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(71) Applicant (*for all designated States except US*): **QINETIQ LIMITED** [GB/GB]; Registered Office, 85 Buckingham Gate, London SW1E 6PD (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **COWLING, Donald** [GB/GB]; QinetiQ Bincleaves, Bldg PK2, Newtons Road, Weymouth,, Dorset DT4 8UR (GB). **KANOURAS, Antonios** [GR/GR]; Bizaniou 32,, Pulaia,, Thessaloniki TK 555 35 (GR). **RENTON, Ian** [GB/GB]; 27 Townsville Road, Moordown, Bournemouth BH9 3HL (GB). **STINCHCOMBE Darren** [GB/GB]; QinetiQ Bubckeaves, Bldg 49 Rm 5, Newton Road, Weymouth,, Dorset DT4 8UR (GB).

(74) Agent: **TOCHER, A., J.**; IP QinetiQ Formalities, Cody Technology Park, A4 Building, Room G016, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

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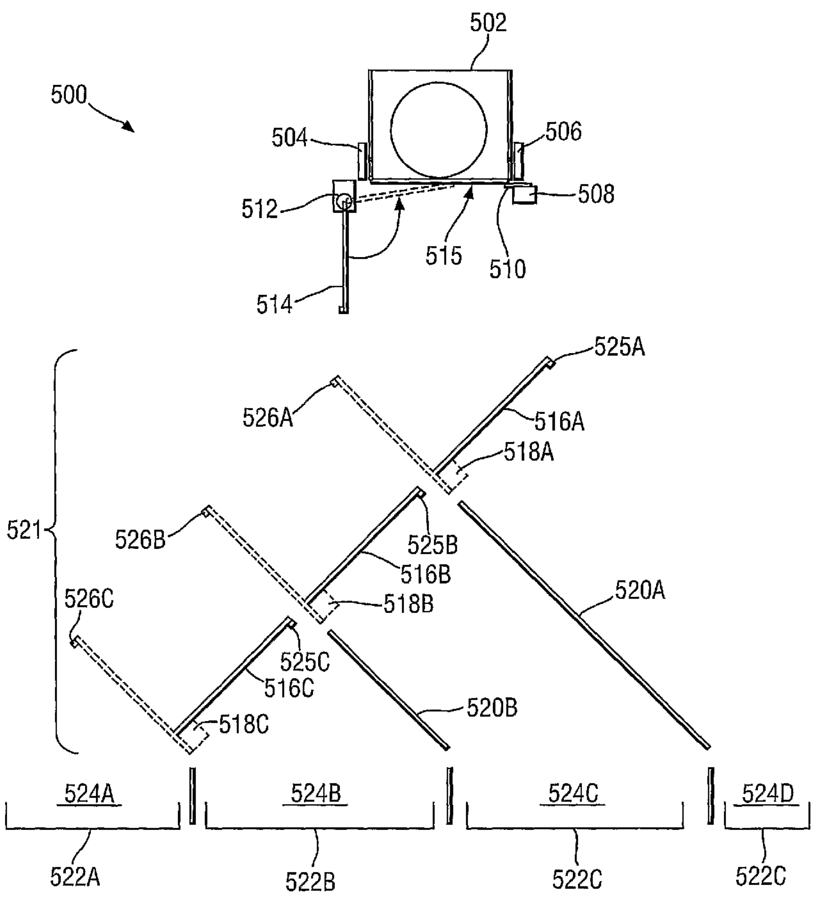
(54) Title: APPARATUS AND METHOD FOR SORTING OBJECTS BY COLOUR



(57) Abstract: Apparatus (500) for sorting objects by colour comprises an input (502) for receiving objects to be sorted, a plurality of outputs (524A, 524B, 524C, 524D), classifying means (504, 506) for classifying an input object into one of a plurality of predetermined colour classes and for generating a control signal corresponding to that colour class and positioning means (521) for directing an object to an output corresponding to a colour class into which the object has been classified by the classifying means, in response to the control signal. The classifying means comprises means for obtaining a measure of an input object's transmissivity with respect to white light and is arranged to classify the input object on the basis of said measure, thus providing a simple mechanism which does not require direct detection of the input object's colour.

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APPARATUS AND METHOD FOR SORTING OBJECTS BY COLOUR

The invention relates to apparatus for, and methods of, sorting objects by colour, particularly (although not exclusively) to sorting glass bottles by colour.

Colour sorting is a primary step in the process of utilisation of recycled glass performed at material reclamation facilities (MRFs). Manufacturers of glass bottle typically distinguish three main colours for supply of recycled glass, namely clear (or flint), amber (or brown) and green.

Colour sorting remains largely a manual operation performed at MRFs. Glass is a difficult material to handle in a MRF due to its fragile characteristics. Most MRFs do not deal with mixed waste streams that include glass because it breaks easily in an automated environment and produces contamination therein. Also current glass recycling procedures require cullets to be prepared according to gradation and contamination specifications, a requirement that current technologies cannot reliably meet. Of the three main colours for supply of recycled glass, clear glass has the highest value and the lowest tolerance for contamination by other colours. The contamination allowance is generally about 0.5% by weight of non-clear glass. In comparison, brown and green fractions can tolerate between 2 and 3% by weight contamination of foreign colour glass.

However, manual sorting is only effective when glass particles are large enough to recognise and handle. Common manual sorting protocols assume the loss of all pieces of broken glass having a dimension less than 50 mm, which totals over 40% of recycled glass in some commingled collection programmes. Furthermore, in some cases it may not be economically feasible to manually separate more than one colour (usually clear due to higher market value) from mixed waste glass. In such cases, mixed colour residue may be sent to alternative applications such as construction aggregate. In other cases, sorting for utilisation of all three colours may be practical.

Colour sorting by consumers is clearly desirable, however, glass collection programmes vary in the degree to which consumers are requested to sort by colour. Bottle banks usually collect sorted colours, whilst kerbside programmes often collect a commingled stream of bottles. There is therefore a variation in supply which requires different types of sorting protocol by recyclers. If glass containers are not colour-sorted by consumers, recyclers have two principal options, namely, to sort the glass at the point of collection, or colour-sort the glass at a material reclamation facility (MRF).

The process by which coloured glass is presently sorted is therefore slow, labour-intensive, expensive and wasteful of glass. An automated system is disclosed in US patent 6 144 004; this systems carries out automatic colour classification and separation on the basis thereof. However it employs standard photosensors, e.g. photodiodes, which have the disadvantages of significant cost and relatively narrow spectral response which can limit classification performance.

It is an object of the present invention to at least ameliorate these problems.

According to a first aspect of the present invention, this object is achieved by apparatus for sorting objects by colour, the apparatus comprising, an input for receiving objects to be sorted, a plurality of outputs, classifying means for classifying an input object into one of a plurality of predetermined colour classes and for generating a control signal corresponding to that colour class, and positioning means for directing an object to an output corresponding to a colour class into which the object has been classified by the classifying means, in response to the control signal, characterised in that the classifying means comprises means for obtaining a measure of an input object's transmissivity with respect to white light and is arranged to classify the input object on the basis of said measure.

Apparatus of the invention provides sorting on the basis of colour without complexity associated with direct sensing or evaluation of an object's colour.

Preferably, the means for obtaining a measure of an input object's transmissivity with respect to white light comprises a white-light LED and a light-dependent resistance (LDR), with the apparatus being arranged such that, in operation thereof, an input object is interposed between the white-light LED and the LDR. LEDs and LDRs have the advantages of ruggedness and longevity. To provide a higher degree of confidence in the classification carried out by the apparatus, and in particular to reduce instances of mis-classification of objects due to the presence of labels and such like (e.g. on glass bottles) the LED may be comprised in an array of LEDs and the LDR comprised in an array of LDRs, with the apparatus being arranged such that, in operation thereof, an input object is interposed between the LED array and the LDR array.

A particularly simple but effective positioning means comprises a first diverting paddle pivoted along a substantially horizontal edge thereof to allow rotation of the first diverting paddle in a substantially vertical plane between extreme angular positions -θ and +θ with respect to the vertical, where $20° \leq \theta \leq 80°$, the extreme angular positions of the diverting paddle defining an object–receiving aperture positioned vertically above said substantially horizontal edge, and wherein the first diverting paddle is positioned to receive objects under gravity from the classifying means via said aperture and has associated actuating means for moving the first diverting paddle between its extreme angular positions in response to a control signal from the classifying means.

The number of outputs of the positioning means may be extended from two to three by providing a second diverting paddle substantially identical to the first diverting paddle and positioned vertically below the first diverting paddle to receive objects under gravity therefrom when the first diverting paddle is in one of its extreme angular positions, and wherein the first and second diverting paddles lie substantially in the same plane when both are in said extreme angular position.

The positioning means may be extended to have four or more outputs by means of n ($n \geq 1$) additional diverting paddles, each substantially identical to the first diverting paddle, and wherein the ith diverting paddle is positioned with respect to the (i-1)th as the second diverting paddle is positioned with respect to the first.

Preferably the extreme angular positions of one or more diverting paddles are defined by mechanical end stops suitable for withstanding the impact of an object passing through the positioning means under gravity. This prevents wear and damage to the pivoted edges of the diverting paddles. Incidence of damage to a diverting paddle may be reduced by providing it with a padded upper surface.

In order to increase the rate of input of objects, the apparatus may further comprises a hopper or a conveyor belt for inputting objects to the classifying means.

The apparatus preferably further comprises a plurality of bins for receiving objects output by the positioning means, allowing for sorted objects to be stored by the apparatus. In the case of sorting glass bottles, space within the bins may be better utilised either by providing crushing means within the bins, or by providing each bin with a sharp vertical edge arranged to effect smashing objects received into the bin under gravity from the positioning means.

A substantially even distribution of objects may be achieved by providing each bin with an angled plate arranged to distribute objects evenly across the cross-sectional area of the bin.

Conveniently, the classifying means further comprises an entry bay for receiving objects to be sorted, and on which the LED and LDR, or, as the case may be, the LED array and the LDR array, are mounted, the entry bay being positioned vertically above the positioning means and being arranged to release objects under gravity into the positioning means.

