

[54] **BLUEBERRY SORTER**
[75] Inventors: **William Fred McClure; Roger Phillip Rohrbach**, both of Raleigh, N.C.
[73] Assignee: **Research Corporation**, New York, N.Y.
[22] Filed: **Mar. 21, 1972**
[21] Appl. No.: **236,613**
[52] U.S. Cl. **209/73, 209/111.6, 209/111.7, 209/74, 250/223, 250/227**
[51] Int. Cl. **B07c 5/342**
[58] Field of Search **209/111.7, 111.6, 209/73, 74; 250/227, 223, 224, 226**

[56] **References Cited**

UNITED STATES PATENTS		
3,393,800	7/1968	Durand, Jr. 209/111.7
3,530,341	9/1970	Hutchinson 250/227
3,565,248	2/1971	Messerschmidt 209/111.7
3,206,022	9/1965	Roberts, Jr. et al. 209/111.6 X
3,380,586	4/1968	Frobese et al. 209/111.6 X

Primary Examiner—Allen N. Knowles
Attorney—Harold L. Stowell et al.

[57] **ABSTRACT**
An automatic sorting apparatus for objects, such as fruit, has a plurality of individual cups arranged in a spaced array on a conveyor means to singularly receive and carry fruit from a feeding station to an optical reading station where light from a source of illumination under the conveyor means passes through bottom apertures in the cups to be diffused by the carried fruit with the scattered light being captured by fiber optic means disposed at an angle other than 180° with respect to the source of illumination. Optical means coupled to the fiber optic means generates electrical signals proportional to the transmittance of the fruit at a plurality of selected wavelengths and electronic means is activated by such transmittance related signals to generate sorting signals which indicate the condition of the carried fruit. A logic network interprets such signals and responsively actuates an ejection system wherein air valves are selectively activated to cause air blasts to eject the fruit from the cups at different sorting stations in accordance with the sensed condition of the fruit.

19 Claims, 24 Drawing Figures

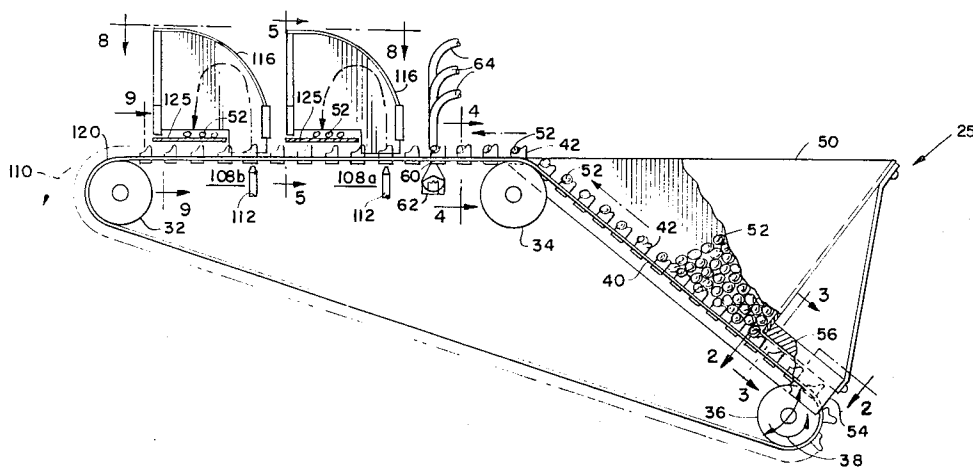


FIG. 1.

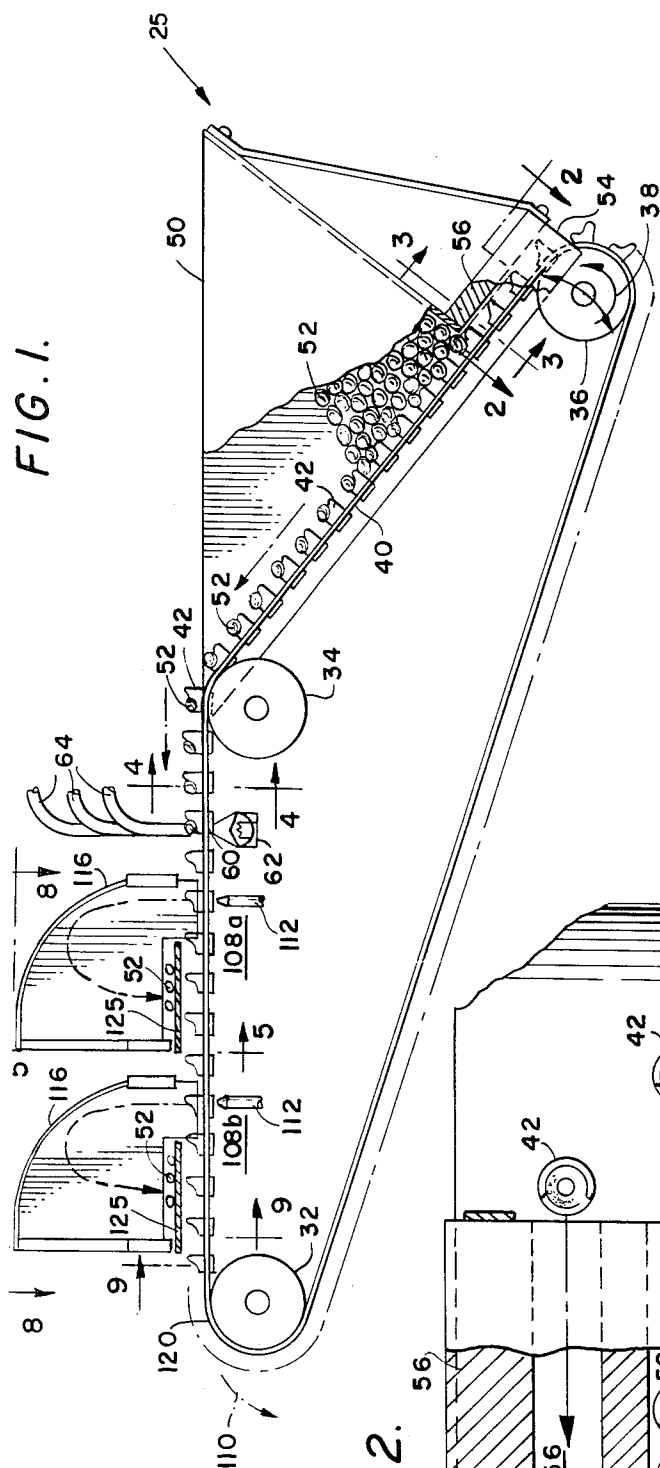


FIG. 2.

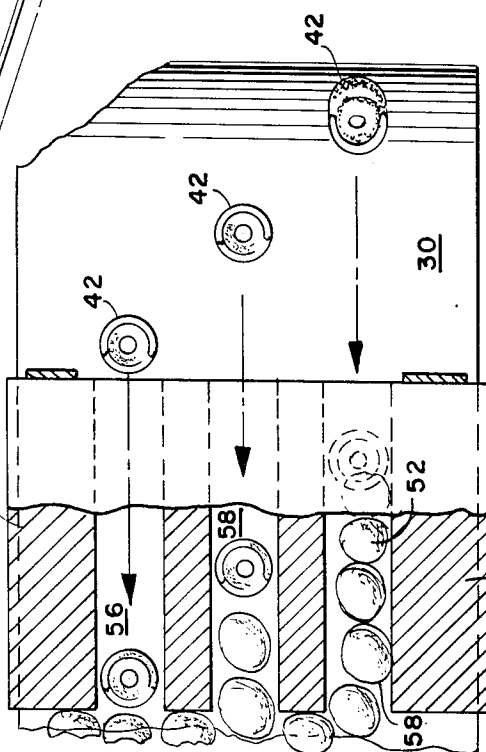


FIG. 3.

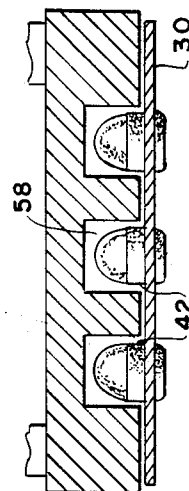


FIG. 4.

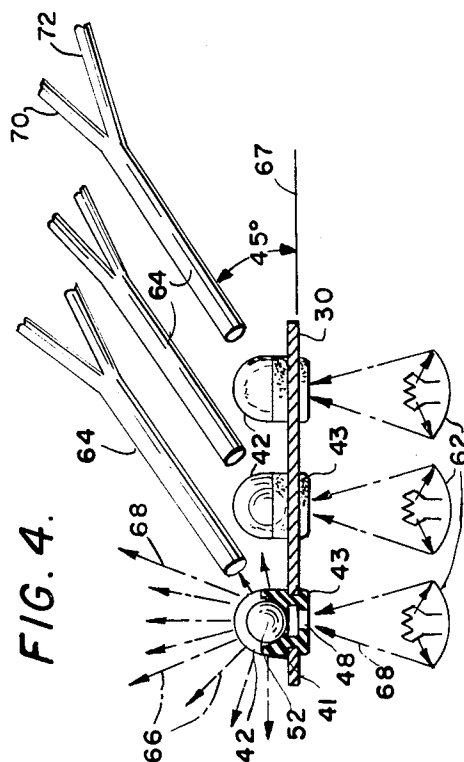


FIG. 9.

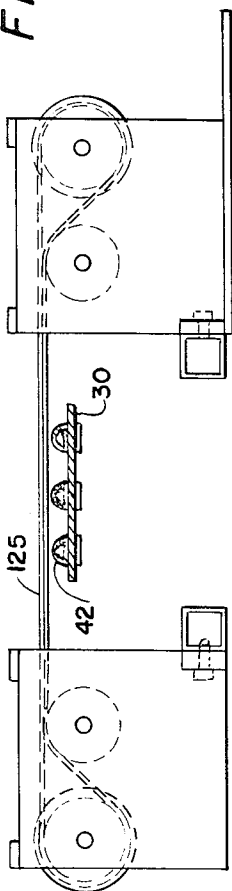


FIG. 7.

