified truckdriver. The truck should be equipped with a low-gear transmission, and it should be in good mechanical condition so that it will be responsive to the operator and will facilitate coordination of travel speeds of truck and harvester.

One manufacturer features a swingable bulk loader that is intended to reduce the risk of accidental damage to the equipment caused by lack of coordination of travel speed. Swingable bulk loader booms may be featured in future models by other manufacturers.

Crew Communication and Coordination

Communication between the harvester operator, the tractor driver, and the driver of the truck being loaded should be by simple and easily understood signals. Hand signals seem to be effective and practical. The harvester operator should be within easy reach of all controls and should be in position to observe and direct operations and maneuvers.

It is good practice to begin by filling a truck box about two-thirds of the way forward and to right of center, to work fore and aft evenly, and

to complete the filling by working from the far side to the near side.

Heavy log chains have been used between truck and harvester to equalize the rate of travel and thereby protect the harvester bulk loader against damage from lack of travel coordination between drivers. Tractor and truck drivers should be alert for visible signals from the harvester operator. When the truck is nearly loaded, the tractor driver should be especially alert to truck stalling. Many operators select only one truckdriver to drive each truck in turn while it is being loaded. With this arrangement, it is necessary to train only one truckdriver to respond to the operator's signals and coordinate the truck speed with the harvester movement.

Safety of Workers

Workers' safety should be guarded by proper maintenance of all protective devices, especially guards over chains, sprockets, and power-drive shafts. Alert supervision and an alert crew contribute to individual safety and to the productivity of the team. A warning signal just before a travel clutch or a machine clutch is engaged is good practice. Goggles and respirators may be needed for dusty conditions.

SUMMARY OF PRACTICAL SUGGESTIONS

The following suggestions, if carried out, will result in more profitable, safe, and efficient operation of potato-harvesting machinery and methods used under conditions set forth in this handbook.

1. Take all possible precautions before harvest to minimize the problems of oversize and immature potatoes as well as clods, weeds, and vine elimination.

2. In very stony soil, efforts to completely mechanize may be economically unsound except with some stone clearing. Stone clearing may be feasible on much of the acreage, but on steep slopes erosion may be serious enough so that it would be better to put the land to other use than for potatoes or any other root crop.

3. Choose the harvesting method and equipment most suitable to your particular requirements.

4. Have all equipment available and ready to operate in anticipation of requirements. Select equipment with adequate capacity to avoid bottlenecks during operation.

5. Select harvesting equipment, with enough capacity to insure completion of harvest before tuber temperatures fall below 40° F. If necessary to operate at low temperatures, use lower apron speeds and more gentle handling in order to offset the increased vulnerability of the potatoes to bruising.

6. Choose an alert, capable operator for the harvester.

7. Train the crew to work as a team and to aim at fully coordinated operations.

8. Control depth of operation for minimum damage to and maximum recovery of potatoes, and for regulation of the quantity of soil to be separated.

9. Regulate the travel speed to keep the quantity of soil lifted within the capacity of the aprons for separation without using severe or tuber-damaging agitation.

10. Regulate the apron speed and agitation in accordance with the natural soil padding or with the rubber covering on the apron rods. Use of low-magnitude agitation will give a wider practical range in apron speeds than is obtainable with high-magnitude agitator sprockets. Try to solve separation problems by thinning the flow of material rather than by increasing agitation.

11. Keep apron rods well rubberized where potatoes drop 6 inches or more.

12. Control the bulk loader for minimum drop and gentle delivery of potatoes into the truck box.

13. Use as wide a pitch as possible in digger-windrower and harvester aprons, consistent with the varietal shape and size of the potatoes being harvested.