Corresponding to the first aspect of the invention, there is provided a method of sorting objects by colour comprising the steps of:

(i) classifying an input object into one of a pre-determined set of colour classes; and

(ii) positioning the object according to the colour class into which the object is classified

characterised in that step of classifying the object comprises the steps of

(iii) obtaining a measure of the object's transmissivity with respect to white light; and

(iv) assigning a colour class to the object on the basis of said measure.

According to a second aspect of the invention, there is provided apparatus for sorting objects by colour, the apparatus comprising an input for receiving objects to be sorted, a plurality of outputs classifying means for classifying an object into one of a plurality of predetermined colour classes and for generating a control signal corresponding to that colour class, the classifying means comprising means for obtaining measures of the object's transmission as a function of wavelength in a plurality of spectral bands, and a microcontroller arranged to classify the input object on the basis of said measures and output the control signal, and positioning means for directing the object to an output corresponding to a colour class into which the object has been classified by the classifying means, in response to the control signal, characterised in that the means for obtaining measures of the object's transmission as a function of wavelength in a plurality of spectral bands comprises a white-light LED and two or more LDRs, each LDR being arranged to receive light from the LED through a filter passing light of a single, unique primary colour, and wherein the apparatus is arranged such that, in operation thereof, the object is interposed between the white-light LED and the colour filters.

Corresponding to the second aspect of the invention, there is provided a method of sorting objects by colour comprising the steps of:

(i) obtaining measures of the transmission an object to be sorted as a function of wavelength in a plurality of spectral bands;

(ii) classifying the object into a colour class on the basis of said measures; and

(iii) positioning the object according to the colour class into which the object is classified,

characterised in that the step of obtaining measures of the transmission an object to be sorted as a function of wavelength in a plurality of spectral bands comprises the step of interposing the object between a white-light LED and an LDR to produce a signal from the LDR corresponding to the object's transmission in a given spectral band, the LDR being arranged to receive light from the LED via the object and through a colour filter which passes only light having a wavelength within said spectral band.

Embodiments of the invention are described below by way of example only and with reference to the accompanying drawings in which:

Figure 1	shows a vertical cross-section through an apparatus of the invention;
Figure 2	shows a flow chart illustrating steps in the operation of the Figure 1 apparatus;
Figures 3 and 4	are circuit diagrams for sensors comprised in the Figure 1 apparatus;
Figure 5	shows a circuit diagram for a limit switch which is comprised in the Figure 1 apparatus;
Figure 6	shows a servo-motor system comprised in the Figure 1 apparatus;
Figure 7	shows a microcontroller comprised in the Figure 1 apparatus;
Figure 8	shows a decision tree of a colour classification algorithm which is implemented on the Figure 7 microcontroller;
Figure 9	illustrates construction of the Figure 1 apparatus;
Figure 10	illustrates an alternative apparatus of the invention; and
Figure 11	illustrates operation of the Figure 10 apparatus.

Figure 1 shows a diagram of a system 100 of the invention for sorting glass bottles on the basis of colour. The system 100 comprises a body 102 having an input tube 104 for receiving bottles and output tubes 106, 108, 110, 112, 114, 116 through which sorted bottles are output. A pivoting tube 120 having substantially the same internal diameter as pipes 104, 106, 108, 110, 112, 114, 116 is attached to the armature of a servo-motor (not shown) which operates to rotate the pivot tube 120 about an axis 111 which is substantially orthogonal to the pivoting tube's central longitudinal axis. The end of the pivoting tube 120 shown adjacent to the input tube 104 in Figure 1 may be brought into alignment with any one of the output tubes 106, 108, 110, 112, 114, 116 by the servo-motor.

The system 100 further comprises white LED clusters 105, 107. The white light sources 105, 107 are directional, i.e. most of the light they emit is directed towards the pivoting tube 120. (Other non-flickering, directional, white light sources are also suitable.)

The pivoting tube 120 is fitted with a fixed Plexiglass® stopwindow 118 to which is attached a colour sensor 150 for establishing the colour of a bottle inserted into the system 100, and a proximity sensor 160 for detecting the presence of objects in the pivoting tube 120. The pivoting tube 120 is fitted with a further Plexiglass® window 194 at the end of the tube 120 which is remote from the stopwindow 118. The window 194 is arranged to be opened and closed by means of a high-speed servo motor 190. The input tube 104 is also fitted with a Plexiglass® window 199 which is arranged to be opened and closed by means of another high-speed servo motor 195.

An infrared sensor 180 is mounted on the exterior of the pivot tube 120, and infrared reflecting patches 109A-F, are provided between the input and output tubes 104, 106, 108, 110, 112, 114, 116. During operation of the system 100, the sensor 180 emits infrared (IR) radiation, a portion of which is reflected sequentially by one or more of the patches, such as 109A, back to the sensor 180 as the pivoting tube 120 rotates.

The system 100 further comprises a limit switch 170 which is located next to an end of the pivot tube 120 when the latter is aligned with the input tube 104.

When the pivoting tube 120 is properly aligned with tubes 104, 116 the limit switch 170 is in a depressed state and an electrical signal is produced indicating that the switch 170 is in this state.

The colour sensor 150, the proximity sensor 160, and the IR sensor 180 are each arranged to provide data to a microcontroller (not shown in Figure 1) which in turn outputs control data to the high-speed servo motors 190, 195 and to the servo-motor to which the pivoting tube 120 is attached.

Figure 2 shows a flow diagram which illustrates operation of the system 100. The initial state, or rest state of the system 100 is such that the pivoting tube 120 is fully aligned with tubes 104, 116 and the Plexiglass® windows 194, 199 are in an open condition. A person inserts a glass bottle into the input tube 104. The bottle slides down the input tube 104 under gravity and enters the pivoting tube 120 in which it comes to rest against the stop window 118. The proximity sensor 160 detects that a bottle has entered the pivoting tube 120 (step 210) and the microcontroller sends a control signal to the high-speed servo motors 190, 195 to close windows 194, 199 (step 212), and also a control signal to the pivoting tube's servo motor so that the pivoting tube is put into counter-clockwise rotation about the axis 111 (214). As the pivoting tube 120 comes into alignment with the tube 101 and then tube 103, the colour of the glass bottle is read by the colour sensor 150 (216). The bottle's colour is classified (218) as clear, green or brown and a signal corresponding to the bottle's colour is passed from the colour sensor 150 to the microcontroller, which in turn outputs a corresponding control signal to the pivoting tube's servo motor so that rotation of the pivoting tube 120 is stopped when it is aligned with tube 106 if the bottle's colour is clear (220), tube 108 if the bottle's colour is green (222) and with tube 110 if the bottle's colour is brown (224). If the bottle's colour is not determined or not clear, green or brown the microcontroller outputs a signal to the pivoting tube's servo motor so that rotation of the pivoting tube 120 is stopped when the pivoting tube 120 is aligned with the tube 116 (225).

As the pivoting tube is rotated, positional feedback information is provided to the microcontroller by the sensor 180. For example, if the bottle is classified as clear, the pivoting tube's servo motor is instructed to stop counter-clockwise rotation of the pivoting tube 120 when four pulses of IR radiation have been received by the sensor 180 from IR reflecting patches 109W, 109X, 109Y and 109A (220). If the bottle is classified as green, the pivoting tube's servo motor is instructed to stop counter-clockwise rotation of the pivoting tube 120 when five IR pulses have been received, one from each of IR reflecting patches 109W, X, Y, A and B (222). If the bottle is classified as brown, the pivoting tube's servo motor is instructed to cease counter-clockwise rotation when the sensor 180 has received six IR pulses, one from each of IR reflecting patches 109W, X, Y, A, B, C (224). If the bottle is none of clear, green and brown, or cannot be classified, the pivoting tube's servo motor is instructed to cease counter-clockwise rotation when the sensor 180 has received nine IR pulses, one from each of IR reflecting patches 109W-109F (225).

When the pivoting tube has been brought into alignment with a tube corresponding to the classified colour of the bottle (tube 106 for clear, tube 108 for green, tube 110 for brown, or tube 116 for none of clear, green and brown), and the pivoting tube's servo motor has stopped rotating (226), the microcontroller issues a control signal to high-speed servo motor 190 so that the window 194 is opened and the bottle then moves out of the pivoting tube 120 and into an appropriate output tube (106, 108, 110, 116) under gravity (228).

The proximity sensor 160 detects when the bottle has exited the pivoting tube 120 and after a short delay (to ensure the bottle has completely exited the pivoting tube 120) a signal is passed to the microcontroller by the sensor 160 which issues a control signal to the pivoting tube's servo motor to rotate the pivoting tube 120 in a clockwise direction (229) until it is aligned with tubes 104, 116 (230). The control signal issued to the pivoting tube's servo motor is terminated when the sensor 180 has detected a number of IR pulses corresponding to the angular distance between whichever output tube has been utilised, and the input tube 104. For example if the bottle sorted was classified as brown, so that the bottle was sorted into output tube 110, then the pivoting tube's servo-motor is instructed to rotate clockwise until the sensor 180 has detected five IR pulses (one from each of IR reflecting patches 109W, 109X, 109Y, 109A, 109B). However, in any case the pivoting tube's servo motor does not cease clockwise rotation of the pivoting tube 120 until the tube 120 has closed the limit switch 170 and a corresponding signal has been received by the microcontroller (230, 232).

Once the pivoting tube's servo motor has stopped (234) the microcontroller issues a control signal to the high-speed servo motor 195 to open the window 199. The system 100 is then ready to receive a further bottle for sorting.

Clear is the colour most frequently used, followed by green and then brown. By arranging the system so that the output tube (106) into which bottles having the most common colour (clear) are sorted is the shortest angular distance from the input tube 104, followed by the output tube 108 into which bottles having the second most commonly occurring colour (green) are sorted, and then the output tube 110 into which bottles having the least common colour (brown) are sorted, the time taken and energy needed to sort a given number of bottles is minimised.