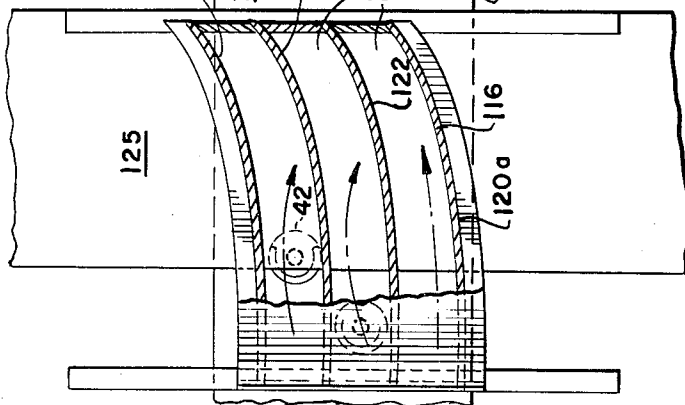


FIG. 6.

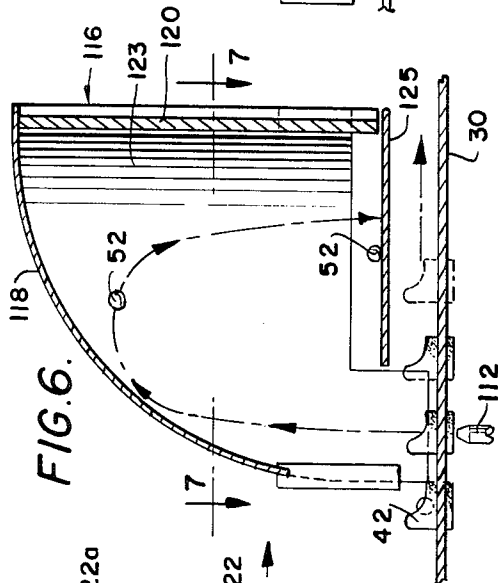


FIG. 5.

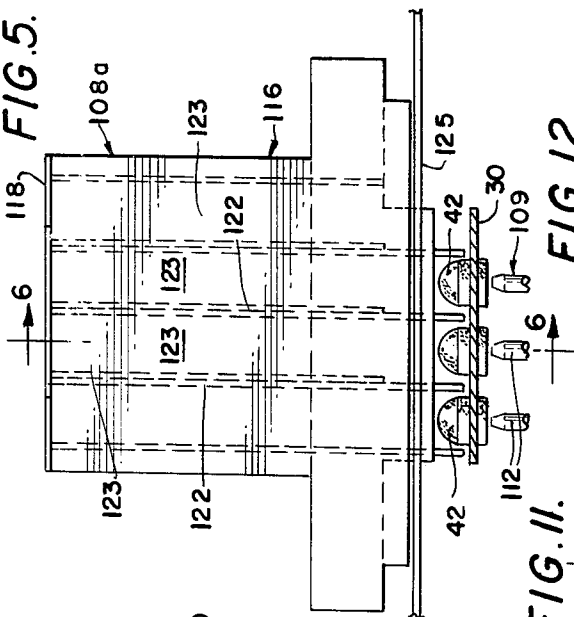


FIG. 12.

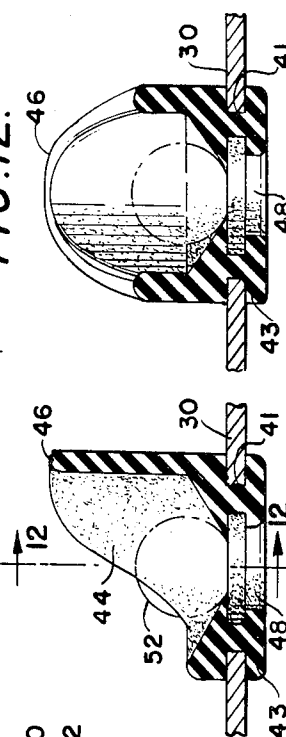


FIG. 10.

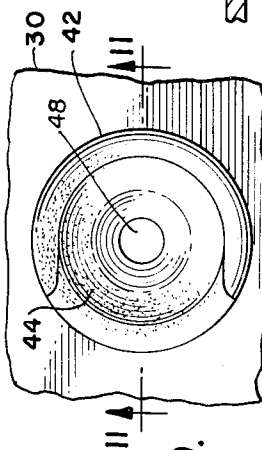


FIG. 8.

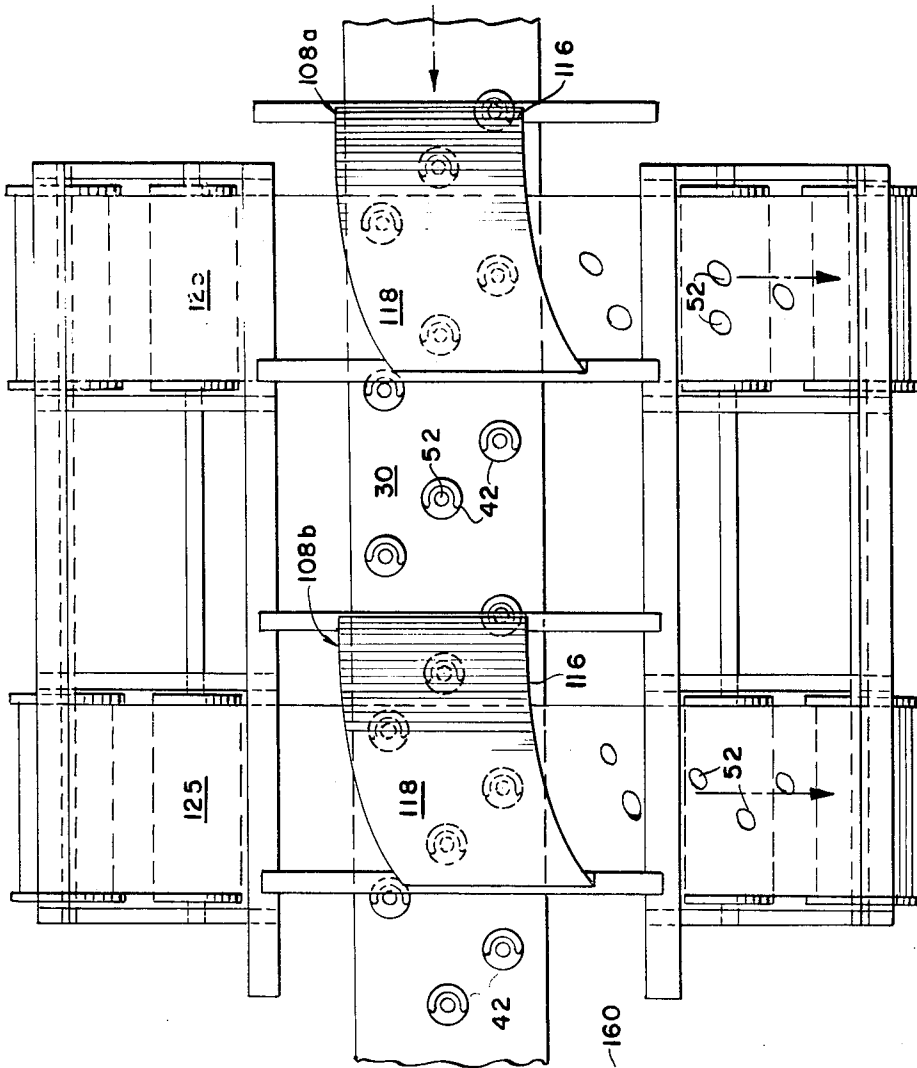


FIG. 13.

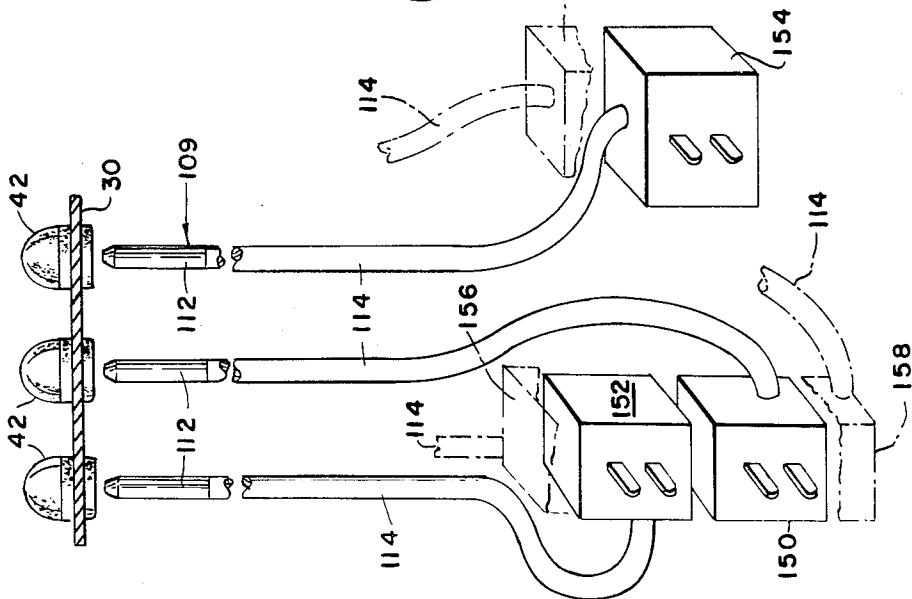


FIG. 14A.

