# A Direct-Loading, Offset Pickup Machine for Citrus

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## ABSTRACT

A drip-line pickup system was designed to increase fruit-handling capacity and the efficiency of trash and unwholesome fruit separation and to reduce damage. The tractor-drawn pickup machine had a rod draper chain for pickup that allowed some trash to fall through it before reaching the double-belt trash eliminator. The pickup machine had a steered rear axle and a sorting conveyor for removing unwholesome fruit before the fruit were loaded directly into a high-lift truck. The average pickup rate and ground speed were 448 kg/min and 1.36 km/h, respectively, and fruit recovery efficiency was 98 percent.

## INTRODUCTION

In 1978, more than 6.85 million t of oranges were produced in Florida on 234,300 ha (579,000 acres) and 1.98 million t of grapefruit were produced on 48,700 ha (120,300 acres) (Fla. Agri. Statis., 1978). Approximately 87 percent of this production was processed into products. Mechanical harvesting for processed fruit has been under development since the late 1950s. The most common mechanical system uses abscission chemicals to loosen the fruit, shakers to remove the fruit to the ground, and windrowing and pickup machines to gather the fruit from the ground (Coppock, 1969, Whitney and Sumner, 1977, Sumner and Churchill, 1977, Wilson et al., 1977).

Raking equipment is used to gather the fruit to an accessible location for pickup (Churchill and Sumner, 1977). Pickup equipment for citrus has been under development since 1967 (Churchill et al., 1976). Marshall and Hedden (1970) designed and built an experimental machine for picking up oranges from the ground midway between two rows. Sumner and Hedden (1974) designed and built a combination rake-pickup machine equipped with oblique rakes to move oranges to the center of the area between rows for pickup. Churchill and Sumner (1977) reported on an offset pickup machine that picked up oranges gathered into a windrow at the tree dripline, about 1.8 m (6 ft) from the tree trunks, and placed them in a storage bin. An offset rake was used to gather the oranges into a windrow for pickup located at the tree dripline (Sumner and Hedden, 1980). The design and performance of the direct-loading pickup machine are given in this paper.

Article was submitted for publication in June 1980; reviewed and approved for publication by the Power and Machinery Division of ASAE in October 1980. Presented as Paper No. 80-1529.

Cooperative research by the USDA-SEA-AR, the University of Florida, Agricultural Research and Education Center, Lake Alfred; and the State of Florida Dept of Citrus.

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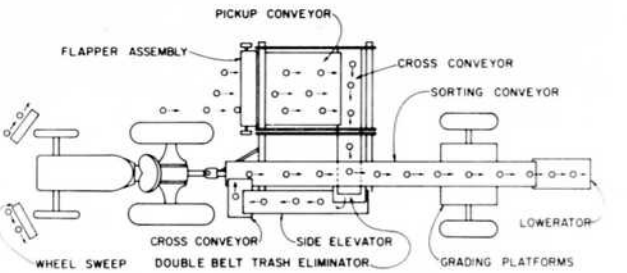


**FIG. 1 Plan view of fruit flow through direct-loading, offset pickup machine for dripline operation.**

The design requirements for an offset pickup machine (Churchill and Sumner, 1977) and those for a center-of-the-row pickup machine (Churchill et al., 1976) for citrus were incorporated in the design of the direct-loading offset pickup machine.

Specific design parameters were:

1 Tractor drawn with easy attachment and detachment to a grove tractor.

2 Steerable axle for ease of turning at row ends and staying in line with the windrow.

3 Low pickup profile for clearance (76.2 cm or 30 in.) under tree canopy.

4 Pick up fruit at the tree dripline, 1.8 m (6 ft) from the tree trunk.

5 Fold up pickup assembly to maximum width of 2.4 m (8 ft) for transport and turning at the row ends.

6 Trailable behind tow truck at 72 km/h (45 mi/h).

7 Powered by self-contained hydraulic system driven from the power-take-off at the tractor.

8 Provisions for hand sorting of unwholesome fruit on machine.

9 Pickup speed of 1.3 km/h (0.8 mi/h) in fruit load of 27 kg/m (18 lb/ft) of windrow.

10 Direct loading into grove high-lift truck.

11 Provisions for trash removal.

## DESIGN OF PICKUP MACHINE

Fig. 1 shows the fruit flow diagram for the improved offset pickup machine. This unit combined several proven principles from previous pickup machines and devices. It was tractor-drawn with a steerable rear axle, and loaded the fruit directly into a high-lift grove truck. Engineering specifications for the machine components are given in Table 1.