Figure 3 shows a circuit diagram of the proximity sensor 160. The sensor 180 has the same construction. A pulse-width modulated IR LED 161 emits IR radiation, a portion of which is reflected, by a bottle in the case of the proximity sensor 160, or an IR reflecting patch such as 109A in the case of the sensor 180, and then detected by an IR sensor integrated circuit 162 (e.g. IS1U60 or IS471F manufactured by Sharp®) which generates an output voltage at 163. The IS1U60 is arranged to detect pulse-width modulated radiation having a central frequency of 38 kHz. The IR LED 161 may be modulated in this way by the microcontroller or alternatively by a 555 integrated circuit configured as a stable multivibrator. If an IS471F is used for the sensor 162, modulation of the IR LED 161 is provided by a modulation system internal to the IS471F integrated circuit. The sensor 160 provides digital output at an output point 164.

Figure 4 shows a circuit diagram of a circuit portion 151 of the colour sensor 150. The portion 151 comprises a light-dependent resistor (LDR) 152 and a red filter

153. The voltage at the output 154 is a function of the intensity of red light incident on the LDR 152. The colour sensor 150 comprises two further circuit portions such as 151; one comprises a green filter and the other comprises a blue filter. Light transmitted through a bottle in the pivoting tube 120 is incident on each of the filters and voltage signals corresponding to the intensities of the red, green and blue components in the passed light are generated at respective outputs (such as 154) of each of the three circuit portions (such as 151). The colour of a bottle within the pivoting tube 120 is classified as clear, green or brown by the microcontroller on the basis of the three voltage signals received from the three circuit portions of the sensor 150. A suitable classification algorithm which may be implemented on the microcontroller is described in detail below.

Figure 5 shows a diagram of a circuit 169 for use with the limit switch 170. A signal generated at an output 171 of the circuit 169 is passed to the microcontroller and indicates whether the pivoting tube 120 is properly aligned with the input tube 104, or whether further clockwise rotation of the tube 120 is needed to restore the pivoting tube 120 into alignment with the input tube 104 (229, 230, 232.)

Figure 6 shows a suitable arrangement for interfacing the pivoting tube's servo motor to the microcontroller. Similar arrangements may be used for interfacing the servo motors 190, 195. Servo motors have several useful properties, such as ease of use with microcontrollers (TTL signal compatible), built in driver electronics, high torque geartrains and modest cost.

Referring to Figure 7, the microcontroller of the system 100 is indicated by 300. The microcontroller 300 comprises a PIC16F872 8-bit microcontroller chip 301 clocked by a 4 MHz ceramic resonator 302. The chip 301 has analogue inputs an0, an1, an2, an3, digital inputs in0 to in7, and outputs out0 to out7. The three outputs from the colour sensor 150 are each input to an analogue input of the chip 301. Outputs signals from the proximity sensor 160, the sensor 180 and the limit switch circuit 169 are each input to a digital input of the chip 301. Control signals for the three servo motors are generated by the microcontroller at three of the outputs out0 to out7. The microcontroller chip 301 may be programmed to execute the flowchart 200 of Figure 2 in any suitable programming language.

Figure 8 shows a decision tree 400 for classifying the colour of a bottle as green, brown or clear. The microcontroller chip 301 digitises each of the three outputs of the colour sensor 150 to produce three 8-bit words, and is programmed to execute the decision tree 400. The digitised output signal of each of the three portions of the colour sensor 150 therefore has a value in the range 0 to 255. When the colour of a bottle has been classified, a signal is output by the microcontroller 300 to the pivoting tube's servo motor so that the pivoting tube 120 is rotated to align with a corresponding output tube.

Figure 9 shows the construction of the body 102 of the system 100. The body 102 comprises two pieces 102A, 102B of sheet material, for example aluminium or steel, connected by spacing elements 102C, 102D, 102E, 102F. 110mm diameter PVC piping may be used for the input 104 and output 106, 108, 110, 112, 114, 116 tubes.

Phototransistors or photodiodes may be used instead of LDRs in the colour sensor 150 in alternative systems of the invention. Windows 118, 194 may be made of transparent materials other than Plexiglass® for example Perspex®. It is desirable that the window 199 is transparent so that one may see into the machine to detect obstructions etc, although this is not essential.

An aperture having a diameter smaller than that of the input tube 104 may be provided at the entrance thereof so that bottles which are too large to be handled by the system 100 cannot be inserted into the input tube 104.

The system 100 may be modified to provide classification into more than three colour classes by suitable adaptation of the of the classification algorithm 400 of Figure 8 and other programming of the microcontroller 300. Bottles having colours other than clear, green or brown may then be sorted into one or more of the output tubes 112, 114 with unclassified bottles or bottles having a colour not falling into an envisaged class being output from the system 100 through output tube 116.

The system 100 operates to sort glass bottles by colour, however alternative systems of the invention may sort other objects by colour provided the objects to be sorted transmit or reflect light of a characteristic colour.

A second apparatus of the invention is indicated generally by 500 in Figure 10. The apparatus 500 comprises an entry bay 502 for receiving glass bottles which are to be sorted on the basis of their colour and is arranged to receive bottles in generally horizontal orientation (perpendicular to the plane of Figure 10). An LED array 504 and an array 506 of light-dependent resistors (LDRs) are mounted on opposing sides of the entry bay 502. The bottom of the entry bay 502 consists of a hinged flap 515. During one phase of operation of the apparatus 500, the hinged flap 515 is held in a closed (horizontal) position by an arm 510. In another phase of operation of the apparatus 500, the arm 510 is moved out from underneath the hinged flap 515 under control of a servomotor 508 so that the hinged flap 515 pivots downwards under control of a longer arm attachment 514 which itself pivots downwards under control of a servomotor 512. In yet another phase of operation of the apparatus 500 the hinged flap 515 is moved from a vertical (open) position to a horizontal (closed) position under a force applied by the control arm 514 and the servomotor 512, and the hinged flap is retained in a horizontal position by the arm 510 which is moved underneath it under control of the servomotor 508. The entry bay 502 is arranged to admit glass bottles up to 400mm long by 150mm wide: this encompasses the vast majority of glass bottles presently in circulation. In alternative embodiments of the invention, the entry bay may have a size sufficient to accommodate larger bottles. The servomotor 512 is a high-torque model, and need only be powered when it is necessary to restore the hinged flap 516 to a horizontal position from a vertical position.

The LED array 504 comprises a series of 16 individual LEDs, each positioned at a height of approximately 10mm above the bottom of the entry bay 502 (defined by the hinged flap 515 when in a horizontal position) to form a linear array extending in a direction perpendicular to the plane of Figure 4. The array 506 of LDRs comprises a linear array of 16 individual LDRs, each LDR being positioned opposite an LED of the LED array 504, also at a height of approximately 10mm above the bottom of the entry bay 502. Each LDR of the LDR array 506 is comprised in an LDR circuit such as 151 in Figure 4, which generates an analogue output voltage when the LDR is illuminated. However, none has an associated colour filter, such as 153 in Figure 4. A variable resistor, such as 155, within each LDR circuit is adjusted so that, during operation of the apparatus 500, the analogue output voltages of the LDR circuits are as large as possible within the range 0 to 5 volts. The individual LDRs are standard, commercially available devices.

The individual LEDs are white-light LEDs. LEDs are preferable to light bulbs due to a number of factors. Mains operated light bulbs tend to suffer from AC 'beating' where the light intensity oscillates at mains frequency (50 Hz). LDRs are able to detect this oscillation and this can lead to misclassification. DC light bulbs are an alternative, however, these generally require very high current to operate. Overall, LEDs are substantially more rugged and durable than light bulbs.

The apparatus 500 further comprises a positioning system 521 positioned underneath the entry bay 502. The positioning system 521 comprises three diverting paddles 516A, 516B, 516C, each of which is pivoted along an edge thereof about a horizontal axis under control of a servomotor 518A, 518B, 518C, and two fixed plates 520A, 520B. The paddles 516A, 516B, 516C have associated end stops 525A, 526A, 525B, 526B, 525C, 526C defining their extreme clockwise (525A, 525B, 525C) and anticlockwise (526A, 526B, 526C) rotational positions. Four receiving bins 522A, 522B, 522C, 522D are positioned under underneath the positioning system 521 to receive glass bottles which have passed through the positioning system 521. Servomotors 518A, 518B, 518C receive power only when required to move the paddles 516A, 516B, 516C between their associated end stops 525A, 526A, 525B, 526B, 525C, 526C. The end stops 525A, 526A, 525B, 526B, 525C, 526C are engineered to withstand the impact of a bottle passing through the system 521 under gravity. This prevents wear on bearings within the servomotors 518A, 518B, 518C by absorbing impact shock within the structure of the apparatus 500. Paddles 516A, 516B, 516C may be provided with a padded surface layer to reduce the impact load from bottles passing through the positioning system 521. Bottles are output from the positioning system 521 via exits 524A, 524B, 524C, 524D underneath which are located receiving bins 522A, 522B, 522C, 522D for storing sorted bottles.

Servomotors 508, 512 are Hitec HS-700 BB models or similar; servomotors 518A, 518B, 518C are Hitec HS-325 BB models or similar.

The apparatus further comprises a PIC16F877 microcontroller (not shown) which controls operation of the apparatus 500. The PIC16F877 is a low cost, high performance microcontroller, having eight analogue inputs with associated on-board ADCs and multiplexers so that the eight ADCs can accommodate the 16 analogue signals from the LDR circuits. The microcontroller requires certain other components to operate, such as an oscillator clock. All essential components are located with the microcontroller on a main board. A 20 MHz clock is suitable. The microcontroller is arranged to receive signals from the LDR circuits, and to output control signals to the servomotors 508, 512, 518A, 518B, 518C.

General body elements of the apparatus 500 are made from durable 3 or 6 mm PVC and aluminium sheeting. 6mm polycarbonate sheeting may be used to allow visibility of internal workings of the apparatus 500 for testing purposes, as well as giving visibility of operation, if required.