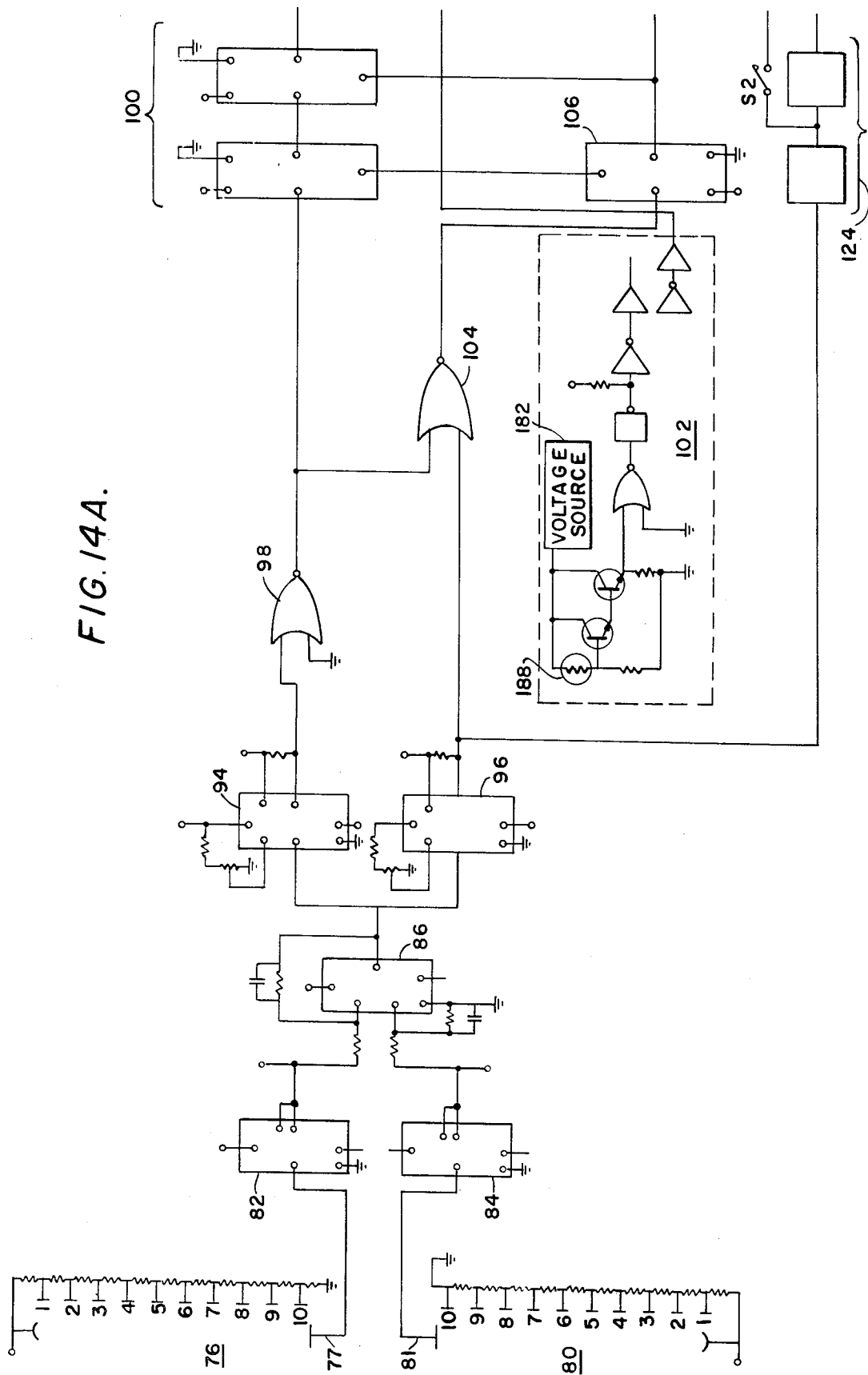


FIG. 14B.

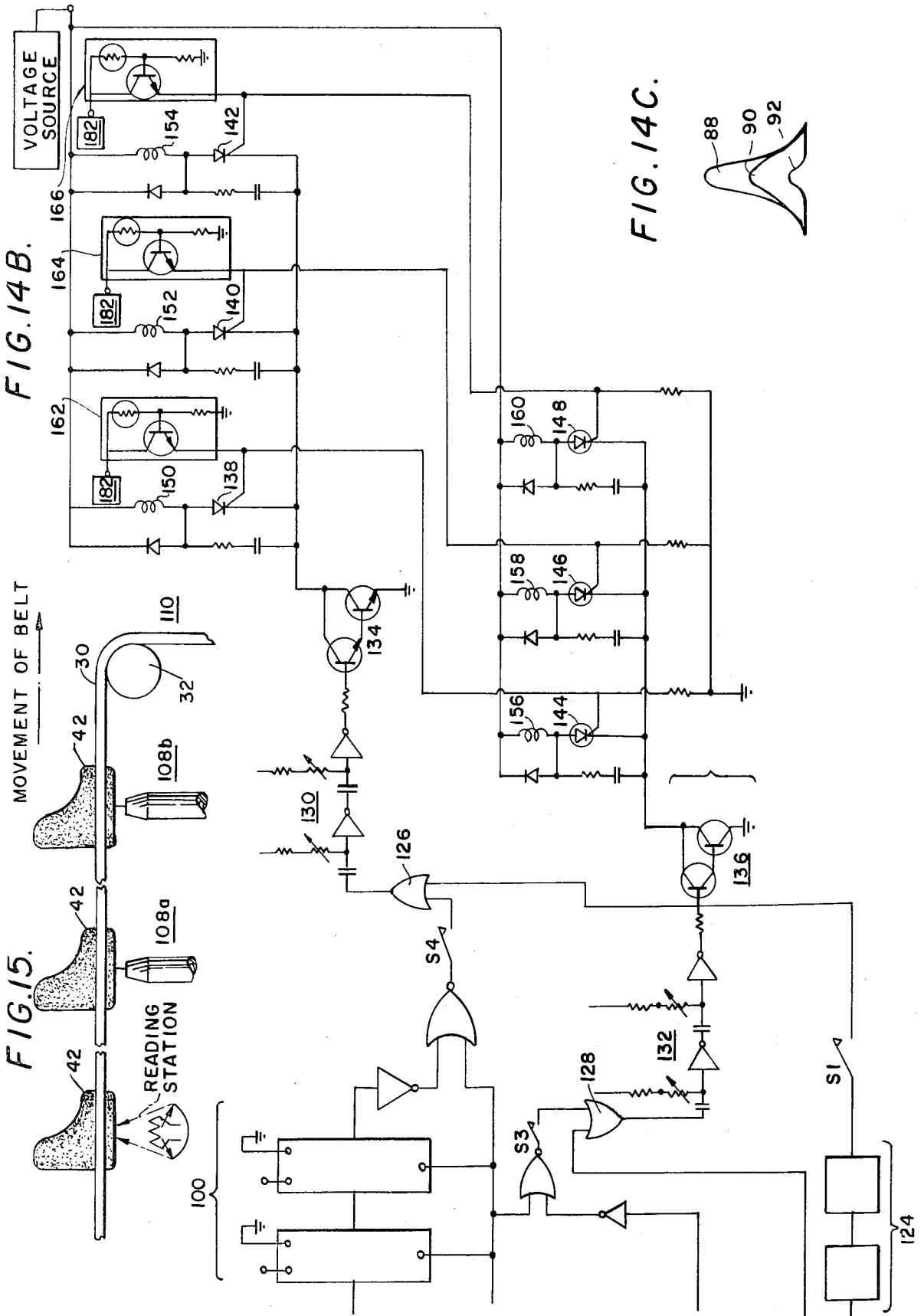


FIG. 14C.



FIG. 16.

