Catching Frame Development for a Citrus Harvest System

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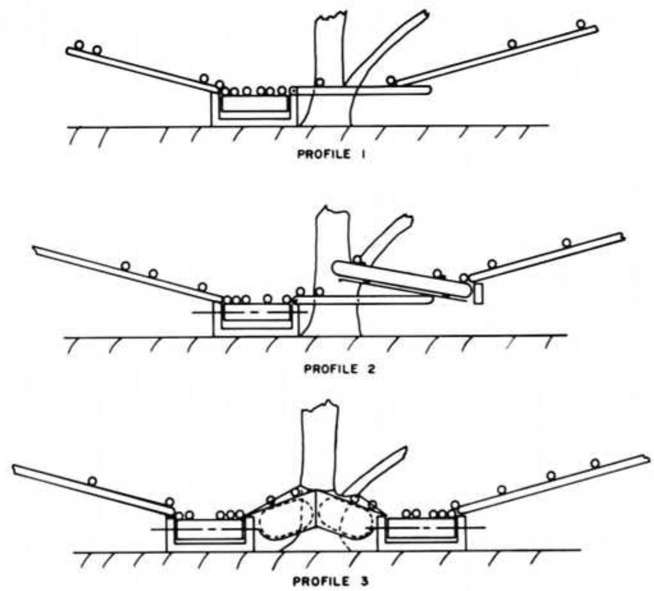

FIG. 1 Sketch of the catching frame profiles tried and methods of forming a fruit seal between frames and around the trunk of the tree.

IN 1974, Florida citrus plantings totaled 330.8 thousand hectares (817.3 thousand acres), which produced 9.3 million metric tons (230.3 million boxes) of fruit. Approximately 85 percent of this production was processed into products (reference 4). The crop was harvested almost entirely by hand labor.

Florida citrus industry has been searching for several years for ways to avoid total dependency on seasonal labor for harvesting the crop. Mechanical systems have been developed for fruit destined to be processed into products, but they have received only limited industry acceptance (Coppock 1969). The main reason has been the low economic justification obtained under a wide range of conditions.

Limb shaker-catching frame harvest systems similar to those successful in other tree crop industries have shown considerable merit in citrus, especially when assisted by an abscission chemical to loosen the fruit (Coppock and Hedden 1968, Wilson 1969). A problem in the acceptance of these systems has been in the development of a catching frame that would fit a wide range of operating conditions without it becoming too expensive, fragile, complex or bulky for effective performance. A "catch dump" catching frame concept was conceived which showed promise of overcoming problems encountered with previous frames. A review of developments leading up to the "catch-dump" concept, the development of the concept into a harvest system and the system performance are reported in this paper.

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EARLY DEVELOPMENT WORK

The main thrust of powered catching frame development began about 1960 when light-weight inertia shakers suitable for mounting on frames were developed. In 1968, Coppock and Hedden reported on an experimental shaker-catching frame harvest system which employed two tractor-drawn frames, one for each side of a tree. One frame contained fruit handling conveyors and the other one deflected the fruit across a seal onto that frame. Coppock (1967) reported on another version of this harvest system which incorporated a fruit conveyor in each frame with a crossover conveyor at one end. This enabled each frame to operate independently thus eliminating the necessity of having to closely align them on the trees.

International Harvester Company initiated the commercial development of a shaker-catching frame harvest system for citrus in 1965 (U.S. Patent No. 3,347,032). They used a roll-up cloth frame concept with longitudinal fruit conveyors located on each frame. The frames were tractor mounted and incorporated their own fruit handling equipment. To complete the system an automated inertia shaker operated from the tractor seat was mounted on each tractor. The shakers were positioned by telescoping the boom and moving laterally along the tree canopy.

These early harvest systems revealed several catching frame design requirements necessary for use under a wide range of operating conditions. The shaker positioning mechanism must enable the shaker to reach and clamp onto all major limbs located on one-half of a tree. To do this the shaker must move in three dimensions relative to the catching frame, that is, in and out of the tree, laterally along the tree canopy and vertically. Lateral movement relative to the tree canopy was essential to avoid interference with limbs projecting directly toward the base of the positioning mechanism. It was essential that the operator view the positioning of the shaker clamp whether or not the shaker was controlled from a station on the frame or from a position on the shaker. This was accomplished best by sighting along the shaker boom. Heavily foliaged trees made viewing difficult especially if the limbs were low to the ground.

