LITERATURE CITED

1. Biale, J. B. 1954. Physiological requirements of citrus fruits. Citrus Leaves **54**: 11, 29.
2. Hayward, F. W., M. F. Oberbacher and W. Grierson. 1961. Perforation in polyethylene bags as related to the decay of oranges. Proc. Fla. State Hort. Soc. **74**: 237-239..
3. Hopkins, E. F. and K. W. Loucks. Citrus decay. Citrus Industry **27**: 10: 11-14.
4. Kaufman, J., R. E. Hardenburg and J. M. Lutz. 1956. Weight losses and decay of Florida and California oranges in mesh and perforated consumer bags. Proc. Amer. Soc. Hort. Sci. **67**: 244-249.
5. Kidd, Franklin and Czril West. 1920. Dept. Sci. and Ind. Res. Food Inv. Board Report. 16-25.

PICKING CITRUS FRUIT BY MECHANICAL MEANS

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Picking citrus fruit is an operation which involves separation of the fruit from a tree and placement of it into a suitable container on the ground. Hand picking is a strenuous and time consuming task which requires the major portion of the hand labor needed in producing and harvesting a citrus crop. It is becoming increasingly dificult to find suitable labor willing to do this type of work as long as they can find work elsewhere.

Previous attempts to pick citrus by mechanial means have not been very successful. These attempts included tree shaking and separation of one fruit at a time by snapping the supporting twig or by pulling the fruit with a suction force. Patents on such devices date back before the turn of the century.

Problems associated with the design of fruit picking equipment differ greatly from those associated with the design of equipment for harvesting annual row-crops. A citrus tree represents a major investment which must produce a profitable return to the grower for many years. Therefore, any picking device or method must not damage the trees in any way which would reduce their annual production or their productive life. Also, the fragility of the fruit requires that it be handled with care. However, this is more important for fruit produced for the fresh fruit market than for fruit produced for processing. Not only do these requirements have to be met, but the machine and the method which is to be used must be justified economically. That is, the machine must save enough on labor requirements over hand picking to offset the investment and operating costs. These and other design problems associated with fruit picking equipment seem insurmountable when measured by past knowledge. However, research has revealed basic information which may make their solution less difficult.

Methods of Fruit Separation.—Oranges, grapefruit and tangerines are attached to their supporting twig through a small button (calyx). It is at this button that separation occurs when the fruit is picked. The conventional hand method of separating this fruit is illustrated in Figure 1.

In Florida most oranges and grapefruit are separated by grasping the fruit in hand and rotating it and at the same time giving it a sharp jerk at an angle to its major axis. As shown in Figure 1, separation forces A and B are acting on the button. Force A is the reaction of the twig to force B which is applied by the hand. These forces are applied progressively around the button as the fruit is rotated, thus reducing the danger of plugging, that is removing part of the peel with the twig. If force B were applied as a straight pull or quick jerk parallel to the axis of the fruit, it would be transmitted equally to the entire button. This would increase the total force requirement as well as increase the danger of plugging. Tangerines, which are highly susceptible to plugging when picked in the same manner as oranges and grapefruit, are usually clipped close to the button using small hand clippers.

The motions employed in the conventional method of separation are varied and complex. They are extremely difficult to duplicate by mechanical means. These motions as nearly as possible are broken down into categories in Figure 1 and listed as spinning, tree shaker No. 1 and tree shaker No. 2 concepts. The motions in these categories are more easily duplicated by mechanical means.

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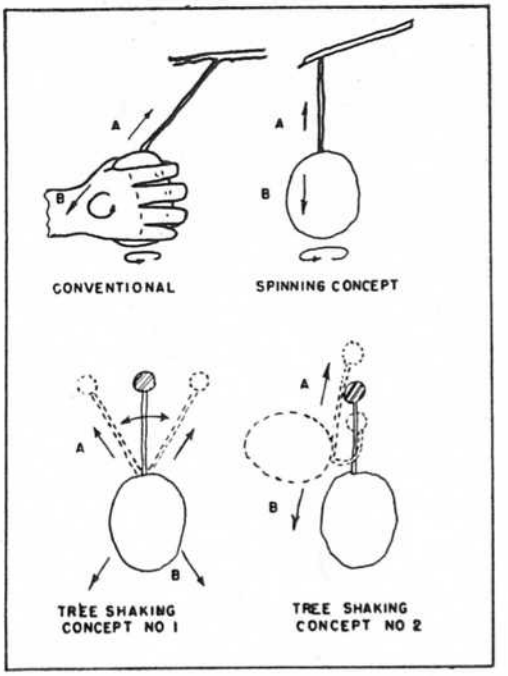

Figure 1. Force analysis of separating citrus fruit by the conventional method and by the spinning and tree shaking concepts.

The spinning concept consists of rotating fruit, in a plane normal to its major axis and the axis of the twig, while applying a force parallel to its axis. This rotation sets up a torsional force in the twig tending to make it curl while the force parallel to the axis of the twig prevents this from occurring. Tests have shown that oranges, grapefruit and tangerines can be separated in this manner without plugging. The number of revolutions required seem to be influenced by fruit maturity as well as by size and length of the twigs and magnitude of the parallel force.

Tree shaking concept No. 1 consists of shaking limbs in a plane normal to the axis of the fruit and depends on the resultant forces of inertia and gravity to effect separation. Force A in this case is the applied force and force B is the resultant of the reaction forces caused by inertia and gravity. The magnitude of force A and its direction relative to the axis of the fruit depends on the stroke of the limb, the weight of the fruit, length of twig and the speed of shaking.

Tree shaking concept No. 2 differs from concept No. 1 in that the limb is shaken in a plane parallel to the axis of the fruit. In this case gravity and inertia forces act in the same plane, thus increasing the reaction to shaking force A. By maintaining shaking velocities of the limb above the free fall velocity of the fruit, a rotational effect of the fruit about the button end is obtained as shown in Figure 1. As the limb moves in the upper half of the stroke, the force A is applied to the fruit at an angle to the fruit axis; thus separation is attained.

Spindle Picker.—Several mechanical devices employing the spinning concept for separating fruit from its supporting twig have been studied. These included: rotating rubber rollers and rotating cones to comb the tree, and rotating, auger-shaped spindles made of neoprene which move in and out of the tree canopy. The latter device offers a means for separating the fruit as well as for collecting it after separation.

The picking unit shown in Figure 2 employs the rotating auger principle. It contains 16 spindles spaced $4\frac{1}{2}$ inches on centers in a square pattern. The auger flights are made of $\frac{1}{4}$-inch 35-45 durometer neoprene. The soft flexible auger enables the unit to separate fruit ranging from 2 to $3\frac{1}{4}$ inches in diameter. Manipulation of the unit in the tree is accomplished by a positioning mechanism which can move in three planes. In operation the unit is pushed into the tree canopy with the spindles rotating in the same direction. Any fruit in the path of the unit is engaged between sets of four spindles and rotated until it is detached from the twig. The fruit is then conveyed by the auger flights to the rear of the spindle where it is collected.

When tested in oranges, the device picked almost all fruit entering the spindles. It picked several fruit at a time without causing visible damage to the fruit or excessive damage to the trees. However, it was necessary to selectively position the unit in the tree canopy such that large limbs were avoided. Obviously this requires too much time for such a unit to be practical. Basically, the concept of spinning fruit by means of auger-shaped spindles was sound. However, the greatest factor hindering the incorporation of this concept into a practical machine is the lack of a means for positioning the picking unit such that it will remove all the fruit from the canopy of the tree in a continuous and non-selective operation.