The pickup assembly consisted of two rod draper chain assemblies placed side by side to form a pickup frame 1.5 m (61 in.) wide. A flapper cylinder assembly measuring 35.6 cm (14 in.) O.D. × 1.5 m (5 ft) long was mounted just in front and above the pickup chain to assist in loading the fruit onto the chain. The side boards on the pickup frame extended 79 cm (31 in.) in front of

TABLE 1. ENGINEERING SPECIFICATIONS OF DIRECT-LOADING, OFFSET PICKUP MACHINE.

| | | | |
|---|---|---|---|
| Overall specification: | | | |
| Width and length (operating position) | | 4.3 x 9.3 m | (14.3 x 30.3 ft) |
| Width and length (transport position) | | 2.3 x 7.1 m | ( 7.6 x 23.4 ft) |
| Height and weight | | 3.4 m, 3810 kg | (11.2 ft, 8400 lb) |
| Draw bar weight (operating position) | | 1240 kg | (2734 lb) |
| Draw bar weight (transport position) | | 1440 kg | (3175 lb) |
| Tire size (2) | | 31.5 — 40.6 cm | (12.4 — 16 in.) |
| Axle (power steering) | | | |
| Component specifications: | | | |
| Pickup conveyor | | | |
| Rod draper chain | 1.11 x | 73.66 x 3.97 cm | (7/16 x 29 x 1 9/16 in.) |
| Frame width and height | | 154.9 x 76.2 cm | ( 61 x 30 in.) |
| Angle of incline (operating position) | | 22° | |
| Conveyor speed | | 41.5 m/min | (136 ft/min) |
| Cross conveyor | | | |
| Rod draper chain | 1.11 x | 73.66 x 5.08 cm | (7/16 x 29 x 2 in.) |
| Frame width | | 76.2 cm | (30 in.) |
| Conveyor speed | | 30.7 m/min | (100.74 ft/min) |
| First trash eliminator (belt) | | | |
| Frame width and length | | 76.2 x 41 cm | (30 x 16 in.) |
| Angle of incline | | 24° | |
| Conveyor speed | | 26.8 m/min | (88 ft/min) |
| Second trash eliminator (belt) | | | |
| Frame width and length | | 76.2 x 41 cm | (30 x 16 in.) |
| Angle of incline | | 26° | |
| Conveyor speed | | 38 cm/min | (125 ft/min) |
| Side elevator | | | |
| Rod draper chain | 1.11 x | 73.66 x 5.08 cm | (7/16 x 29 x 2 in.) |
| Frame width | | 76.2 cm | (30 in.) |
| Conveyor speed | | 38 m/min | (125 ft/min) |
| Short cross conveyor (belt) | | | |
| Frame width and length | | 61 x 66 cm | (24 x 26 in.) |
| Conveyor speed | | 78.3 m/min | (257 ft/min) |
| Sorting conveyor (belt) | | | |
| Frame width and length | | .61 x 6.8 m | (2 x 22.2 ft) |
| Conveyor speed | | 45 m/min | (147.5 ft/min) |
| Lowerator (belt) | | | |
| Frame width and length | | .61 x 2.5 m | (2 x 8.3 ft) |
| Conveyor speed | | 0 — 152 m/min | (0 — 500 ft/min) |
| Pickup flapper assmebly | | | |
| Length and diameter | | 1.5 m x 35.6 cm | (5 ft x 14 in.) |
| Rotation speed | | 60 rpm | |

the chain to prevent oranges from rolling from the windrow. Two gauge wheels, that were mounted to the frame at the front of the pickup chain controlled the depth of the pickup assembly by following the ground contour. The overall height of the pickup frame was 76.2 cm (30 in.) which provided a low profile for clearance of foliage at the tree dripline.

From the pickup chain, the fruit were discharged onto a rod draper chain cross conveyor that elevated them and then discharged them onto a double-belt trash eliminator system, as shown in Fig. 2. The first belt assembly of the trash eliminator was set at an incline of 24 deg from horizontal to remove maximum trash and the second belt assembly of the trash eliminator was set at a slightly greater incline to remove most of the remaining trash without losing wholesome fruit. After the fruit passed over the trash eliminator system, they discharged onto the side elevator. From the side elevator, they fell onto a short, cross conveyor belt that transferred them onto the sorting belt. Platforms were mounted on both sides of the sorting conveyor to accommodate three hand sorters, if necessary, for separating out any remaining trash, plus unwholesome fruit. From the sorting conveyor, the oranges fell onto a cleated belt conveyor (lowerator) that had an adjustable speed control to uniformally distribute them into the high-lift grove truck.

Hydraulic power was supplied by two hydraulic pumps, 114 L/min (30 gal/min) and 25 L/min (6.5 gal/min) attached to a 1:4 ratio gear box that was attached directly from the power-take-off of the tractor. This arrangement provided for easy detachment from and attachment to the tractor. The hydraulic diagram is shown in Fig. 3.