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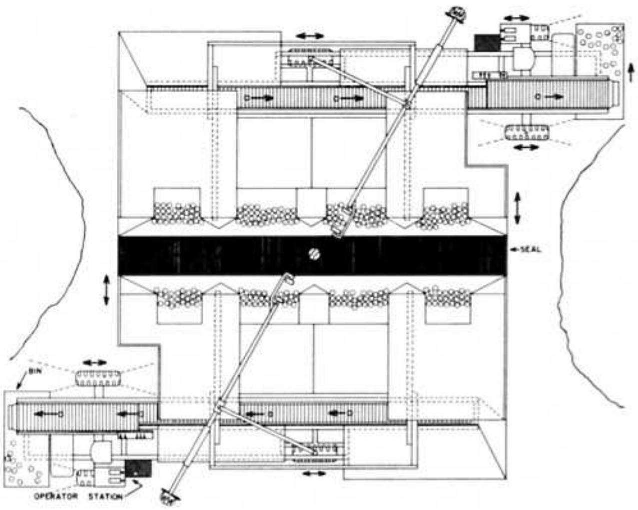

FIG. 2 Plan view of shake-catch harvest system in operating position showing the relationship of component parts. Both catching frames are identical so one back and the other drives forward down the row.

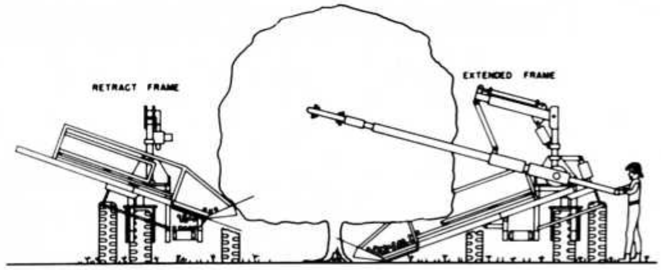

FIG. 3 Sectional views of the catching frames with surfaces extended and retracted showing "catch-dump" concept.

An effective fruit seal must be formed between the frames at the base of the tree when they are pushed together. It was necessary that limbs branching out below 18 in. on the trunk be removed in preharvest preparation. The catching frame profile and the sealing method of the early harvest systems are compared in Fig. 1. In Fig. 1, profile 1, the seal was formed by placing "V" shaped openings in overlapping panels around the trunk of each tree. This maneuver required excessive time and operator skill. When a tight seal was not obtained the catching surface funnelled the fruit into any opening resulting in large fruit loss. Poor fruit drainage was obtained on the deflector frame when it was on the lower side of a sloping terrain. In profile 2, the fruit from one frame was moved across the seal with panel conveyors extending almost the length of the seal on to the other frame containing a longitudinal conveyor. This arrangement helped alleviate the sloping terrain problem encountered in profile 1, but still required considerable operator skill for positioning. Profile 3 enabled a more efficient seal to be devised. The frames were built symmetrically about the row line with a conveyor on each side, thus lowering the profile and enabling the frames to pass easily under low hanging branches. This arrangement enabled a bumper seal to be used so that the frames could be pushed together without critical alignment on the trunk. When an opening occasionally occurred in the seal only the fruit falling over the opening was lost. The frames operated equally well on sloping and level terrain since they performed as independent machines.

In the earlier harvest systems fruit was conveyed continuously from the frames during the harvest operation. A cross conveyor was used to move fruit from a longitudinal conveyor to a fixed discharge point on the frame. This restricted operation to when the frame was fully extended and made it essential that a fairly constant distance be maintained between the propelling unit and the trunk of the tree. A "catch-dump" catching frame design concept which showed considerable promise in overcoming some of the problems encountered with previous catching frames was conceived. It consisted of placing a catching frame under a tree, collecting the fruit in basins on the frame and dumping it as the machine moved to the next tree.

DEVELOPMENT OF HARVEST SYSTEM

A harvesting sysxtem was developed using catching frames incorporating the "catch-dump" frame concept. It was designed to handle fruit in a manner compatible with presently available equipment for transporting. Schematic diagrams of the harvest system are shown in Fig. 2

TABLE 1. DESIGN SPECIFICATIONS.

Machine	Hyd powered
Length	792 cm (26 ft)
Wheel base	518 cm (17 ft)
Turning radius	579 cm (19 ft)
Weight (empty)	4692 kg (10,300 lb)
Ground speed	4 forward and 1 reverse
Road	9.6 km/hr (6 mph)
Operating	1.6-3.2 km/hr (1-2 mph)
Engine	29.8 kw (40 hp)
Transport unit	3-wheel
Tires (front)	14-17.5
Tires (rear)	18-10.50
Wt on rear wheels (unloaded)	2540 kg (5600 lb)
Wt on front wheels	2041 kg (4500 lb)
Rear wheels (differential dr)	6:1 ratio
Front wheels (chain dr)	3:1 ratio
Max torque to ground (all wheels)	2016 kg-m (14583 lb-ft)
Catching surface	
Extend	472 x 792 cm (15.5 ft x 26 ft)
Retracted	335 x 792 cm (11 ft x 26 ft)
Cover material	CH-4 Astro turf on expanded metal
Fruit holding cap	408 kg (900 lb)
Extension relative to trans frame	274 cm (9 ft)
Fruit handling	
Conveyor	50.8 mm (2-in.) pitch, rod draper chain
Width	47.7 mm (18-in.)
Speed	12.19 cm/sec (0.40 fps)
Storage bin cap	408 kg (900 lb)
Positioning mechanism	
Turret lift arm (extendable)	91-213 cm (3-7 ft)
Rotation speed at end of 7 ft arm	30.48 cm/sec (1 fps)
Lift speed at end of arm	15.24 cm/sec (0.5 fps)
Suspension	Pendulous
Shaker mechanism	Inertia type
Reciprocating wt rel to crank	74.84 kg (165 lb)
Unbalance wt	184.16 kg (406 lb)
Stroke of reciprocating wt	203 mm (8 in.)