Referring to Figure 11, the apparatus 500 operates as follows. After start-up (602) and initialisation (604) of the apparatus 500, the LED array 504 is turned on (606). The LDR array 506 receives light from the LED array and each LDR circuit generates an output voltage which is digitised by an ADC and input to the microcontroller. The microcontroller reads the digitised output voltages (608) and carries out a classification algorithm which initially establishes whether a bottle is present in the entry bay (612). Operation of the algorithm will be described in detail later. If no bottle is present in the entry bay 502 the microcontroller continues to monitor the output voltages of the LDR circuits. If the microcontroller establishes that a bottle is present (612), the algorithm proceeds to classify the colour of the bottle as 'clear', brown, green or 'opaque' (614). An 'opaque' classification may occasionally result when a bottle having a large label enters the entry bay 502, so that most of the LDRs in the LDR array 506 do not receive light from an LED in the LED array 504. Once the colour of the bottle has been established the microcontroller outputs a control signal to the servomotor 507 so that arm 510 is moved out from underneath the hinged flap 515 which then pivots downwards so that the bottle is output from the entry bay 502 under gravity into the positioning system 521. Further control signals from the microcontroller are passed to servomotors 518A, 518B, 518C so that the paddles 516A, 516B, 516C of the positioning system 521 adopt a configuration corresponding to the classified colour of the bottle and so that the bottle is directed to a bin corresponding to that colour (616). If a paddle in its extreme clockwise rotational position is denoted R, and in its extreme anticlockwise rotational position is denoted L, then a suitable scheme is as follows:

Classified colour	Position of paddle 516A	Position of paddle 516B	Position of paddle 516C	Receiving bin
'Clear'	R	R	R	522A
Brown	R	R	L	522B
Green	R	L		522C
'Opaque'	L			522D

Once the bottle has been output into a bin corresponding to its colour classification, the microcontroller outputs suitable control signals to the servomotors 512, 508 so that the arm 514 restores the hinged flap 515 to a horizontal position (thus closing the entry bay 502) (620) and arm 510 moves under the hinged flap 515 to secure it in the horizontal (closed) position (622). The apparatus 500 is then ready to receive another bottle for classification and sorting. Power is only supplied to servomotor 508 when it is necessary to to move the arm 510. To aid this movement, a low friction bearing (not shown) is used between the arm 510 and the bottom of the hinged flap 516, for example a layer of PTFE material.

The classification algorithm implemented by the microcontroller classifies a bottle's colour by comparing each of the output voltages from the LDR circuits with a set of pre-determined voltage ranges. An output voltage from an LDR circuit is associated with a bottle of certain colour, according to the following table:

Colour	***Voltage Range***
Label (Opaque)	<1V
Brown	>1V to < 2V
Green	>2V to < 4V
Clear	>4V to < 4.6V
Nothing	>4.6 V

Colour is therefore determined according to the amount of light from the LEDs in the array 504 which passes through a bottle and is incident on one or more of the LDRs. The voltage produced by an LDR circuit depends on the amount of light incident on the LDR, and this is dictated by the transmission properties of the space between the LED array 504 and the LDR array 506, which varying according to the colour of bottle within the entry bay 502. Absence of a bottle in the entry bay 502 is indicated by an LDR circuit output voltage greater than 4.6 V. To determine colour, all 16 analogue voltages from the LDR circuits are compared against the voltage ranges in the table above, to provide 16 colour assessments. The colour associated with the voltage output of each LDR circuit is used by the classification algorithm as a vote for a particular colour. The colour with the highest number of votes is then determined as the actual colour of the bottle in the entry bay 502. However, in determining colour, only votes corresponding to 'clear', brown and green are used; those for 'opaque' and 'nothing' are discarded.

Empirical testing has shown this method of resolving colour to be highly effective as it measures colour along the entire length of a bottle. Should light transmission be blocked, for example by a label, this will not necessarily prevent determination of the colour of a bottle. As long as at least two LDR circuits return the same colour classification, the apparatus 500 will be able to determine colour with a high degree of confidence.

The apparatus 500 may be modified to allow classifying and sorting of bottles into more than three colour categories. For example, to sort into four colour categories (plus one 'opaque'/unclassified category) the positioning system 521 may comprise four paddles rather than three, and an extra bin may be provided. The algorithm used to program the microcontroller may be altered to provide for classification into an additional colour category.

Currently bottles are sorted into either clear (flint), green, brown (amber) or miscellaneous. These cover all the basic glass colours currently handled at reprocessors. Blue glass is not currently sorted separately as it can be mixed in with green.

Bottles may be fed in by hand, either directly into the entry bay 502, or by passing them along a short tube. This arrangement is suitable for bottle banks operating 'bring' schemes where users insert bottles one at a time by hand and is intended to replicate the methods currently used. However, whereas current bottle banks have inputs for each colour type, the apparatus 500 has just one input taking all colours.

Alternatively, the apparatus 500 may comprise other means for inputting bottles to the entry bay 502. For example, the apparatus 500 may comprise a large hopper above the entry bay 502, capable of accommodating a large number of glass bottles and arranged to feed bottles one at a time into the entry bay 502. Such an arrangement is suitable for use in pubs, clubs, bars and restaurants where a large number of empty glass bottles are generated. Empty bottles are poured en masse into the hopper for sorting.

Alternatively, the apparatus 500 may further comprise a conveyor belt onto which bottles are placed. Bottles are conveyed to the entry bay 502, where they are fed in one at a time for classifying. This arrangement is suitable for use in a recycling truck where it can be used to sort glass taken from kerbside collection schemes as collection takes place.

Angled plates may be placed in the bins 522A, 522B, 522C, 522D to spread bottles within the bins 522A, 522B, 522C, 522D over a wider area.

To improve utilisation of storage space within the bins 522A, 522B, 522C, 522D, sharp edges may be provided therein under the exits 524A, 524B, 524C, 524D of the positioning system 521. The vertical separation of a sharp edge and its corresponding exit is arranged so that bottles are smashed by the sharp edge when exiting the positioning system 521 under gravity. Alternatively, crushing mechanisms may be placed in each of the bins 522A, 522B, 522C, 522D to crush bottles output by the positioning system 521. Broken or crushed glass takes up less volume than intact glass bottles; therefore more bottles may be processed by the apparatus 500 before the bins 522A, 522B, 522C, 522D have to be emptied.

Power for the apparatus 500 is provided by 24 volt batteries (car batteries), and, together with voltage regulators, provide supplies of 6 volts and 5 volts respectively. The batteries may be trickle-charged constantly by using solar collectors mounted to the top of the unit, or larger solar panels mounted on the top of the apparatus 500. (If mechanical crushers are used within the bins 522A, 522B, 522C, 522D, an additional power supply is required.)

Hopper or conveyor belt input feeds either draw power from regulated mains supplies or on board generators, or are powered by groups of stand-alone batteries.

In order to save power in periods in which the apparatus 500 is not in use, switching on of the LED array 504 may be controlled by a switch which is activated by the presence of a bottle in the entry bay 502 of the apparatus 500.

CLAIMS

1. Apparatus (500) for sorting objects by colour, the apparatus comprising:
an input (502) for receiving objects to be sorted;
a plurality of outputs (524A, 524B, 524C, 524D);
classifying means (504, 506) for classifying an input object into one of a plurality of predetermined colour classes and for generating a control signal corresponding to that colour class; and
positioning means (521) for directing an object to an output corresponding to a colour class into which the object has been classified by the classifying means, in response to the control signal;
characterised in that the classifying means comprises means for obtaining a measure of an input object's transmissivity with respect to white light and is arranged to classify the input object on the basis of said measure.

2. Apparatus according to claim 1 wherein the means for obtaining a measure of an input object's transmissivity with respect to white light comprises a white-light LED and a light-dependent resistance (LDR), and wherein the apparatus is arranged such that, in operation thereof, an input object is interposed between the white-light LED and the LDR.

3. Apparatus according to claim 2 wherein the LED is comprised in an array (504) of LEDs and the LDR is comprised in an array (506) of LDRs, and wherein the apparatus is arranged such that, in operation thereof, an input object is interposed between the LED array and the LDR array.

4. Apparatus according to any preceding claim wherein the positioning means comprises a first diverting paddle (516A) pivoted along a substantially horizontal edge thereof to allow rotation of the first diverting paddle in a substantially vertical plane between extreme angular positions -θ (526A) and +θ (525A) with respect to the vertical, where $20° \leq \theta \leq 80°$, the extreme angular positions of the diverting paddle defining an object–receiving aperture positioned vertically above said substantially horizontal edge, and

wherein the first diverting paddle is positioned to receive objects under gravity from the classifying means via said aperture and has associated actuating means (518A) for moving the first diverting paddle between its extreme angular positions in response to a control signal from the classifying means.

5. Apparatus according to claim 4 further comprising a second diverting paddle (516B) substantially identical to the first diverting paddle and positioned vertically below the first diverting paddle to receive objects under gravity therefrom when the first diverting paddle is in one of its extreme angular positions, and wherein the first and second diverting paddles lie substantially in the same plane when both are in said extreme angular position.

6. Apparatus according to claim 5 further comprising n ($n \geq 1$) additional diverting paddles (516C), each substantially identical to the first diverting paddle, and wherein the ith diverting paddle is positioned with respect to the (i-1)th as the second diverting paddle is positioned with respect to the first.

7. Apparatus according to any one of claims 4 to 6, wherein the extreme angular positions of a diverting paddle are defined by mechanical end stops (526A, 525A) suitable for withstanding the impact of an object passing through the positioning means under gravity.

8. Apparatus according to any one of claims 4 to 6 , wherein one or more diverting paddles has a padded upper surface.

9. Apparatus according to any preceding claim further comprising a hopper for inputting objects to the classifying means.

10. Apparatus according to any one of claims 1 to 8 further comprising a conveyor belt for inputting objects to the classifying means.

11. Apparatus according to any preceding claim further comprising a plurality of bins for receiving objects output by the positioning means.

12. Apparatus according to claim 11 wherein at least one bin comprises crushing means for crushing objects output by the positioning means.

13. Apparatus according to claim 11 wherein at least one bin comprises a sharp vertical edge arranged to effect smashing of objects received into the bin under gravity from the positioning means.

14. Apparatus according to claim 11 wherein at least one bin comprises an angle plate arranged to evenly distribute objects received from the positioning means within the bin.