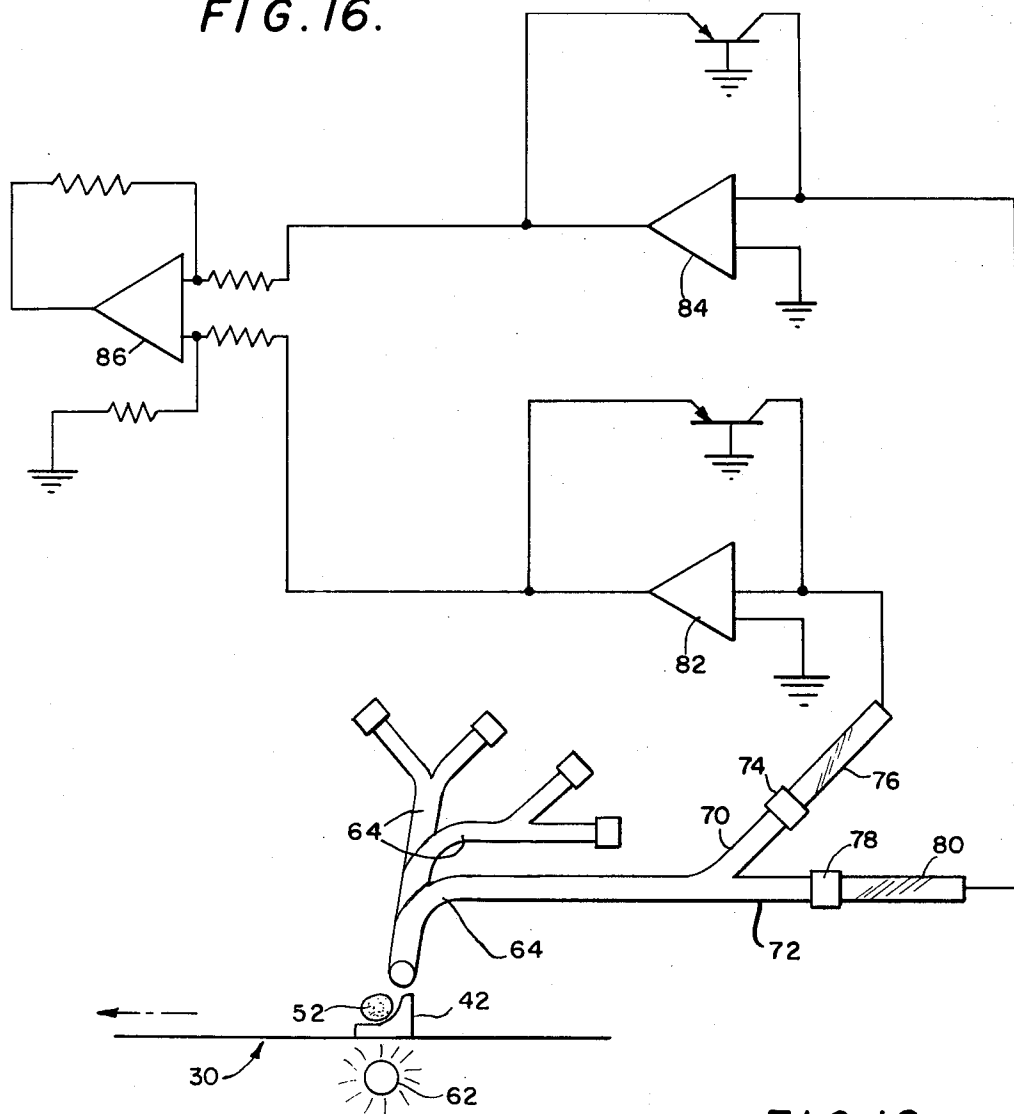
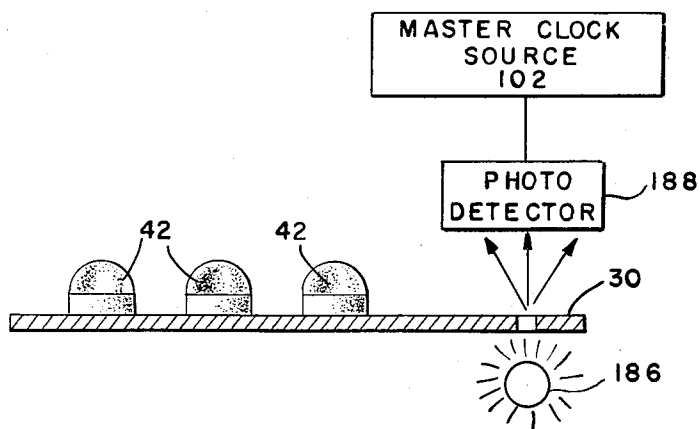
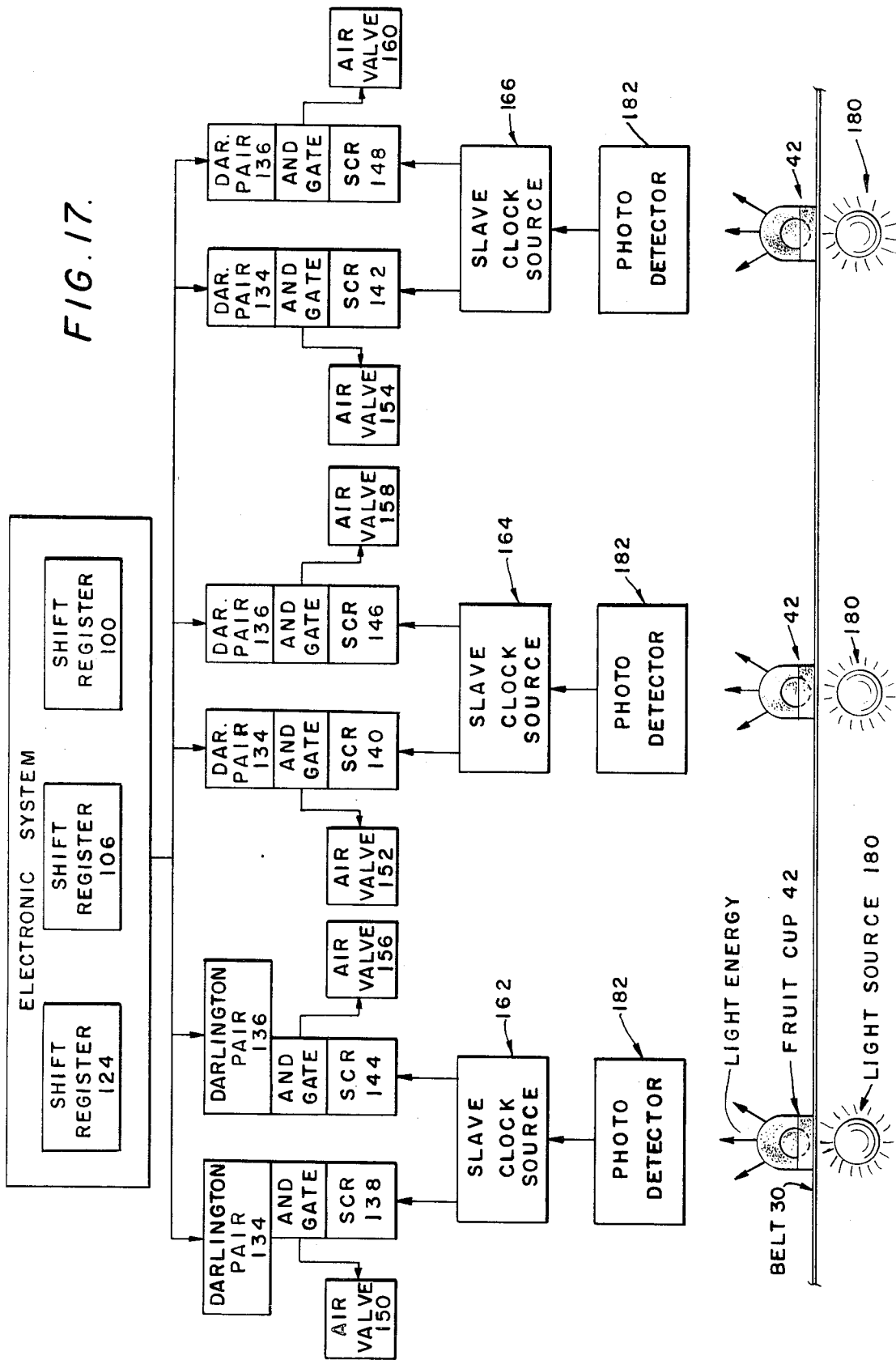
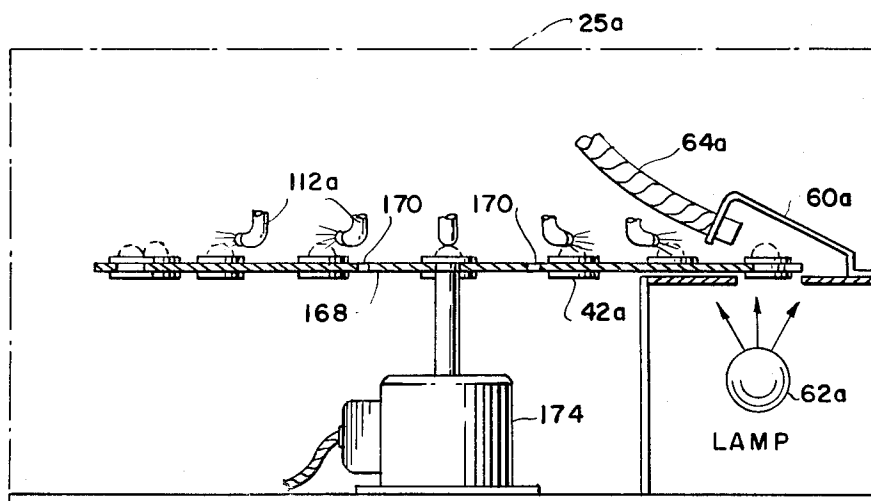
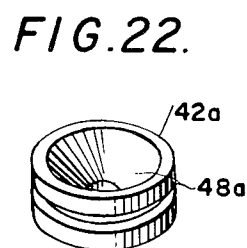
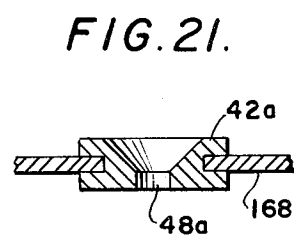
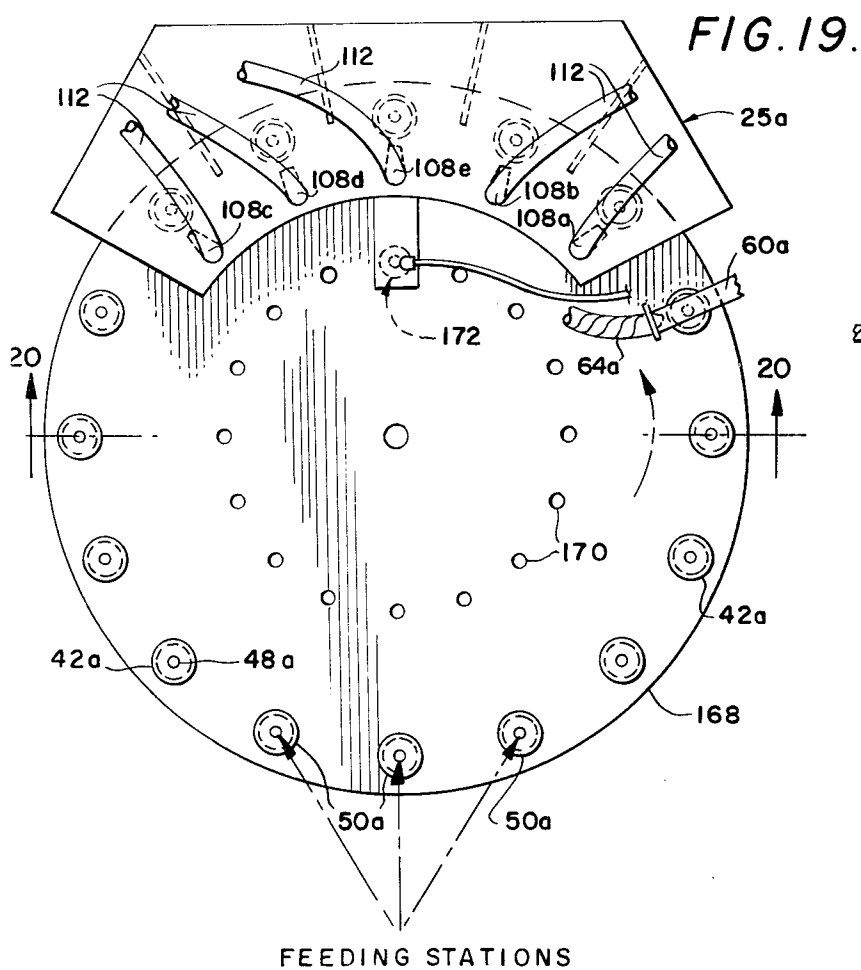


FIG. 18.







BLUEBERRY SORTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally appertains to new and novel improvements in sorting and classifying systems and attendant devices and methods and is especially directed to a new and novel automatic sorting apparatus and method for use in separating objects in accordance with a sensed physical property thereof, and, in particular, the automatic sorting of agricultural products such as fruit, in accordance with the sensed and evaluated interior condition, quality or other state thereof.

With particular regard to agricultural products, such as fruit, the introduction of mechanical harvesting systems has made it necessary to develop automatic sorting systems that will keep pace with the mechanized harvesting techniques. This has been required for two main reasons. In the first place mechanized harvesting is largely non-selective and, therefore, a quantity of mechanically harvested fruit contains the complete spectrum from green to overmature fruit. Green fruit can be easily sorted by hand, but the level of maturity beyond the green state is rather difficult, if not impossible, for manual laborers to distinguish. For example, a blueberry beyond the green or maroon color state (immature) is blue and unless it has begun to deteriorate, it cannot be readily selected for maturity with only the aid of the human eye. In the second place, the volume rate of fruit produced for processing by mechanical harvesting devices is very high and manual techniques for sorting cannot, over any substantial period of time, maintain pace with such high volume. Furthermore, as manual labor becomes more expensive, the cost factor will become such that the use of manual labor will be prohibitive. Coupled with this is the fact that such hand labor is becoming increasingly scarce.