and 3, and the design specifications are listed in Table 1.

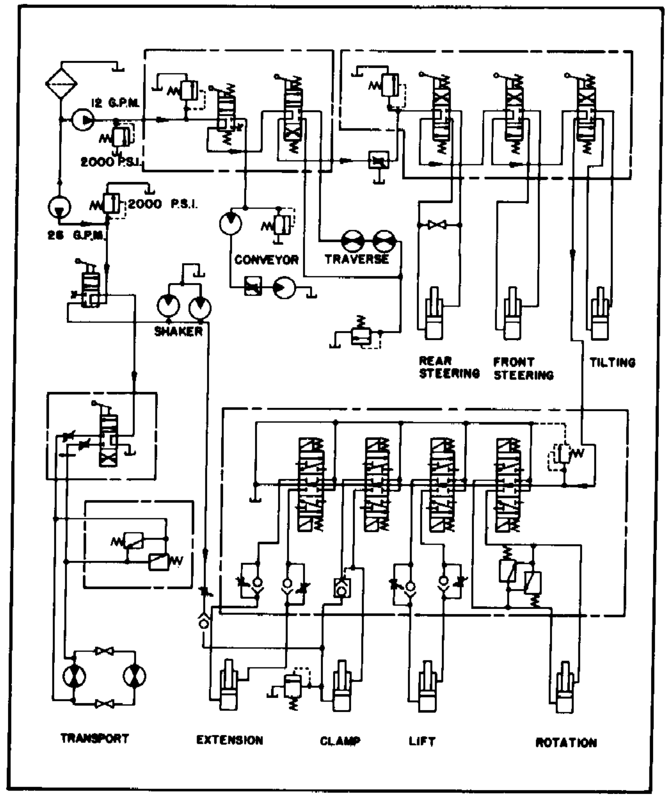

FIG. 4 Graphic diagram of hydraulic system for catching frame employing "catch-dump" concept.

A 3-wheel transport unit was used in a compromise between weight distribution, maneuverability and simplified catching surface construction. Two wheels were hydraulically powered through an axle containing a differential and the third wheel hydraulically powered through a chain drive. Torque requirements of all wheels were balanced and connected parallel in the hydraulic circuit. A framework to resist high torques was constructed between the 2-wheel axle and the third wheel to support the weight when catching surfaces were extended. The shaker positioning mechanism was pivoted over the third wheel and the major hydraulic components concentrated near the engine and operator's position. The shaker positioning controls were located on the shaker but the shaker speed control was located on the transport unit. All controls other than the shaker positioning were located accessible to the operator from either the operator's seat on the machine or from a standing platform. This feature enabled the use of either one or two operators.

Each frame consisted of sloping padded surfaces with 4 rectangular basins at the lower side to collect the fruit. Cam operated panels were provided in the bottom of the basins to open when the frames were retracted, dumping the fruit onto a longitudinal conveyor. The catching surface was made of expanded metal covered with C-4 Astro Turf which provided a durable surface that kept fruit bounce to a minimum. Two cam-operated panel doors were built in the catching surface to accommodate the shaker mount and third wheel when the catching surface was retracted.

Bumper row seals extending the full length of the frames were used. The portion of the seal which contacted the tree was made of fabric covered polyurethane foam but the outer portion was Astro Turf covered panels hinged to the frame. Flexibility of the material accommodated some misalignment of the seals encountered in positioning the frames.

A straight through fruit handling and cleaning system was built into the transport unit to remove trash and to move the fruit to a storage bin. It consisted of a longitudinal conveyor and a 45-deg elevator made of steel rod draper chain. The longitudinal conveyor slowly fed the fruit into the elevator which was operated at a faster speed. This spread the material so that the leaves and sticks would drop through the chain openings.