15. Apparatus according to claim 4 wherein the classifying means further comprises an entry bay (502) for receiving objects to be sorted, and on which the LED and LDR, or, as the case may be, the LED array and LDR array, or LDR array, are mounted, the entry bay being positioned vertically above the positioning means and being arranged to release objects under gravity into the positioning means.

16. Apparatus substantially as hereinbefore and described and illustrated in Figure 10.

17. Apparatus according to any one of claims 1 to 15 further comprising a battery power-supply, and a solar collector or solar power arranged to trickle-charge the battery power-supply.

18. A method of sorting objects by colour comprising the steps of:
(i) classifying an input object into one of a pre-determined set of colour classes; and
(ii) positioning the object according to the colour class into which the object is classified

characterised in that step of classifying the object comprises the steps of
(iii) obtaining a measure of the object's transmissivity with respect to white light; and
(iv) assigning a colour class to the object on the basis of said measure.

19. Apparatus (100) for sorting objects by colour, the apparatus comprising:
an input (104) for receiving objects to be sorted;
a plurality of outputs (106, 108, 110, 112, 114, 116);
classifying means (150, 300) for classifying an object into one of a plurality of predetermined colour classes and for generating a control signal corresponding to that colour class, the classifying means comprising means for obtaining measures of the object's transmission as a function of wavelength in a plurality of spectral bands, and a microcontroller (300) arranged to classify the input object on the basis of said measures and output the control signal; and
positioning means (120, 118, 190, 194, 300) for directing the object to an output corresponding to a colour class into which the object has been classified by the classifying means, in response to the control signal;
characterised in that the means for obtaining measures of the object's transmission as a function of wavelength in a plurality of spectral bands comprises a white-light LED (105) and two or more LDRs (152), each LDR being arranged to receive light from the LED through a filter (153) passing light of a single, unique primary colour, and wherein the apparatus is arranged such that, in operation thereof, the object is interposed between the white-light LED and the colour filters.

20. Apparatus according to claim 19 wherein the apparatus is arranged to withdraw input objects, and to output objects, under gravity.

21. Apparatus according to claim 20 wherein the input and outputs are formed by an inclined input tube (104) and inclined output tubes (106, 108, 110, 112).

22. Apparatus according to claim 21 wherein the positioning means comprises a pivoting tube (120) closed at one end and having at its other end a window (194) arranged to open and close and a motor arranged to rotate the pivoting tube in a substantially vertical plane in response to control signals from the microcontroller , and wherein the ends of the input and output tubes remote from the input and outputs are positioned adjacent to the locus of said other end of the pivoting tube, with that of the input tube being located higher than those of the output tubes.

23. Apparatus according to claim 22 wherein the pivoting tube is arranged to rotate through one of a series of angles in response to control signals output by the microcontroller, rotation through each angle corresponding to alignment of said other end with an output tube, and wherein rotation through the smallest angle of the series corresponds to alignment of said other end with the output tube corresponding to the colour class into which input objects are most frequently classified.

24. Apparatus according to claim 23 wherein the output tubes are arranged such that rotation of the pivoting tube through the nth smallest angle brings said other end into alignment with the output tube corresponding to the colour class into which input objects are sorted with the nth highest frequency, where $1 \leq n \leq N$ and N is the total number of output tubes corresponding to colour classes.

25. Apparatus according to claim 22 wherein the pivoting tube incorporates an infrared sensor (160) for detecting the presence or absence of an object within the pivoting tube, the infrared sensor being arranged to provide corresponding signals to the microcontroller, the microcontroller being arranged to initiate rotation of the pivoting tube in response to said signals.

26. Apparatus according to claim 22 wherein the pivoting tube incorporates an infrared sensor (180) for detecting the pivoting tube's angular position with respect to the input tube, and a series of infrared-reflecting patches (109W,

109X, 109Y, 109A, 109B, 109C, 109D, 109E, 109F) arranged between the output tubes are positioned to reflect infrared radiation emitted by the sensor back to the sensor.

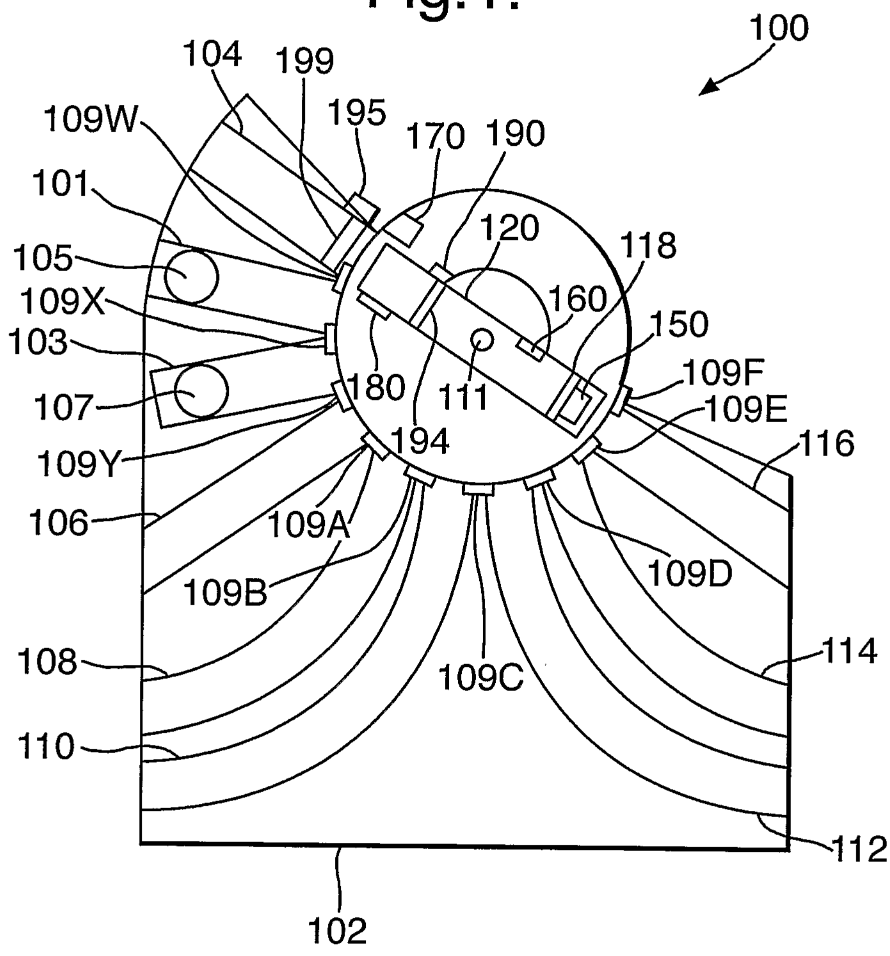
27. Apparatus according to claim 22 further comprising a limit switch arranged to be closed by the pivoting tube when the pivoting tube is aligned with the input tube.

28. Apparatus according to claim 21 wherein the input tube has an aperture at its input end to prevent insertion of objects having a dimension greater than that of the aperture into the input tube.

29. Apparatus for sorting objects by colour substantially as hereinbefore described and illustrated in Figures 1, 3, 4, 5, 6, 7 and 9.

30. A method of sorting objects by colour comprising the steps of:
(i) obtaining measures of the transmission an object to be sorted as a function of wavelength in a plurality of spectral bands;
(ii) classifying the object into a colour class on the basis of said measures; and
(iii) positioning the object according to the colour class into which the object is classified,
characterised in that the step of obtaining measures of the transmission an object to be sorted as a function of wavelength in a plurality of spectral bands comprises the step of interposing the object between a white-light LED and an LDR to produce a signal from the LDR corresponding to the object's transmission in a given spectral band, the LDR being arranged to receive light from the LED via the object and through a colour filter which passes only light having a wavelength within said spectral band.

Fig.1.


100
104
199
195
170
190
109W
101
120
118
105
160
109X
150
103
109F
107
180
111
109E
194
116
109Y
106
109A
109D
109B
114
108
109C
110
112
102

