

Electronic Sorting of Lemons

mechanical sorting by color of other fruit and vegetables indicated by successful lemon sorter

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A photoelectric color sorter—which can duplicate manual sorting practices—has been developed for use in lemon packing houses.

The machine is capable of separating lemons into the five well-defined color categories—Yellow, Silver B, Silver A, Light Green, and Dark Green—commonly used in commercial packing houses.

During tests the experimental machine operated for several weeks under actual packing-house conditions. No stoppage occurred. No clogging tendency was indicated nor was there evidence of weakness in any part of the machine.

The color of an individual lemon is far from uniform and the greener fruit, especially, is likely to be extremely blotchy. However, the average color of the surface is a satisfactory criterion of storage life, and lemons are sorted commercially on this basis. Therefore, a photoelectric sorter must view substantially the entire fruit surface and yield a signal which is a measure of average color. A rough segregation can not be tolerated, because even a small quantity of fruit that becomes overripe in storage may cause serious damage to an entire lot.

The experimental photoelectric sorter is so constructed that the fruit enters the

machine—4 to 5 lemons per second—on a concave roller conveyor which arranges the lemons in single file with the major axis perpendicular to the direction of motion. The fruit falls freely from the end of the conveyor and passes through an optical compartment wherein the color measurement is made in approximately 0.01 second.

The electrical signal generated as a result of the optical measurement is passed through a vacuum-tube amplifying and analyzing device. The output of this unit controls the position of deflecting vanes which direct the fruit into one of five conveyor channels corresponding to the five commercial color classes. Because of the orienting action of the upper conveyor, contact between the deflecting vanes and the sensitive blossom end of the fruit is avoided.

This system of handling the lemons is satisfactory from the standpoints of continuity of operation and freedom from damage to the fruit.

Test Results

Tests on the effect of fruit-surface condition were performed with fruit typical of the five commercial color classes. The color of each lemon was measured by the machine under the four

usual conditions of commercial surface treatment: 1, as picked; 2, washed and left wet; 3, washed and dried; and 4, waxed and polished. The output signal from the electronic apparatus was measured for each. The signal produced by each fruit was found to be independent of surface condition within the limits of accuracy of the measurement—which is comparable to the accuracy of manual sorting and adequate for commercial purposes.

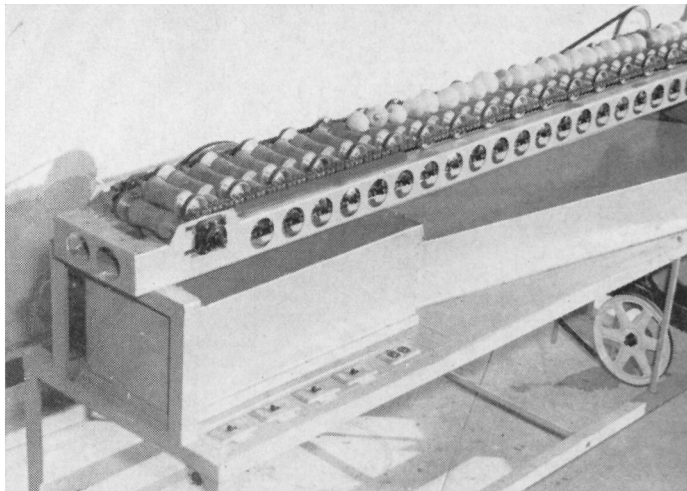
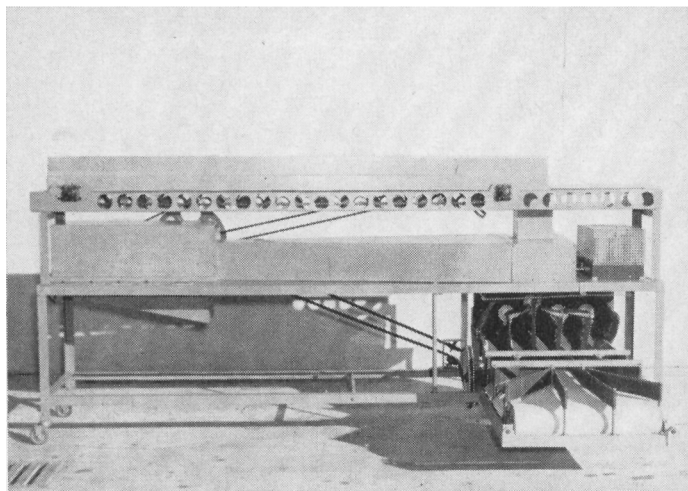
Tests—though not of precise nature—were made to determine the warmup period required to bring the apparatus to its full operating efficiency; and to determine whether there might be long-term drift in calibration. The results of the tests indicated clearly that the machine is commercially acceptable.

In tests for continuity of operation the machine operated successfully for several weeks under packing house conditions.

Relatively high impact loads occur in the mechanism associated with the lemon-deflecting vanes. The possibility of vane failure through fatigue was investigated by subjecting one of the vane assemblies to the standard endurance test of one million cycles of operation. No failure occurred, and no appreciable

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Left. The experimental color sorter. Lemons, introduced at the upper left, are carried to the right, and fall freely through an optical unit wherein the color measurement is made in 0.01 sec. The resulting signal controls the position of four deflecting vanes—lower right—which divide the fruit into five color classes. **Right.** A roller conveyor arranges the lemons in single file with their major axes perpendicular to the direction of travel. This orientation prevents contact between the deflecting vanes and the sensitive blossom end of the fruit.



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wear was discernible at the end of the test.

Because lemon damage prior to storage is reflected in high storage losses through rot and mildew the possibility of mechanical injury to the fruit in the photoelectric sorter was evaluated by a standard dye test and by a storage test.