An inertial shaker and positioning mechanism similar to the one described by Coppock and Hedden (1968) were used. Construction of the shaker was simplified and the lift arm made extendable to allow some shaker translation along the frame. Six of the eight positioning movements were electrically controlled but hydraulically powered. The other movements, tilt and rotation, were hand powered. Controls for the powered movements were located on the shaker handle easily accessible to the operator.

A graphic diagram of the hydraulic system is given in Fig. 4. A dual purpose power circuit was used for propelling the machine and for operating the shaker since the power demands for these functions were similar and the operations performed at different times. Other circuits, were used for positioning the shaker, positioning catching frame surfaces and operating the conveyors. The power circuit was connected to the clamping circuit so that it would recharge that circuit should the pressure drop during shaker operation.

PERFORMANCE

The harvest system performed well mechanically when harvesting trees in previously prepared groves. Preparation consisted primarily of removing low-hanging limbs, hedging trees in drive middles, and removing water sprouts from inside the trees. Although the initial cost of preparation was high, it would be necessary only every 3-5 yrs. The hydraulic systems on the catching frames were adequate for extended operation, but some difficulty was experienced with the panel doors on the catching surface blocking the view of the operator when the surface was retracted. The "catch-dump" concept worked satisfactorily but a slight problem was encountered in handling dead limbs which were sometimes shaken off. This usually occurred when the trees were mechanically harvested for the first time. One operator was able to handle each catching frame but it was evident in high yielding trees that an extra operator would have increased the harvest rate.

Typical performance characteristics of the harvest system in 'Hamlin' oranges where the trees had been pruned and the fruit loosened with an abscission chemical are given in Table 2. Included in the system was a worker who followed the catching frame, picking that fruit left on the skirts of the trees and picking up the fruit that missed the catching surfaces. A 98.3

TABLE 2. PERFORMANCE CHARACTERISTICS OF THE SHAKE-CATCH HARVEST SYSTEM IN 'HAMLIN' ORANGES*.

Fruit yield, boxs/tree†	6.0
Sustained harv. rate, trees/hr	16.2
Sustained harv. rate, boxes/hr	97.2
Fruit recovery eff., percent‡	98.3
Fruit picked up, percent	4.5
Fruit picked from skirts, percent	1.2
Fruit removed with stems, percent	3.6
Fruit split, percent	1.0
Diesel fuel consumption, l/hr	8.0

*Trees were pruned for the harvest system
†Florida field box weighs 40.8 kg (90 lb)
‡Includes fruit picked from skirts and picked from ground

TABLE 3. TIME AND MOTION STUDY OF ONE CATCHING FRAME IN SHAKE-CATCH HARVEST SYSTEM IN 'HAMLIN' ORANGES*.

Elements	Percent of total time	Cycles per tree	Std time per tree (min)
Move to tree	6.2	1.0	0.27
Position frame	5.2	1.0	0.23
Position shaker	38.7	5.0	1.70
Shake limbs	25.5	4.0	1.12
Retract frame	6.4	1.0	0.28
Empty bin	7.3	0.3	0.32
Avoidable delay	0.9	0.1	0.04
Unavoidable delay	10.0	0.3	0.43

*Bins emptied every three trees

percent fruit recovery efficiency was obtained with 5.7 percent of this coming from the fruit gleaned by the worker.

Results of a time and motion study of one catching frame operating in the shake-catch system are given in Table 3. Positioning the shaker and shaking the limbs consumed 64.2 percent of the operational time. This area offered the greatest potential for increasing the harvest rate either by improved design or by tree shaping. Ten percent of the time was spent in unavoidable delays. This is an indication of the catching frames operator's inability to coordinate the operation so that both machines were in operating position at the same time.

SUMMARY

Performance study of several shaker-catch citrus harvest systems resulted in a new catching frame concept. A harvest system incorporating the new catching frame was developed and tested in oranges. Tests conducted in 'Hamlin' oranges previously prepared by tree shaping and abscission chemical application resulted in the following typical performance characteristics: sustained harvest rate of 16.2 trees per hr (97.2 boxes per hr), fruit recovery efficiency of 98.3 percent and fruit split of one percent.

References

1 Coppock, G. E. 1969. Review of citrus harvest mechanization. p. 777-819. IN: B. F Cargill and G. E. Rossmiller (Technological Implications). Fruit and vegetable harvest mechanization.

2 Coppock, G. E. and S. L. Hedden. 1968. Design and development of a tree shaker system for citrus fruit. TRANSACTIONS of the ASAE 11(3):339-342.

3 Coppock, G. E. 1967. Harvesting early and midseason citrus fruit with tree shaker harvest systems. Proc. Fla. State Hort. Soc. 80:98-104.

4 Florida Agricultural Statistics-Citrus Summary, 1974. Florida Dept. Agr. and Consumer Services.

5 Wilson, W. C. 1969. Four years of abscission studies on oranges. Proc. Fla. State Hort. Soc. 82:75-81.