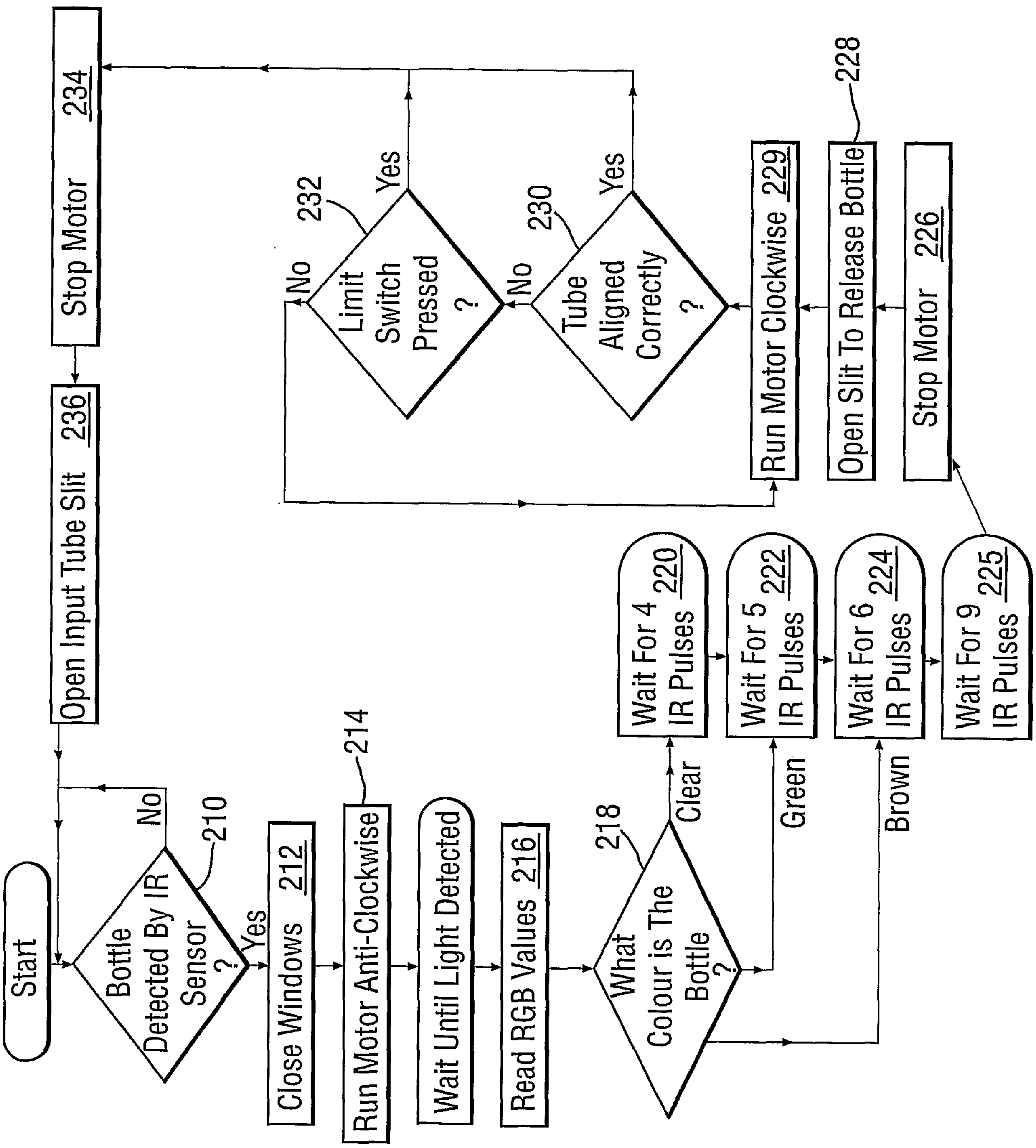

Start
Bottle Detected By IR Sensor ?
210
No
Yes
Close Windows 212
Run Motor Anti-Clockwise
214
Wait Until Light Detected
Read RGB Values 216
What Colour is The Bottle ?
218
Clear
Green
Brown
Wait For 4 IR Pulses 220
Wait For 5 IR Pulses 222
Wait For 6 IR Pulses 224
Wait For 9 IR Pulses 225
Stop Motor 226
Open Slit To Release Bottle
228
Run Motor Clockwise 229
Tube Aligned Correctly ?
230
Limit Switch Pressed ?
232
Stop Motor 234
Open Input Tube Slit 236

Fig.2.

Fig.3.

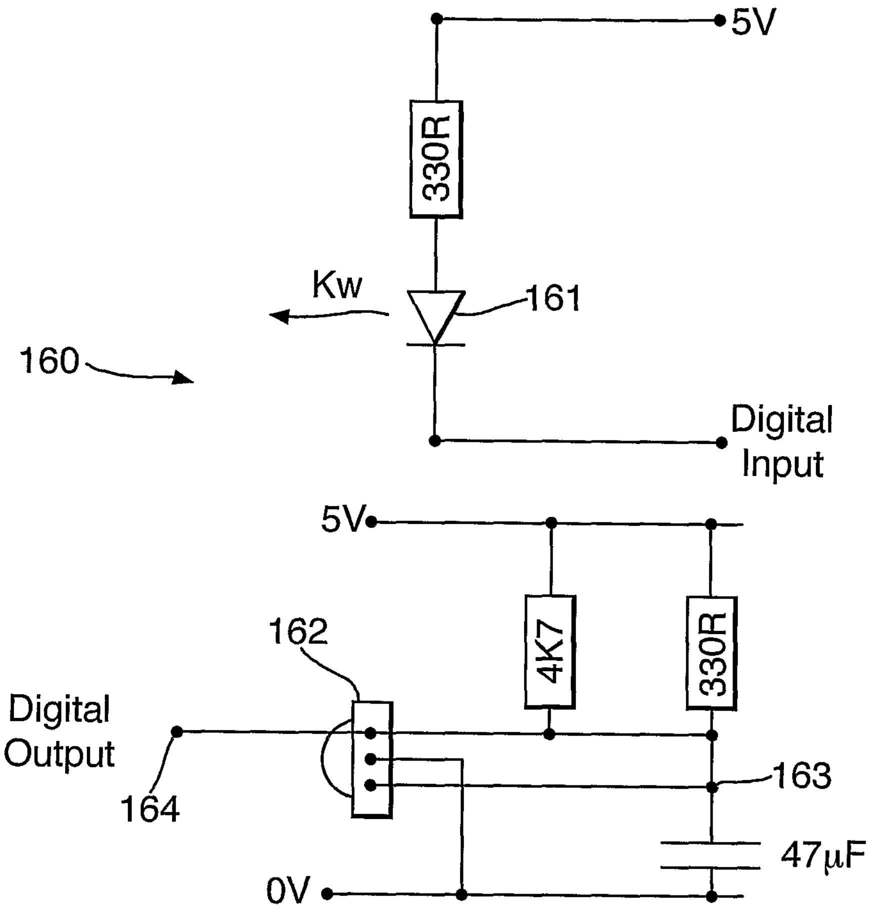

5V
330R
Kw
161
160
Digital
Input
5V
162
4K7
330R
Digital
Output
164
163
47μF
0V

Fig.4.

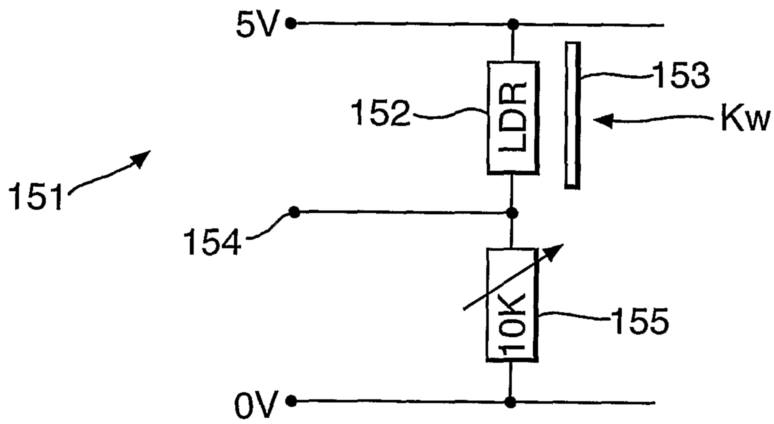

5V
153
152
LDR
Kw
151
154
10K
155
0V

Fig.5.

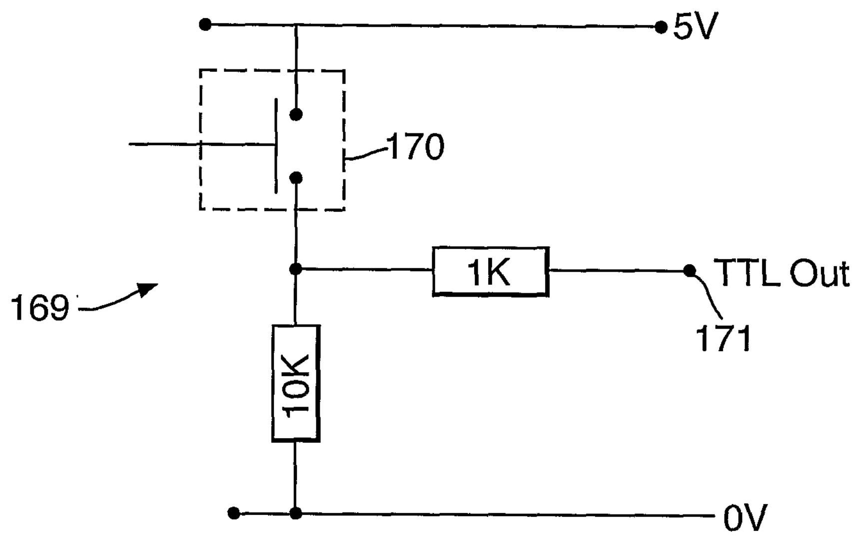

5V
170
1K
TTL Out
171
169
10K
0V

Fig.6.

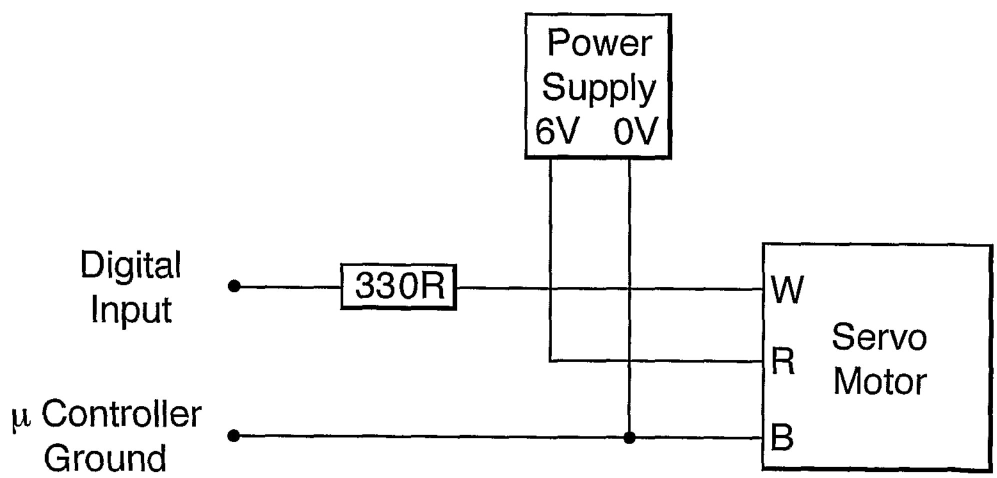

Power
Supply
6V 0V
Digital
Input
330R
W
R
B
Servo
Motor
μ Controller
Ground

Fig.7.