For these reasons, considerable attention has been given, of late, to the development of automatic sorting systems and techniques whereby agricultural products, such as fruit, can be automatically sorted and classified in accordance with the viewed or sensed condition and appearance thereof after such products are delivered to a feeding station by the mechanical harvesters.

Such developments have been based on discoveries that agricultural products by their biological nature act as optical diffusers and can be illuminated from a light source so that they reflect radiant energy which can be measured as a quality index to give an evaluation of the interior condition or quality of such products. Stemming from the need for more precise light transmittance measurements of the interior quality of agricultural products have been attempts at the development of radiation sensing devices with means responsive to such devices for classifying and sorting the agricultural products.

However, various difficulties have been encountered in the attempts to provide, on the above-stated basis, fully automated sorters that operate in an efficient manner with a rapid turnover of a high volume of products. Difficulties have been encountered in the mechanized handling and conveying of the products past an optical reading station in a fashion so that each product is scanned and its condition sensed in a properly singulated manner. Also, known sorters have required complicated sequential reading and storage mecha-

nisms. In addition, such devices have tended to damage the products during the sorting operation, either at the pick-up or delivery points, especially at the latter, after the products have been viewed, because of the way that the products are sent to different sorted products depots.

SUMMARY OF THE INVENTION

Accordingly, a primary object of the present invention is to provide an automatic sorting apparatus and method for sorting agricultural products, as well as similar objects, in a way to overcome the afore-mentioned and other drawbacks attendant with known apparatus and methods and in a manner to permit a large volume of such products to be dependably and efficiently sorted and separated into differently classified groups without damage or injury to the products.

Another important object of the present invention is to provide a simple and effective optical reading arrangement for an automatic sorting apparatus wherein a fiber optical light bundle has a single blended end adjacent the object to be viewed and classified and an opposing furcated end adjacent a radiant energy sensing device with the fiber bundles transmitting the sensed radiation to at least two separate receptors, thereby eliminating the need for complicated delay and storage mechanisms.

Another important object of the present invention is to prevent saturation of photomultiplier receptors at the furcated end of such fiber bundle by angularly positioning a source of illumination, that supplies light to the objects, and the blended end of the optical bundle relative to each other at an angle other than 180°.

Another important object of the present invention is to provide means for singularly captivating and carrying objects from a feeding station past an optical reading station to sorting stations without damaging or injuring the objects and in a way so that an optimum delivery and conveying rate can be established and maintained.

Another important object of the present invention is to provide an ejection system that responds to a logic network, which interprets signals from an electronic system under activation by transmittance related signals from the viewed objects, and functions to remove objects from their conveying means in a way so that the objects are forcibly ejected from the conveying means and guided in a manner to dissipate the kinetic energy of the ejected objects.

Broadly stated, the apparatus and method of the present invention basically has a sorting cycle that involves:

1. Feeding the objects, such as fruit, to an input conveying means.

2. Captivating in singular fashion the objects and moving them by the conveying means in a spaced and singulated array past a reading station.

3. Reading the physical properties of the objects at the reading station with an optical system.

4. Processing electrical signals generated by the optical system through an electronic circuit.

5. Utilizing a logic network, that interprets signals from the electronic circuitry, to activate on a selective basis an ejection system to forcibly eject the objects onto moving output carriers at different sorting stations.

More specifically considered, the automatic sorting apparatus has cups that are mounted in a spaced apart array on a carrier or input conveyor means and moved thereby through a feeding station, which is supplied with fruit or other agricultural products from a harvester, so that each cup becomes laden with and retains a single piece of fruit. The fruit laden cups move in a particular pattern past an optical reading station where a light source illuminates the fruit through an aperture in each cup. The light thusly entering the fruit in a cup is diffused by the fruit with the scattered light being captured by fiber optic means disposed at an angle with respect to the fruit. Optical means coupled to the fiber optic means generates electrical signals proportional to the transmittance of the fruit at a plurality of selected wavelengths. Electronic means is activated by these transmittance related signals to generate sorting signals which indicate the interior condition of the fruit, as, for example, whether a particular fruit, for example, a blueberry, is underripe, ripe or overripe. An ejection system comprises a plurality of air nozzles disposed adjacent the carrier or input conveyor means and connected through high pressure air valves to a source of pressure air. A logic network interprets the signals from the electronics system to cause selected air valves to be actuated at particular times. Air blasts then pass through the apertures in the fruit laden cups to eject the fruit from the input conveyor means at different sorting stations onto output conveyors in accordance with the sensed condition of the fruit. Also, the air blasts are not activated and some of the fruit is allowed to pass such sorting stations and to reach a gravitational sorting station.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, partly in vertical section, of an automatic sorting apparatus in accordance with the present invention.

FIG. 2 is a transverse cross-sectional view taken substantially on lines 2—2 of FIG. 1 and illustrating the catchment and singularization of the fruit by the carrier conveyor supported and carried cups at the feeding station, which is in the form of a hopper overlying a portion of the carrier conveyor.

FIG. 3 is a vertical cross-sectional view taken substantially on lines 3—3 of FIG. 1 and illustrating the tunnel formation at the feeding station through which the cup supporting carrier conveyor moves.

FIG. 4 is a vertical cross-sectional view taken substantially on lines 4—4 of FIG. 1 and illustrating the optical reading station in operational relation with the fruit laden conveyor carried cups.

FIG. 5 is a vertical cross-sectional view taken substantially on lines 5—5 of FIG. 1 and showing the fruit ejection corridor assembly wherein and whereby the kinetic energy of the fruit ejected from the conveyor cups is dissipated.

FIG. 6 is a vertical longitudinal sectional view taken substantially on lines 6-6 of FIG. 5 and showing the trajectory of the ejected fruit in the ejection corridor assembly and one of the crosswise disposed catcher or output conveyors onto which the fruit is deposited at a sorting station.

FIG. 7 is a horizontal cross-sectional view taken substantially on lines 7—7 of FIG. 6 and illustrating the other curvature of the two-way curved ejection control corridors.

FIG. 8 is a top plan view of the sorting stations with the ejection arrangement and the control corridors in relation with the fruit input conveyor and the output or discharge conveyors and is taken substantially on lines 8—8 of FIG. 1.

FIG. 9 is a vertical cross-sectional view taken substantially on lines 9—9 of FIG. 1 and showing one of the crosswise output conveyors at a sorting station in relation with the cup carrier conveyor.

FIG. 10 is a top plan view of one of the fruit captivating and carrying cups on the carrier or input conveyor.

FIG. 11 is a vertical cross-sectional view through one of the cups and is taken substantially on lines 11—11 of FIG. 10 and shows the side design of the cups. FIG. 12 is a vertical cross-sectional view taken substantially on lines 12—12 of FIG. 11 and showing the frontal design of the cups and the high back wall.

FIG. 13 is a partial schematic illustration of one of the sorting stations illustrating the cups in relation to the ejection air nozzles with the air control valves therefor.

FIGS. 14A and 14B are combination schematic and block diagrams of the electronic system for the automatic sorting apparatus of the present invention.

FIG. 14C is a graph illustrating the relative magnitude of pulses generated by underripe, ripe and overripe fruit carried by the cups on the carrier conveyor.

FIG. 15 is a diagrammatic illustration of the physical relationship of the reading station with the sorting stations.

FIG. 16 is a block diagram illustrating the optical system at the reading station.

FIG. 17 is a block diagram of the synchronization and ejection system.

FIG. 18 is a schematic showing of the master clock source.

FIG. 19 is a top plan view of a modified form of automatic sorting apparatus in accordance with the present invention.

FIG. 20 is a vertical cross-sectional view taken on lines 20—20 of FIG. 19.

FIG. 21 is a transverse cross-sectional view taken substantially on lines 21—21 of FIG. 19 and showing the design of the fruit carrying cups used with the modified form of FIG. 19.

FIG. 22 is a perspective view of the cup shown in cross-section in FIG. 21.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now more particularly to the accompanying drawings and initially to FIGS. 1—18, the automatic sorting apparatus 25 includes a carrier or input conveyor 30 which is in the form of a flexible conveyor belt that is supportively mounted on idler rollers 32 and 34 arranged in a longitudinally spaced apart parallel and coplanar relation and a drive roller 36 which is parallel with the idler rollers and disposed therebelow. The drive roller 36 is positioned in a horizontal plane below the rollers 32 and 34 so that the belt has an upper reach 40 at one end with such reach being inclined at an angle of about 45°. The angle of inclination with respect to the horizontal of the reach 40 can be adjusted by moving the idler rollers 32 and 34 bodily relative to the drive roller 36 that is driven by a suitable drive assembly (not shown) so as to move the belt 30 in a coun-

ter-clockwise direction, as indicated by the arrow 38 in FIG. 1.

The carrier conveyor belt 30 is formed with a patterned series of vertical holes 41 within which the eyelet bases 43 of carrier cups 42 are fixedly secured in a rivet-like fashion. The carrier cups are arranged in a staggered array, as shown in FIG. 2, with the cups being in parallel rows that are longitudinally spaced apart and are slanted from one side edge of the carrier conveyor belt to the opposing side edge.

Each of the cups 42, as shown in FIGS. 10-12, is of cylindrical or rounded form and has an open front face or side 44 and a confronting, relatively high rounded back wall or side 46 with top edges that are inclined from the open front face to the central round top edge of the back wall 46. Thus, each cup is of an open-faced form with a cross-sectional shape or configuration that approximates the geometrical shape of the object to be sorted. For example, as shown, the cups are of cylindrical shape to contain berries. The dimensions of the cups are chosen so that only one piece of fruit can occupy the space within the confines of the cup structure at any one time, thereby, enabling the cups to singularize the fruit in capturing the fruit at a feeding or loading station. The bases or bottoms 43 of the cups have vertical apertures 48 which, in the given instance, structurally result from the eyelet formation of the bases that attach the cups to the carrier belt 30.

The cups are oriented on the upper face of the belt 30 so that they upstand therefrom with the open front sides of the cups facing the direction of motion of the belt, as shown in FIGS. 1 and 2. The cups are in staggered row arrangement, as aforescribed, so as to cooperate with a feeding station in the form of a loading or catchment hopper 50, as shown in FIGS. 2 and 3, in the singularization capture and conveyance of the fruit from the feeding station.