The pickup conveyor and part of the cross-conveyor directly behind the pickup conveyor were tilted up to the main frame for transporting to and from the grove.

Hydraulic valves mounted directly behind the tractor driver controlled the power steering, tilt for transport, and a pickup depth. In addition, four valves were

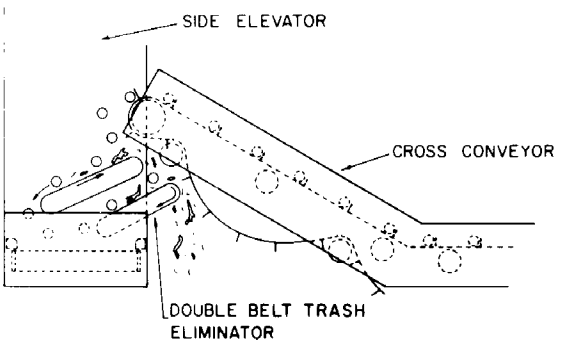


**FIG. 2 Double belt trash eliminator system on direct-loading, offset pickup machine.**

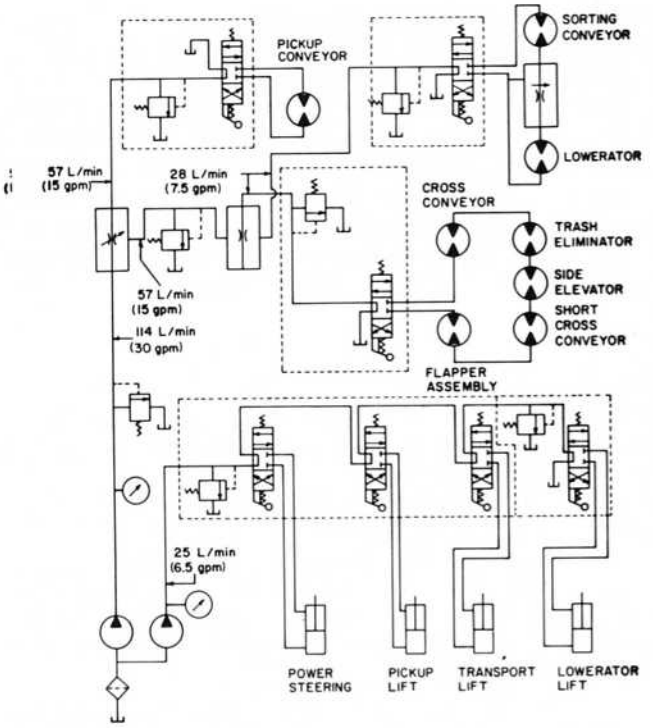


**FIG. 3 Diagram of hydraulic system for direct-loading, offset pickup machine.**

mounted on the sorting-conveyor frame. One controlled the pickup conveyor; another controlled the cross-conveyor, trash eliminators, side elevator, short-conveyor, and flapper; another controlled the sorting belt and lowerator belt; and the fourth controlled the adjustment for raising and lowering the height of discharge into the high-lift truck. The lowerator was lowered perpendicular to the ground for turning at row ends. A high-lift truck was pulled directly behind the pickup machine for loading. The sorting and discharge conveyors were controlled separately to allow fruit to be stored on the machine when starting a new row. This allowed the high-lift to pull into place and hook up to the pickup machine without spilling fruit.

The offset pickup machine required only a tractor operator and a high-lift truck operator. As the high-lift was loaded, the truck operator controlled the pickup machine by operating the four control valves. Two additional hand sorters were used, if necessary under conditions of heavy trash and unwholesome fruit. Fig. 4 shows the offset pickup machine in field operations.

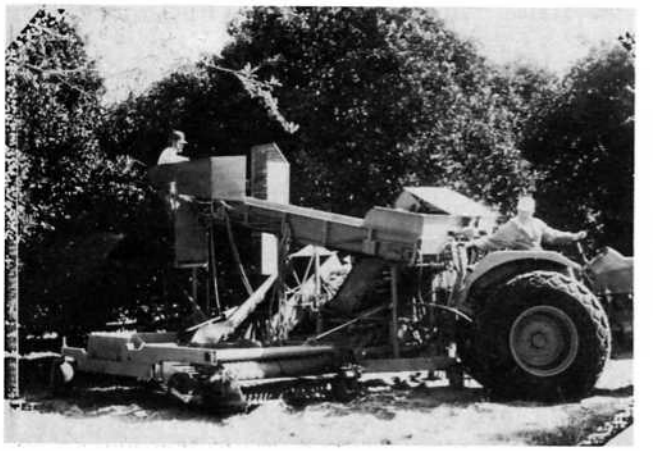

**FIG. 4 Direct-loading, offset pickup machine in field operation.**

## PERFORMANCE

The direct-loading, offset pickup machine was tested during the 1979 harvest season under a variety of grove conditions in which it picked up 16,850 boxes of grapefruit and oranges. Minor modifications were made by relocating the pickup chain headshaft, and the discharge onto the double-belt trash eliminator to improve recovery efficiency. The performance met the general design parameters. Transporting and maneuvering in the grove caused no problems in hedged groves with 2.4 m (8 ft) middles between the tree rows.