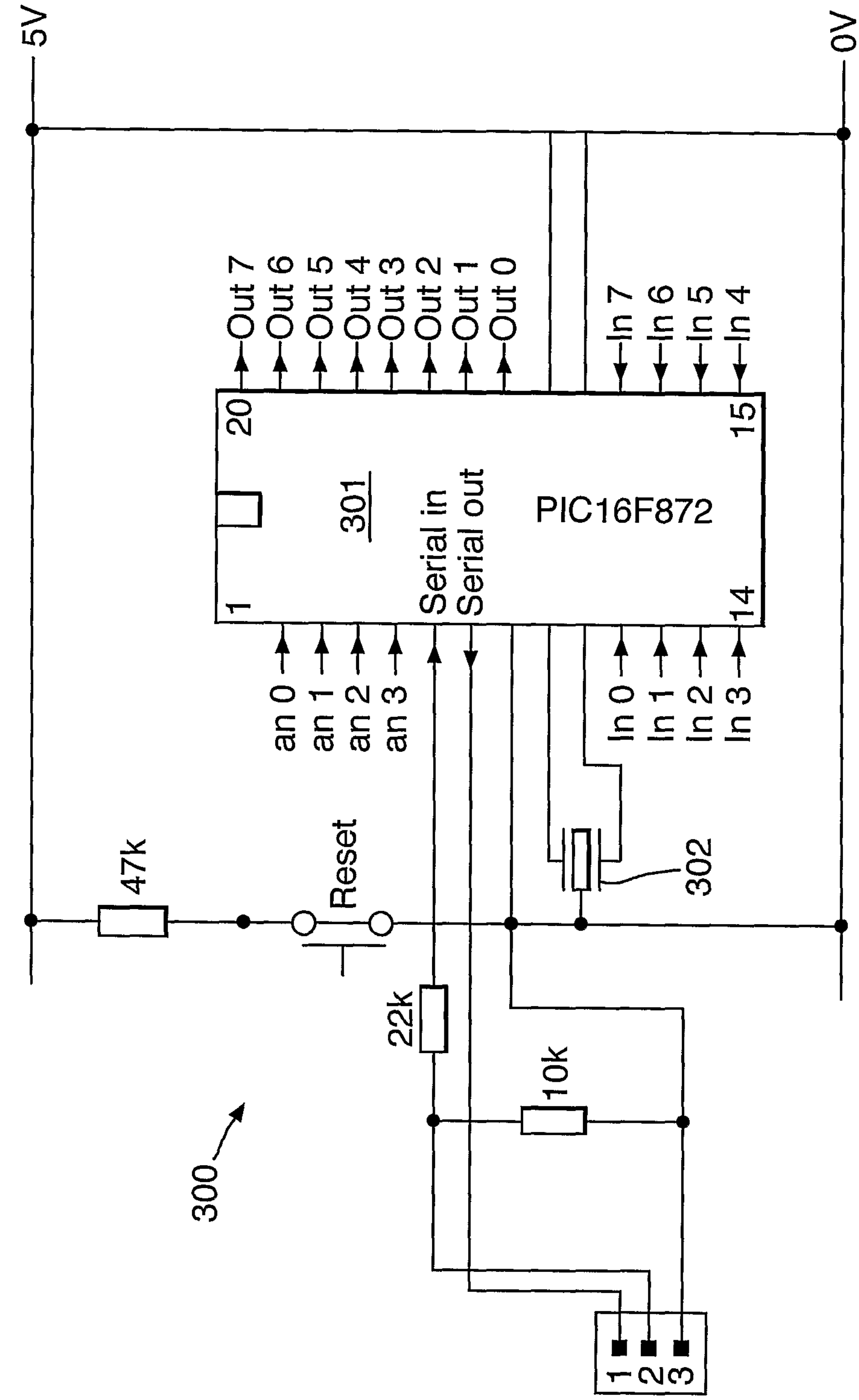

5V
0V
Out 7
Out 6
Out 5
Out 4
Out 3
Out 2
Out 1
Out 0
In 7
In 6
In 5
In 4
20
15
301
Serial in
Serial out
PIC16F872
1
14
an 0
an 1
an 2
an 3
In 0
In 1
In 2
In 3
47k
Reset
302
22k
10k
300
1
2
3

Fig.8.

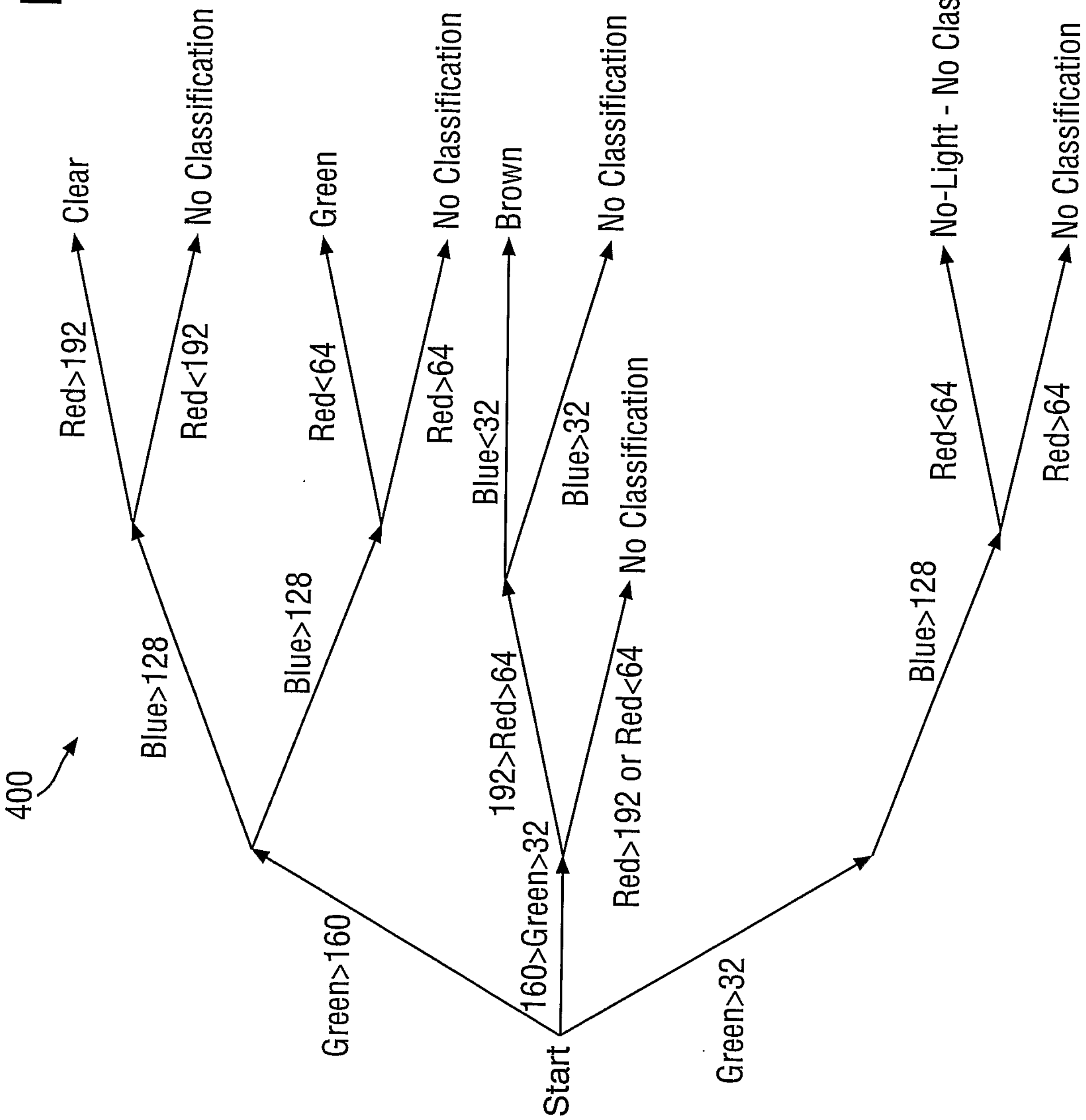

400
Start
Green>160
160>Green>32
Green>32
Blue>128
Blue>128
192>Red>64
Red>192 or Red<64
No Classification
Blue>128
Red>192
Red<192
Clear
No Classification
Red<64
Red>64
Green
No Classification
Blue<32
Blue>32
Brown
No Classification
Red<64
Red>64
No-Light - No Classification
No Classification

Fig.9.

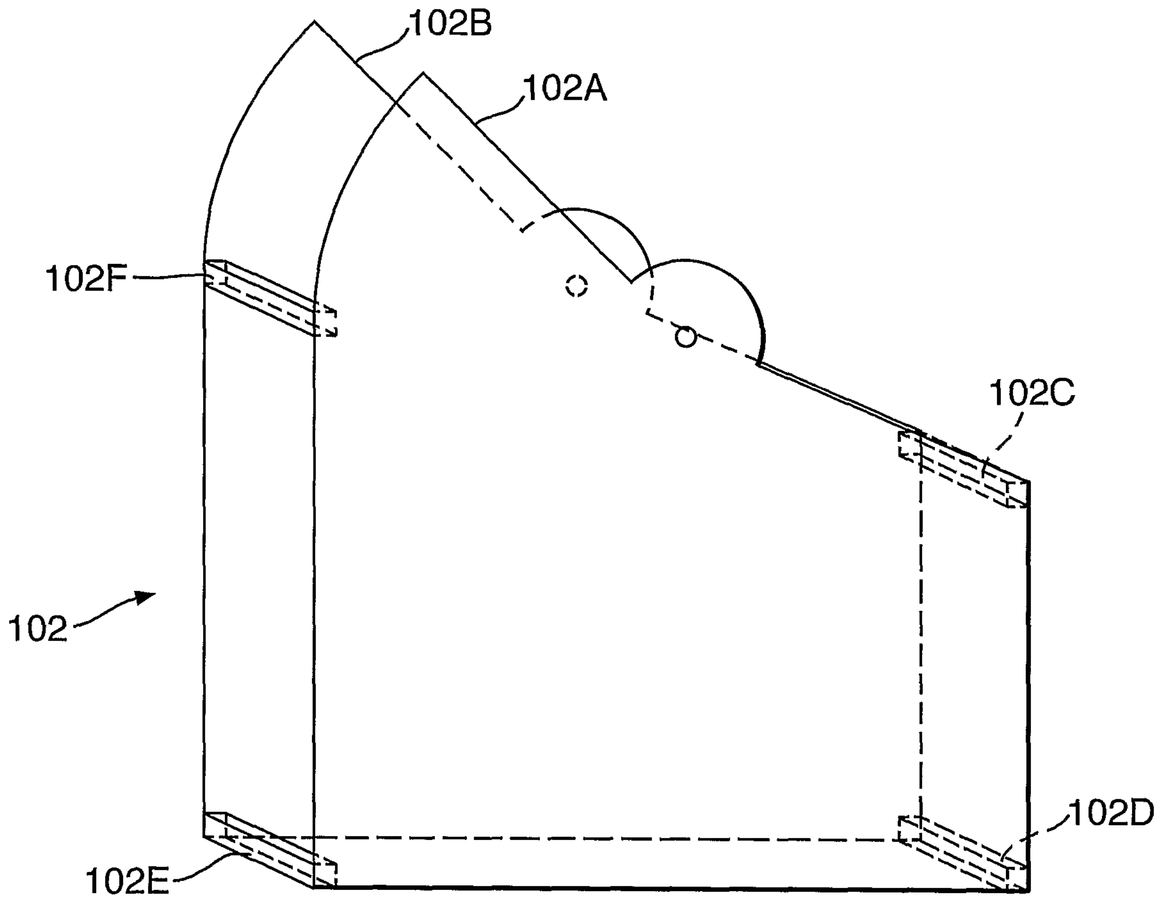


Fig.10.