The carrier belt 30 with the supported cups 42 on its outer face cooperates with the hopper along the inclined end reach portion 40 thereof, with the belt reach portion 40 passing through the hopper as a moving upwardly inclined bottom wall therefor. The belt moves through a slot-like opening 54 formed transversely in the lower edge portion of the outer or front wall of the hopper adjacent to the roller 36. A tunnel element 56 is positioned in the opening so as to close off the same while allowing the belt to pass therethrough below the tunnel element, as shown in FIG. 2. The tunnel element is held in place by suitable support means and is provided with longitudinally extending, individual channels 58 which are in parallelism and are laterally spaced apart the same distance as the spacement between the cups in each of the rows.

The cups 42 entering the hopper 50 pass through the channels 58, as shown in FIGS. 2 and 3, with the length of the channels being such that as one cup in one longitudinal line on the belt face exits from the inner end of the tunnel, the next successive cup enters the same channel at the outer end of the tunnel. As can be appreciated from FIG. 2, the length of the channels is such in relation to the longitudinal spacement between the cups in each line that there is always a cup in a channel to block off the channel at its outer end and to ensure that no fruit 52 can escape from the hopper by falling out through one of the channels. The cups, as can be appreciated from FIG. 3, are of such a size and shape in relation to the cross-sectional shape and area of the

channels that the cups occupy a sufficient amount of the area so that a fruit 52 cannot move past the cup. Thus, any fruit rolling or sliding in a channel will be moved therefrom into the hopper by the cup traveling in the channel.

Due to the slanted row arrangement of the cups on the face of the belt, there is always a cup in one of the channels with one cup in a given row exiting from its channel, while the other cups in the same row are moving through and entering their channels. The cups are disposed in slanted row array for another reason having regard to the reading station 60, as will be explained.

The apparatus 25 was designed primarily for sorting blueberries; however, the features and characteristics of the apparatus permit its utilization in sorting other fruits such as apples, oranges, cranberries, grapes, cherries, and any other fruit or vegetables which have an approximately spherical shape. The adaptation to any fruit of the above types is a matter of changing the cup size in order to achieve singularization of the fruit for the reading head.

Considering FIG. 1, fruit is fed into the catchment hopper 50 at a sufficient rate to keep the cups 42 filled. Filling of the cups 42 takes place on the inclined reach portion 40 of the belt 30 within the hopper 50. The cups 42 are arranged on the belt in the staggered array in order that only one fruit at a time passes under the reading station 60. The cups 42 are designed to scoop the fruit as they progress up the incline.

The cups pass up and out of the hopper with each cup carrying a fruit that it has scooped up from the interior of the hopper. From the upwardly inclined reach 40, the belt moves in a substantially horizontal path past the reading station 60, as shown in FIG. 1, where the fruit laden cups are optically viewed to determine the interior condition, quality, or some other sorting characteristics or physical properties of the fruit.

The reading station, as shown in FIGS. 1 and 4, comprises a plurality of light sources 62 that are vertically disposed transversely beneath the belt 30 in a spaced apart row arrangement with the lateral spacing being the same as the lateral spacing of the cups in their row array on the belt 30. The number of light sources depends upon the number of cups in a row. In the present instance, there are three cups to each row, so that there are three channels 58 in the tunnel element 56 and there are three light sources. But the light sources are in alignment transversely of the carrier belt 30. Above the outer face of the belt and above the cups there are three laterally aligned and spaced apart light sensing probes 64. A probe is provided for each light source and each cup in the row, so that there would be as many probes as cups and light sources. The present form is what may be termed a three channel sorter.

The light sources are lamps that are prefocused to illuminate the interior areas and beyond of the cups by passing light rays through the bottom apertures 48 in each of the cups. In the present instance, the sorter has been developed for use in sorting blueberries and, in regard thereto, it has been found that tungsten lamps function satisfactorily as the light sources.

As shown in FIG. 4, the probes 64 are in the form of blended flexible fiber optic bundles. The probes, as shown in FIG. 1, are in alignment transversely of the carrier belt 30 but due to the slanted row arrangement of the cups on the outer face of such belt only one fruit laden cup is presented at a time to be viewed or sensed

by its associated overhanging probe 64 at the reading station 60. The bundles 64 are bifurcated to permit measurement at two wavelengths as will be described. Polyfurcated fiber optic bundles can be used to perform measurements at more than two wavelengths in a manner to be described.

The particular design of the reading station 60 using light guides having their ends blended near the fruit to transmit light simultaneously to two separate filters permits multiple optical density readings to be made simultaneously and, thereby, eliminates the need for complicated sequential reading and storage mechanisms normally required when multiple optical density readings are desired.

As each fruit laden cup moves past the reading station 60, light from one of the lamps 62 enters the cup through the optical aperture 48 provided in the bottom of each cup. Since fruit, like most biological materials, is an excellent diffuser, light entering the cups through the apertures 48 and entering the berries captively carried by the cups is scattered in all directions, as illustrated by the scattered light ray pattern 66 in FIG. 4. The fiber bundles, as shown in FIG. 4, are oriented at an angle less than 90° to the horizontal 67 and are positioned adjacent the fruit cups 42 in an angular relative manner so as to prevent direct optical coupling of the light ray 68 to the fiber bundle 64 when no fruit is present in a cup.

The reading station is designed to utilize the diffusing property of fruit by sensing a portion of the diffused light at an angle other than 180°. Thus, saturation and possible damage to photomultiplier tubes, as will be described, will be avoided in the event that a cup without any fruit therein should pass the reading station and be subjected to the light rays emitted there. In this respect, the light source or lamps and the probes are out of opposing alignment, as aforescribed, and are in an angular relationship other than 180°.

After passing the reading station 60 and being subjected to the optical viewing at such station, the fruit is conveyed to sorting stations 108a, 108b and 110, as shown in FIG. 1 and, depending upon the viewed and sensed condition of the fruit, such is removed at a selected one of such sorting stations. In the present instance, there are the three sorting stations 108a, 108b and 110 to correspond to the sorting of the berries based on maturity characteristics of (1) ripe; (2) over-ripe or (3) underripe.

The sorting stations 108a and 108b are in longitudinal alignment along the upper horizontal reach portion of the belt 30 forward of the reading station 60, while the sorting station 110 is in the nature of a gravitational dumping of the fruit as the belt moves over the roller 32. The station 110 operates in the case of fruit still in the cups after the cups have moved past the successively arranged stations 108a and 108b and because of the condition of the fruit such has not been ejected at the stations 108a and 108b. Output conveyor means (not shown) is arranged to receive and transport the fruit from the sorting station 110.

Each of the sorting stations 108a and 108b is provided with a set 109 of vertically disposed air nozzles 112, with each set consisting of three nozzles arranged in an aligned row transversely beneath the belt 30 in the area of such stations. There is one nozzle in each set at each station for each channel or each line of cups. Since the present apparatus 25 is a three channel

sorter with three cups in a row, there are three nozzles, per set, as shown in FIG. 13. Each of the nozzles is connected through high pressure air hose 114 to a control air valve, as shown in FIG. 13.

Since there is a set of air valves at each of said sorting stations 108a and 108b with three air valves to a set, there is a total of six air valves in the present three channel form of the apparatus 25. Such air valves 150, 152 and 154 and 156, 158 and 160 are shown in FIG. 13 and are activated in selective fashion by a logic network that interprets signals from an electronic system, as will be described. The air valves are connected to a source of air pressure (not shown) by suitable conduit means.

The air nozzles in each of the two sets are vertically disposed beneath the belt so as, upon opening of the associated control valve, to direct air blasts upwardly toward the under side or face of the belt. As previously stated, each of the cups 42 has an aperture 48 in its bottom and such apertures serve not only as optical passages for the light rays in the optical reading system but also function, in the ejection of the fruit at the sorting stations 108a and 108b, as pathways for the ejecting air blasts from the underlying air nozzles. The air nozzles only function when their valves are opened and the opening of the valves is controlled in a manner to be described.

Each of the sorting stations 108a and 108b is provided with guide and control means 116 for guiding and controlling the fruit ejected upwardly out of the cups 42 by a blast of air from one of the nozzles. Such means 116 includes an arcuate hood 118 which has a vertical wall 120 and which is internally divided by parallel, laterally spaced vertical partitions 122 and vertical end walls 122a into a plurality of vertical corridors 123 that overlie the longitudinal line of the cups 42 on the belt 30. Thus, there is a corridor 123 for each longitudinal line of cups on the belt, so that there are three corridors to correspond to the three channel form of the sorting apparatus 25. The partitions 122 and the end wall 122a are curved in a vertical plane, as shown in FIG. 7. Thus, the parallel corridors are double curved, in a vertical and horizontal sense, so as to constrain the ejected fruit 52 to follow somewhat of a parabolic trajectory.

When a fruit laden cup 42 reaches one of the sorting stations 108a or 108b and the condition of the contained fruit in such cup is such that it has been selected to be discharged at one of such stations, a synchronized air blast from one of the air nozzles will propel the fruit upwardly into one of the corridors 123. The ejected fruit is first trapped in the parallel curved corridor 123 wherein the kinetic energy of the ejected fruit is dissipated as it travels through an approximate parabolic trajectory, as shown in FIG. 6. Since the corridors are curved, the fruit cannot return or bounce out before its kinetic energy is dissipated.

The thusly spent fruit drops without being damaged onto the upper moving face of an output or discharge belt conveyor 125 which moves transversely of the carrier belt 30, as shown in FIG. 5, and lies at each sorting station 108a and 108b in horizontal plane of the carrier belt portion, so that the cups with or without fruit can freely pass the plurality of cross-conveyors 125. The discharged fruit is carried on one of the conveyors 125, that travel in the direction of the arrows of FIG. 8 transversely of the longitudinal path of travel of the carrier

belt 30, to a location at the side of the apparatus 25 for further processing and packaging.

Optical density of the fruit, such as the blueberries, was selected as the basis for sorting the fruit in accordance with the operation of the sorting apparatus 25. For example, it is known that as blueberries mature, the anthocyanin content increases which causes darkening of the fruit and an increase in the optical density at 740 nanometers (nm) with respect to the optical density at 800 nm. A nanometer equals 10^{-9} meters. Furthermore, experimental work with blueberries has determined that

$$\Delta OD = OD_{800} - OD_{740}$$

where OD_{800} = optical density of the berry at 800 nm

OD_{740} = optical density of the berry at 740 nm

is proportional to the maturity of the berries. Thus, blueberries may be sorted for maturity by measuring the optical density of the berries at two wavelengths. Other fruit and other agricultural products may also be sorted for maturity on the basis of chlorophyll content, carotene, or other characteristics by properly selecting the filters as described below.