Data on performance of the direct-loading, offset pickup machine are summarized in Table 2. The average ground speed was 1.36 km/h (0.85 mi/h), and the average down the row fruit pickup rate was 448 kg/min (986.8 lb/min).

Field efficiency (pickup time ÷ total time) of the pickup machine was approximately 60 percent and depended on the amount of time waiting for the truck to empty and return. The waiting time varied with the length of row, number of skips in the row for turning around, distance to the roadside trailer, and number of trucks being used for the hauling operation.

The double-belt trash eliminator satisfactorily

**TABLE 2. TEST RESULTS OF THE DIRECT-LOADING, OFFSET PICKUP MACHINE, 1979.**

| Florida location | Citrus cultivar | Fruit harvested, 1,000 kg (1,000 lb) | Fruit* load, kg/m (lb/ft) | Avg speed, km/h (mph) | Pickup† rate, kg/min (lb/min) | Recovery‡ efficiency, % |
|---|---|---|---|---|---|---|
| North Central | Parson Brown | 48.0 (105.0) | 16.1 (10.8) | 1.6 (1.0) | 431 (950) | 99 |
| Central | Marsh (grapefruit) | 14.3 (31.5) | 26.8 (18.0) | 0.8 (0.5) | 359 (792) | 99 |
| Central | Hamlin | 71.4 (157.5) | 21.4 (14.4) | 1.6 (1.0) | 575 (1267) | 98 |
| Central | Valencia | 318.2 (701.6) | 21.1 (14.2) | 1.6 (1.0) | 567 (1250) | 99 |
| South | Hamlin | 235.6 (519.3) | 15.2 (10.2) | 1.2 (0.8) | 327 (720) | 97 |

*kg of fruit in the windrow per m length
†Down-the-row rate
‡Recovery eff % = $\frac{\text{fruit recovered}}{\text{fruit in windrow}} \times 100$

separated trash and unwholesome fruit from good fruit over a wide range of pickup rates. However, some fruit were lost with the trash when the trash was dense. Wet trash caused more of a problem than dry trash. The dry trash fell through the rod draper chain or was carried out on the trash belts. Wet grass and weeds built up at the discharge point between the pickup chain and cross-conveyor chain causing it to wrap around the head shaft and pull fruit between the two conveyors. Three hand sorters were used when trash was excessive.

The rod draper chain on the pickup conveyor easily broke up pieces of dead wood 1.3 cm (0.5 in.) in diameter or less. The flapper assembly in front of the pickup chain reduced the power requirement of the pickup chain and made possible the recovery of all the fruit at the end of the row. Recovery efficiency was about 98 percent in all groves. Because of wear from direct contact with the sandy soil, the rod draper pickup chain had a service life for handling approximately 20,000 boxes of fruit. However, the other conveyors showed little wear.

In comparison with the original offset pickup machine, the direct-loading, machine had a wider pickup width and a double-belt trash eliminator system which increased the pickup rate by an average of 3 boxes per min. The cross-conveyor had more ground clearance and didn't drag on the ground in unlevel groves. The pickup and cross-conveyor assemblies could be tiled up to 90 deg for transport or turning at the row ends without needing to disconnect the chain to obtain enough slack to tilt the pickup assembly to a vertical position. This machine had a sorting conveyor where 1 to 3 hand sorters (depending on the fruit condition) could grade out unwholesome fruit before it was conveyed into the high-lift truck.

## SUMMARY

The direct-loading, offset pickup machine for citrus was designed, built and tested to meet the established parameters. Increased capacity was obtained with the wider pickup width. The double-belt trash eliminator did an adequate job of removing trash and was not a limiting factor in pickup capacity. A sorting conveyor was provided for removing unwholesome fruit before loading directly into the high-lift truck. It performed satisfactorily and was maneuverable in the grove. At an average ground speed of 1.36 km/h (0.85 mi/h) the pickup rate was 448 kg/min (986.8 lb/min) with a recovery efficiency of 98 percent. This pickup machine met the design objectives and provided for hand sorting if necessary.

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