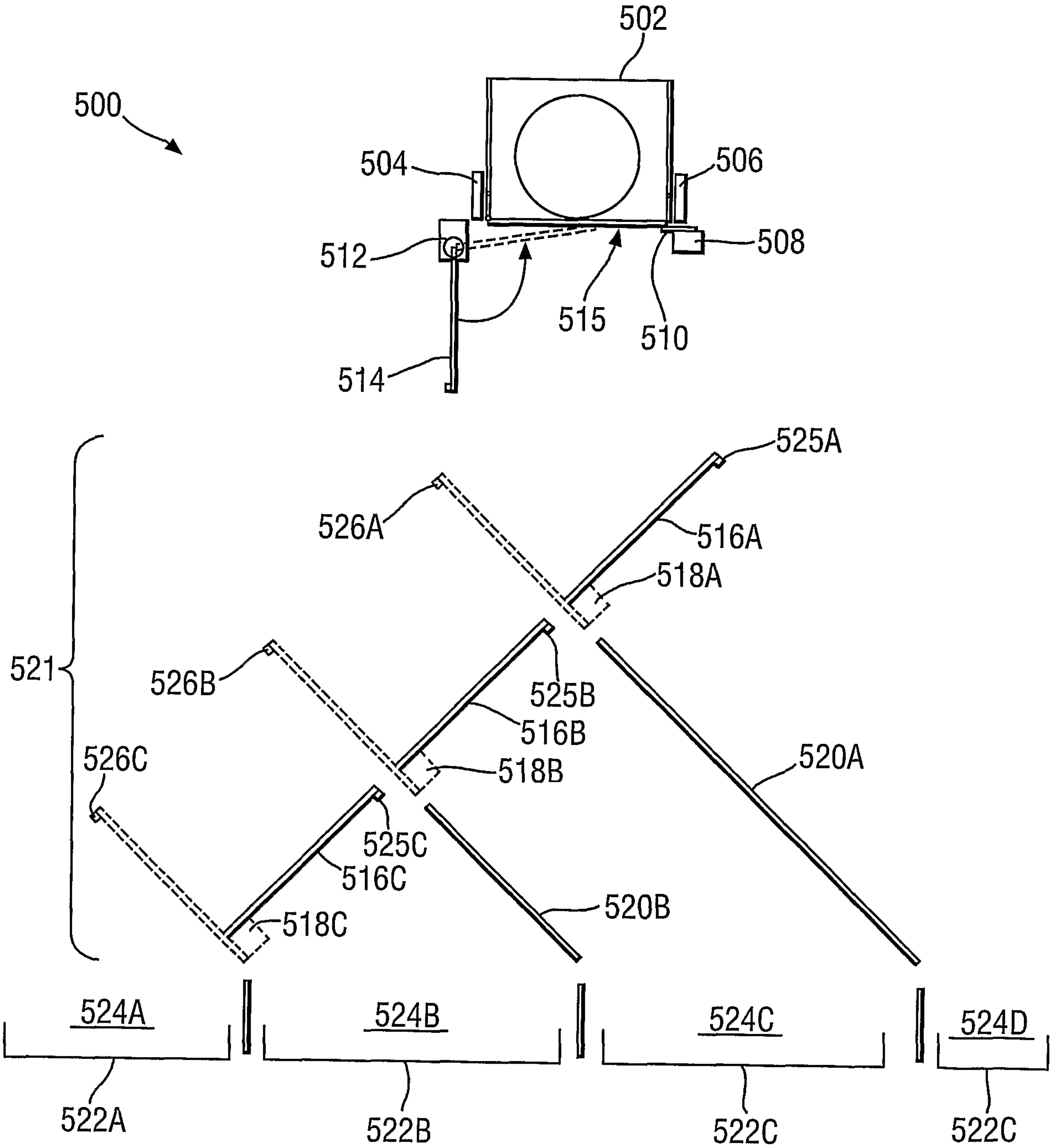
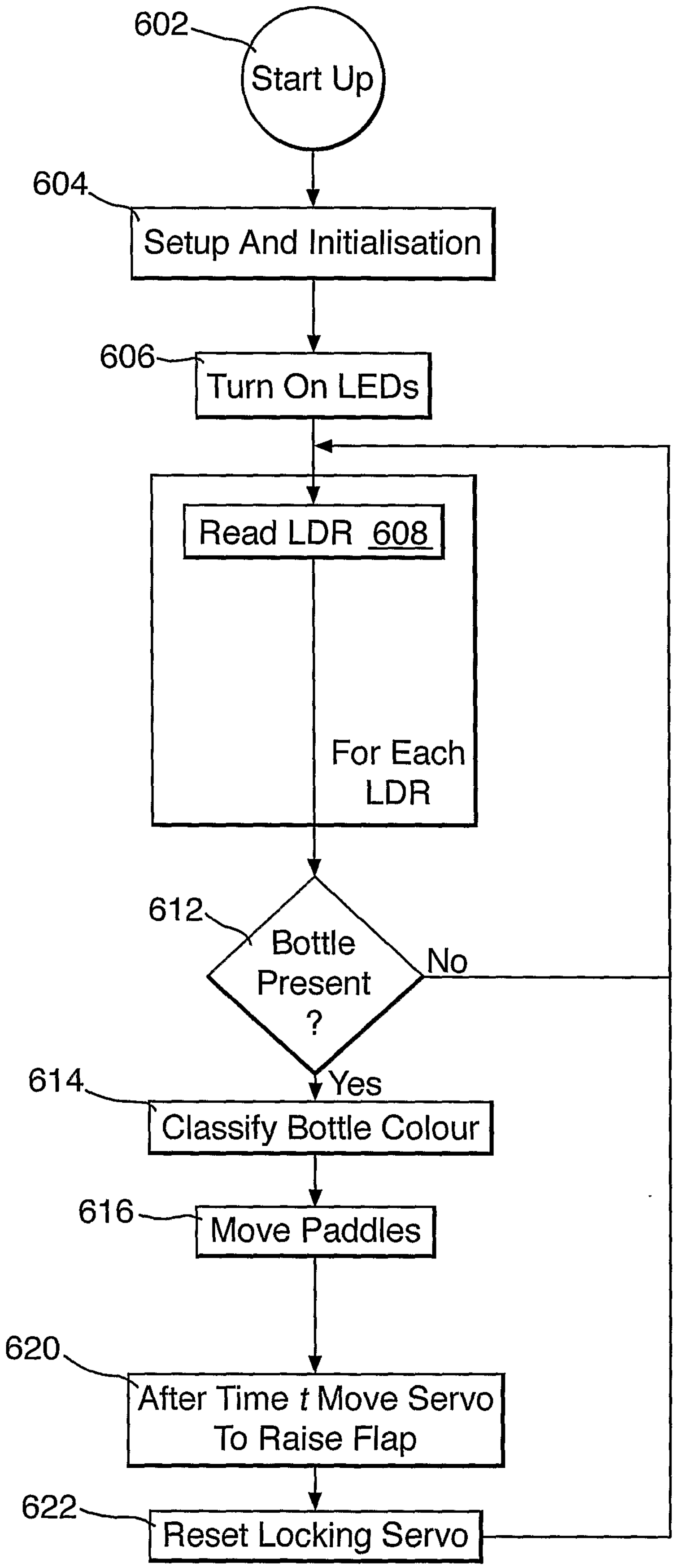

502
500
504
506
512
508
515
510
514
525A
526A
516A
518A
521
526B
525B
516B
518B
520A
526C
525C
516C
520B
518C
524A
524B
524C
524D
522A
522B
522C
522C

Fig.11.



602
Start Up
604
Setup And Initialisation
606
Turn On LEDs
Read LDR 608
For Each LDR
612
Bottle Present ?
No
Yes
614
Classify Bottle Colour
616
Move Paddles
620
After Time t Move Servo To Raise Flap
622
Reset Locking Servo

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/05027

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B07C5/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 562 506 A (BODENSEEWERK GERAETETECH) 29 September 1993 (1993-09-29) column 6, line 38 - column 7, line 17	1-15, 17-28,30
X	DE 43 33 728 A (BODENSEEWERK GERAETETECH) 6 April 1995 (1995-04-06) column 2, line 29 - line 51	1,11,18
X	DE 37 31 402 A (MABEG MUELL & ABFALL) 29 December 1988 (1988-12-29) abstract	1,18
X	EP 0 633 463 A (BODENSEEWERK GERAETETECH) 11 January 1995 (1995-01-11) column 2, line 16	1,18

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 February 2004	08/03/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Wich, R

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 03/05027

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. [X] Claims Nos.: 16,29
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 16,29

The subject-matter of claims 16 and 29 is not defined by technical features. Therefore the scope of these claims cannot be limited to a meaningful search.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 03/05027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 0562506 A2	29-09-1993
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		US 5333739 A	02-08-1994
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		AT 157449 T	15-09-1997
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