Referring to FIGS. 4, 14A and 14B and 16, scattered light passing through the fruit 52 is gathered by the fiber optic bundle 64. In the present embodiment, each bundle 64 is bifurcated and has two branches 70 and 72. The branch 70 is connected to a filter 74 which, in turn, is connected to a photomultiplier tube 76; and the branch 72 is connected to a filter 78 which, in turn, is connected to a photomultiplier tube 80. The present embodiment is disclosed as using bifurcated bundles 64 because, as discussed above, it is possible to sort blueberries on the basis of two wavelengths. If it were desirable to use more than two wavelengths in the sorting process, polyfurcated bundles could be used.

Proper selection of the filters 74 and 78 is dependent upon knowledge of the optical properties of the fruit to be sorted. In the present example involving blueberry sorting, the filter 74 will pass light energy at a wavelength of 740 nm and the filter 78 will pass light energy at a wavelength of 800 nm. Thus, a light energy receiving tube 76 is provided that will read the transmittance of the berry at 740 nm, and the tube 76 will generate a current proportional to transmittance at 740 nm. Likewise a light energy receiving tube 80 is provided that will read the transmittance of the berry at 800 nm, and the tube 80 will generate a current proportional to the transmittance at 800 nm. Such tubes 76 and 80 constitute separate photoelectric means disposed adjacent each filter for receiving light energy filtered by the filters and for generating electrical signals proportional to the maturity of the berries at the wavelengths selected by the filters.

Since the optical density of the fruit is needed and since

$$OD = -\log_{10} T$$

where

$$T = \text{Transmittance}$$

the anodes, 77 and 81, of the tubes 76 and 80, respectively, are connected to logarithmic amplifiers 82 and 84 which produce output voltages proportional to the log of the input currents. Since the input currents to the amplifiers 82 and 84 are proportional to the transmittance of the fruit at 740 nm and 800 nm, respectively,

the output voltages from the amplifiers 82 and 84 will be proportional to the optical densities of the fruit at 740 nm and 800 nm. Of course, the output voltages from the amplifiers 82 and 84 will be proportional to the optical densities of a fruit sample at any selected wavelength, as determined by the filters 74 and 78. The optical density difference, ΔOD , is calculated by feeding the outputs from the log amplifiers 82 and 84 to a difference amplifier 86; the output voltage from the amplifier 86 is proportional to the difference in optical densities of the fruit at 740 nm and 800 nm, and is, therefore, proportional to the maturity or degree of ripeness of the fruit, in accordance with the sensed condition aforesaid.

As each fruit passes the reading station 60, a pulse appears at the out-put of the amplifier 86. Continuing to assume that the fruit is a blueberry, the height of the pulse is directly proportional to the degree of maturity of the berry. Overmature berries produce a relatively large pulse, as illustrated at 88 in FIG. 14C, while the illustrated smaller pulses 90 and 92 correspond to ripe and underripe (green) berries, respectively. The output pulses from the amplifier 86 can, therefore, be used to sort the berries with respect to maturity.

Output pulses from the amplifier 86 are fed to comparators 94 and 96 which have adjustable reference voltage levels set relative to expected pulse outputs from the amplifier 86. For example, assuming that the reference voltage of the comparator 94 is set to the peak voltage 88 (FIG. 14C) expected from the amplifier 86 and that the reference voltage of the comparator 96 is set to the peak voltage 90, then berries passing under the reading station 60 and producing an output pulse at the amplifier 86 greater than or equal to the reference voltage of the comparator 94 will produce a logic level zero output from the comparator 94. This logic zero is fed to an inverter 98 where the zero is converted to a logic level one; and this logic one is fed to a shift register 100 on the first occurring pulse from a standard master clock source 102 (FIG. 14A). The master clock source is driven off of a single channel on the carrier belt 30, as illustrated in FIG. 18. In this respect, a light source 186 illuminates photo detector 188 each time a cup passes. The signal generated by the photo detection 188 is fed to the master clock source 102 (FIG. 14A) to drive that clock source in synchronism with the movement of the conveyor cups 42. The logic one fed from the inverter 98 to the register 100 acts simultaneously to deactivate a gate 104 so that a logic zero is fed to a second shift register 106. The logic information in the shift registers 100 and 106 moves along at the rate of the master clock pulse frequency. The same process would be followed if the comparator 96 was activated, except, in that case, the comparator 94 would not be activated by pulses smaller than the pulse 88 (FIG. 14C). The movement of the berries from the reading station 60 to the sorting stations in FIG. 1 is synchronized with the movement of the logic information in the shift registers 100 and 106 so that the berries will be in sorting positions and ejected as desired at the sorting stations when the registers 100 and 106 actuate the correct air valve as described below.

The state of switches S1, S2, S3 and S4 determines which berries will be ejected at the sorting stations 108a and 108b and which berries will be permitted to drop out at the sorting station 110. The following chart describes the sorting sequence:

Sorting Station	S3 & S4 Closed	S4 & S2 Closed	S1 & S3 Closed
108a	S1 & S2 Open	S3 & S1 Open	S2 & S4 Open
108b	Ripe	Green	Ripe
110	Override	Override	Green
110	Green	Ripe	Override

Thus, the sorting sequence and position is easily determined. The shift register 124 carries the sorting information for green fruit which produces pulse 92 (FIG. 14C). When neither of the comparators 94 or 96 is activated, a logic one is fed to the shift register 124 by the comparator 96. When one of the comparators 94 and 96 is activated, a logic zero is fed to the register 124.

Channeling of the logic information passing through switches S1-S4 is controlled by OR gates 126 and 128. Logic ones coming out of the shift registers 100, 106 and 124 initiate sorting signals; and logic zeros dictate that no sorting will occur. Logic ones from OR gates 126 and 128 are fed through conventional delay-duration circuits 130 and 132. These delay duration circuits permit an adjustable 0-30 millisecond delay of the air pressure signal with an adjustable 10-100 millisecond duration of the air pressure signal.

FIG. 17 illustrates the cup synchronization system in block form. There is one photodetector 182 and one light source 180 disposed on opposite sides of the belt 30 for each channel in the system. As fruit cups pass the synchronization station, light from the source 180 falls upon a detector 182 each time a cup in a particular channel passes. Light falling upon a detector 182 generates a signal which turns on a slave control clock 162, 164 or 166 as determined by the channel passing the light.

The present three channel system includes six AND gates: three AND gates comprise Darlington pair 134 and SCR's 138, 140 and 142, respectively; and another three AND gates comprise Darlington pair 136 and SCR's 144, 146 and 148, respectively (FIGS. 14B and 17).

Air valves 150, 152 and 154 are in the anode circuits of SCR's 138, 140 and 142, respectively; and air valves 156, 158 and 160 are in the anode circuits of SCR's 144, 146 and 148, respectively. The Darlington pairs 134 and 136 are turned on by information from the shift registers 100, 106 and 124. The SCR's 138, 140, 142, 144, 146, and 148 are turned on by the slave clocks 162, 164 and 166. The slave clock signal determines which cup (channel) is at the sorting station (only one cup/channel in a sorting station at a time); and the information signal from the shift registers determines whether a sorting will be performed. If both signals are not coincident, ejection and sorting will not occur. Coincidence of signals at either AND gate requires that one air valve at one of the sorting stations will be activated because the air valves are connected in the anode circuits of the SCR's.

The automatic sorting apparatus 25 can operate at a high practical rate. In this respect, the following data is pertinent:

Maximum speed of the belt 30 is approximately 25 in/sec. Nominal speed is 20 in/sec. At 20 in/sec the apparatus 25 will sort 20 berries/sec or 120 berries/minute. This is approximately 0.4 pint/minute.

Sorting at a rate of 30 pints/minute will require a through-put of 9,000 berries/minute or 150 berries/sec. Designing the belt with 10 cups/in and running at a speed of 20 in/sec gives a sorting rate of 200 berries/sec

(BPS) with 100 percent fill. Percent of fill is normally greater than 90 percent at a speed of 20 in/sec. Thus, a sorting rate of 180 BPS is commercially possible.

In respect to the number of lines per set of the photomultiplier tube, the following data is pertinent:

A fiber optic with a diameter of one-fourth inch is bifurcated giving a bundle size of approximately 3/16 inch diameter.

$$\text{Area of bifurcated bundle} = \pi d^2/4$$

$$= (\pi/4) (3/16)^2$$

$$= (\pi/4) (9/256)$$

$$= 0.0276 \text{ in}^2$$

$$\text{AREA of PMT} = \pi(1.25)^2/4$$

$$= 1.226 \text{ in}^2$$

$$\text{No. of fiber bundles/PMT} = 1.226/0.0276 = 44.4$$

Each photomultiplier tube could handle up to 44 channels.

FIGS. 19-22 illustrate a modification of the automatic sorter. As shown therein, the automatic sorting apparatus 25a includes a sorting disc or platform 168 that is rotated by a drive means 174 and has a plurality of fruit cups 42a disposed in a circular array thereon. Feeding of fruit to the cups at the feeding stations 50a can be either manual or automatic. Fiber optic sensing means 64a are disposed at a reading station 60a to collect light scattered by fruit in the cups from an underlying lamp 62a. A plurality of air nozzles 112a are disposed adjacent the fruit cups 42 to form sorting stations 108c-108g where fruit is ejected from the cups upon command from the reading station. Output conveyor means (not shown) receives the ejected fruit. A plurality of photodiode clock apertures 170 are formed in the disc 168 to provide for synchronization between cup arrival at a sorting station and ejection of fruit by an air blast. A synchronizing photodiode light detector is illustrated at 172. The optical and electrical systems used to control sorting of fruit in this modification are similar to the optical and electrical systems described above in respect to the apparatus 25.

FIGS. 21 and 22 more specifically illustrate the structure of the cups 42a which are in the nature of an annular ring having a flat top surface. Due to the horizontal positioning and movement in a circular path of the conveyor means 168, the cups 42a do not require any high back wall, as in the case of the cups 42 that move in an inclined path to scoop up fruit from the hopper 50 of FIG. 1. However, the optical aperture 48 in the bottom of the cup is still needed and is present.

It is believed that from the foregoing description taken in conjunction with the accompanying drawings the operation of the automatic sorting apparatus 25 or 25a will be fully clear and, therefore, a more detailed operational description is believed unnecessary.