In the dye test, fruit is immersed in a special dye solution which adheres only to those parts of the fruit from which oil has been expressed by bruising or abrasion. Several lemons of each color class were subjected to this test after they had been run through the machine 25 times. No damage was discerned by a trained observer.

The storage test was performed in a packing house where, customarily, the fruit was sorted into four color categories—Yellow, Silver, Light Green, and Dark Green. Accordingly the machine was adjusted to duplicate this procedure and fruit from eight different orchards was sorted and stored with samples of hand-sorted fruit from the same lots. The boxes were inter-stacked to ensure identical storage conditions. At the end of the standard storage period, the fruit was carefully inspected by a fruit physiologist to determine the percentage affected by rot or mildew. There was no significant difference in spoilage between the machine-sorted and the hand-sorted fruit.

Sorting Accuracy

As a part of the storage test the machine-sorted and the hand-sorted lemons that had failed to reach full maturity during the storage period were counted. In each case, the quantity of immature fruit was less than 0.02% of the total—a commercially insignificant fraction.

A further test was performed to determine the consistency with which the machine would place a particular lemon in a given color category. Sixteen fruits—representing approximately equal gradations in the total color range—were selected by visual comparison. This fruit was machine-sorted 25 times. From a practical standpoint, the precision of measurement was approximately equal to that attained in manual sorting.

Because the accuracy of manual sorting is adequate for commercial purposes, it is questionable that even a minor investment in apparatus would be justified solely on the basis of increased precision. The real problem is one of reducing labor costs to a minimum while maintaining the approximate accuracy level of hand sorting.

Color sorting of lemons is one of a sequence of operations—picking, load-

ing, hauling, unloading, dumping, washing, culling, waxing, color sorting, and storage—and if one is interrupted for a protracted period, all of them must cease.

Lemon-sorting apparatus—with an annual use factor of about 30%—would have far greater utilization than most agricultural machines. Therefore, low operating expense rather than low first cost is the important consideration.

It might be practicable to construct a machine to handle the flow of fruit received at a packing house—usually at the rate of about 40 lemons per second—but the advisability of this procedure would be questionable. It would seem better to divide the flow among two or more machines so that a temporary failure of one would not interrupt the operation of the entire receiving line.

A sorting rate of 4 to 5 lemons per second was used in the experimental photoelectric sorter, although it may become commercially necessary to increase the capacity of the machine.

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sort of a venturi tube by means of which the gases are introduced into the irrigation water.

Carbon dioxide can be dissolved in water and some of it will form carbonic acid which is capable of bringing calcium from the soil into solution as calcium bicarbonate. Carbonic acid produced from carbon dioxide in this manner would be a cheap source of acid—if it could be captured and gotten into the soil. One gallon of diesel oil which costs about 10¢ contains about six pounds of carbon. This quantity has an acid producing potential equivalent to 16 pounds of sulfur, costing about 40¢, or equivalent to about 50 pounds of concentrated sulfuric acid, costing about 85¢.

A laboratory experiment was set up to test the effectiveness of carbon dioxide charged water in reclaiming a Fresno fine sandy loam alkali soil. A one-to-five equilibrium water extract was made with water containing 72 ppm—parts per million—of dissolved carbon dioxide.

The net result of the laboratory test was to bring into solution, calcium and magnesium—in excess of that dissolved by untreated water—equivalent to $\frac{3}{4}$ of a ton of gypsum per acre foot of soil. If such a result could be accomplished

in the field, the operation would be economical.

The concentration of 72 ppm of carbon dioxide in an acre foot of water—from exhaust gases of diesel oil, for example—could be achieved only if all the carbon dioxide, possible of production from the carbon in about 10 gallons of diesel oil were captured in solution. However that would be extremely difficult to accomplish because carbon dioxide is a gas which dissolves freely in water only under pressure. The amount of carbon dioxide retained in water flowing in a ditch is very small.

To test the efficiency of introducing carbon dioxide from oil burners into irrigation water, experiments were conducted with water from two wells in Tulare County. In one experiment exhaust gases from diesel fuel burned at the rate of 1.75 gallons per hour were introduced into a stream of water pumped from a well at the rate of 850 gallons per minute. The fuel used should have produced enough carbon dioxide to supply 100 ppm in the water. In a second—and parallel—experiment the fuel burning rate was three gallons per hour and the pumping rate was 1,900 gallons per minute, which should give a carbon dioxide concentration of about 70 ppm.

Water samples were taken at both pumps before and after treatment, and at various distances from the pumps in the distribution ditches. Chemical analyses indicated that from 10% to 20% of the possible carbon dioxide from the fuel was absorbed on various days at Well No. 1 and about 30% at Well No. 2. In both cases, approximately half of the carbon dioxide which was absorbed at the point of treatment merely changed sodium carbonate in the water to sodium bicarbonate. Such a change is of minor importance for improving the quality of the water.

The pH—relative acidity-alkalinity—of the water was reduced, in Well No. 1 from 8.4 to 7.3 and in Well No. 2 from 8.2 to 7.1—still slightly alkaline, but because the pH of water is usually changed easily, no importance is attached to this downward shift. Such a shift results from changing the carbonate to bicarbonate but when the soil irrigated with this water dries out there is a tendency for the bicarbonate to be converted back to the carbonate. The so-called sodium percentage, which is an important criterion in judging water quality, is unchanged.

The remaining carbon dioxide dissolved in the water could bring calcium or magnesium—or both—into solution if it were still present as the water enters the soil. However, as the water flowed along in the ditch, the carbon dioxide was gradually lost to the at-