Of course, while both of the illustrated and described forms 25 or 25a have been specifically disclosed, it is to be understood that neither such description nor illustrations thereof or the "Abstract" constitute the invention which is only defined and delimited by the terms and scope of the appended claims.

What is claimed is:

1. The method of automatically sorting agricultural products in accordance with a sensed physical property thereof comprising:

a. conveying such products in singular successive

- fashion from a feeding station to a reading station;
- b. illuminating the products at the reading station in a manner so that light rays are diffused by the products in a scattered pattern;
 - c. optically capturing the scattered light;
 - d. filtering the captured light to select at least two wavelengths of light energy transmitted from the products;
 - e. simultaneously generating electrical signals proportional to a physical property of the products at each wavelength selected; and,
 - f. simultaneously interpreting such signals and responsive thereto depositing the products at various sorting stations in accordance with the sensed physical properties thereof, wherein the electrical signals generated are optical density signals that generate optical density difference signals and step f) includes
 1. comparing the optical density difference signals with reference level voltages;
 2. generating logic levels output signals in response to the different magnitudes of the optical density difference signals; and
 3. selectively directing discharging air blasts at the products to deposit them at selected sorting stations in accordance with the logic levels output signals.
2. Apparatus for sorting objects by measurement of radiant energy transmitted therefrom at at least two wavelengths comprising a source of radiation to illuminate the object to be sorted, a bundle of light transmitting optical elements having a blended end positioned to receive radiant energy from the object to be sorted, the other end of said bundle being furcated, a radiant energy sensing device at the terminal of each furcation, and means responsive to said radiant energy sensing devices for sorting the illuminated objects, said source of illumination and the blended end of the optical bundle being angularly positioned relative to each other at an angle other than 180°, means for conveying the objects from a feeding station past the source of radiation and said conveyor means having cups for singularly carrying the objects in successive fashion past the source of radiation, each of said cups having an aperture for the passage of illumination from said radiation source to said carried objects to be sorted, said source of radiation and said optical elements being disposed on opposite sides of said conveyor means and illumination from said radiation passes through each conveyor cup aperture to be defracted by said object and received by said optical elements.
3. The invention of claim 2 wherein said radiant energy device comprises separate filter means positioned at each furcation termination for selectively passing a single wavelength of light energy transmitted from said object, and separate photoelectric means disposed adjacent each said filter means for receiving light energy filtered by said filter means and generating electrical signals proportional to a physical property of said objects at each wavelength selected by said filter means.
4. The invention of claim 3 wherein said physical property is the transmittance of said objects.
5. The invention of claim 2 wherein said means responsive to said radiant energy sensing devices for sorting the illuminated object comprise electronic means coupled to said radiant energy sensing means for generating sorting signals based on a physical property of

said objects, and pressure actuated sorting means responsive to said sorting signals for sorting said objects.

6. The invention of claim 2 wherein said conveyor means is a belt and said conveyor cups are disposed on said conveyor belt in a staggered array in a plurality of channels whereby only one such conveyor cup will be located at said radiation source at the same time.

7. The invention of claim 6 further comprising a source of radiation for each said channel and a bundle for each said channel.

8. Apparatus for sorting objects by measurement of radiant energy transmitted therefrom at at least two wavelengths comprising a source of radiation to illuminate the object to be sorted, a bundle of light transmitting optical elements having a blended end positioned to receive radiant energy from the object to be sorted, the other end of said bundle being furcated, a radiant energy sensing device at the terminal of each furcation, means responsive to said radiant energy sensing devices for sorting the illuminated objects, said means responsive to said radiant energy sensing devices for sorting the illuminated object comprise electronic means coupled to said radiant energy sensing means for generating sorting signals based on a physical property of said objects, pressure actuated sorting means responsive to said sorting signals for sorting said objects, said physical property of said objects is transmittance and said electronic means comprise logarithmic amplifier means for generating optical density signals at at least two wave lengths, differential amplifier means for receiving said optical density signals and generating optical density difference signals, comparator means for comparing said optical density difference signals with reference level voltages and generating logic levels output signals in response to the magnitudes of said optical density difference signals, shift register means for receiving and passing said logic signals, a master clock source for driving said shift registers, delay circuit means for delaying and extending the duration of said signals passed by said shift registers, and AND gate means responsive to shift register output signals and to synchronized object position signals for activating said sorting means.

9. The invention of claim 8 wherein said AND gate means comprises a plurality of AND gates, each said AND gate comprising a transistor pair turned on by said shift register output connected in series with a silicon controlled rectifier turned on by slave clock means responsive to the position of said objects to be sorted for generating sorting signals.

10. Apparatus for sorting objects by measurement of radiant energy transmitted therefrom at at least two wavelengths comprising a source of radiation to illuminate the object to be sorted, a bundle of light transmitting optical elements having a blended end positioned to receive radiant energy from the object to be sorted, the other end of said bundle being furcated, a radiant energy sensing device at the terminal of each furcation, means responsive to said radiant energy sensing devices for sorting the illuminated objects, said means responsive to said radiant energy sensing devices for sorting the illuminated object comprise electronic means coupled to said radiant energy sensing means for generating sorting signals based on a physical property of said objects, and pressure actuated sorting means responsive to said sorting signals for sorting said objects, said pressure actuated sorting means includes ejector means

comprising air nozzles for directing air blasts through said cup apertures to eject objects from the cups and air valves controlling the passage of air to and through the air nozzles, said air valves being selectively activated by the sorting signals.

11. The invention of claim 10 further comprising ejection corridors disposed adjacent said ejector means for receiving and directing objects ejected from the conveyor means, said corridors having a plurality of curved parallel partitions to form a plurality of curved channels through which said ejected objects pass in a curved trajectory to dissipate kinetic energy possessed by said ejected objects.

12. The invention of claim 11 further comprising sorting conveyor means moving through said ejection corridors and having upper faces on which the objects fall in leaving the corridors.

13. Apparatus for sorting objects by measurement of radiant energy transmitted therefrom at at least two wavelengths comprising a source of radiation to illuminate the object to be sorted, a bundle of light transmitting optical elements having a blended end positioned to receive radiant energy from the object to be sorted, the other end of said bundle being furcated, a radiant energy sensing device at the terminal of each furcation, means responsive to said radiant energy sensing devices for sorting the illuminated objects, conveyor means for conveying the objects from a feeding station past the source of radiation and said conveyor means having cups for singularly carrying the objects in successive fashion past the source of radiation, each of said cups having an aperture for the passage of illumination from said radiation source to said carried objects to be sorted, and synchronizing light means disposed on one side of said conveyor means, photo detector means disposed opposite said synchronizing light means on the other side of said conveyor means, and clock signal generating means coupled to said photo detector means for generating clock signals each time a said conveyor cup passes between said synchronizing light source and said photo detector.

14. An automatic sorting apparatus for sorting agricultural products in accordance with a sensed physical property thereof comprising:

- a. conveyor means for conveying the products in singularized successive fashion from a feeding station to a reading station;
- b. a source of illumination disposed at the reading station for illuminating the products;
- c. fiber optic means disposed at the reading station for capturing the light rays diffused by the products;
- d. optical means coupled to the fiber optic means for generating electrical signals proportional to the transmittance of the products at at least two wavelengths;
- e. an electronic system activated by such transmittance related signals to generate sorting signals which indicate the physical condition of the products;
- f. means for ejecting the products from the conveyor means at selected sorting stations forward of the reading station;
- g. a logic network for interpreting the signals from the electronic system for selectively activating said ejecting means at various sorting stations, said conveyor means comprise a moving belt having an

upper horizontal reach, said reach having an inclined end portion, a loading hopper overlying the inclined end portion and adapted to contain the products and defining the feeding station, a plurality of cups secured to the belt and arranged on the outer face thereof to upstand from said horizontal reach, said conveyor belt with the cups moving through the bottom portion of the hopper so that the cups scoop up in a singularizing fashion the products from the hopper, and said belt has opposing side edges and the cups are arranged in parallel rows that are slanted from one side edge to the other.

15. The invention of claim 14 wherein each cup has a bottom aperture, said source of illumination underlying the belt and the light rays therefrom passing through the apertures to enter the products and be diffused thereby and said fiber optic means includes a bundle of light transmitting elements having a blended end positioned above the belt to receive radiant energy from the products.

16. The invention of claim 15 wherein said blended end of the optical bundle and the source of illumination are angularly positioned relative to each other at an angle other than 180°.

17. The invention of claim 15 wherein said means for ejecting the products from the conveyor means includes air nozzles vertically underlying the conveyor belt at the sorting stations and connected to high pressure air lines and air valves in said lines controlling the passage of air to and through the nozzles, said nozzles being arranged to pass blasts of air when the associated air valve is activated by the electronic system through the apertures in the cups to eject the products from the cups.

18. The invention of claim 17 including ejection corridors disposed at the sorting stations and into which the ejected products are propelled by the air blasts, said corridors having a plurality of parallel curved partitions to form a plurality of curved vertical channels through which the propelled products pass in an approximate parabolic trajectory so as to dissipate kinetic energy possessed by said products and output conveyor means forming the bottom of each corridor and on which the products fall after passing through the channels.

19. An automatic sorting apparatus for sorting agricultural products in accordance with a sensed physical property thereof comprising:

- a. conveyor means for conveying the products in singularized successive fashion from a feeding station to a reading station;
- b. a source of illumination disposed at the reading station for illuminating the products;
- c. fiber optic means disposed at the reading station for capturing the light rays diffused by the products;
- d. optical means coupled to the fiber optic means for generating electrical signals proportional to the transmittance of the products at at least two wavelengths;
- e. an electronic system activated by such transmittance related signals to generate sorting signals which indicate the physical condition of the products;
- f. means for ejecting the products from the conveyor means at selected sorting stations forward of the reading station;

17

g. a logic network for interpreting the signals from the electronic system for selectively activating said ejecting means at various sorting stations, said conveyor means comprising a moving belt having an upper horizontal reach, said reach having an inclined end portion, a loading hopper overlying the inclined end portion and adapted to contain the products and defining the feeding station, a plurality of cups secured to the belt and arranged on the outer face thereof to upstand from said horizontal

18

reach, said conveyor belt with the cups moving through the bottom portion of the hopper so that the cups scoop up in a singularizing fashion the products from the hopper, and a tunnel for each row of cups adjacent the back wall of said hopper with the length of each tunnel being not less than the spacing between successive cups of a row whereby at least one cup of each row of cups is always in a tunnel.

* * * * *

15

20

25

30

35

40

45

50

55

60

65