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Snyder

[11] **3,829,690**

[45] **Aug. 13, 1974**

[54] **METHOD AND APPARATUS FOR THE EXAMINATION OF ARTICLES FOR DEFECTS**

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[51] **Int. Cl.** **G01n 21/16**

[58] **Field of Search** 250/302, 458, 461; 356/237, 240

[56] **References Cited**

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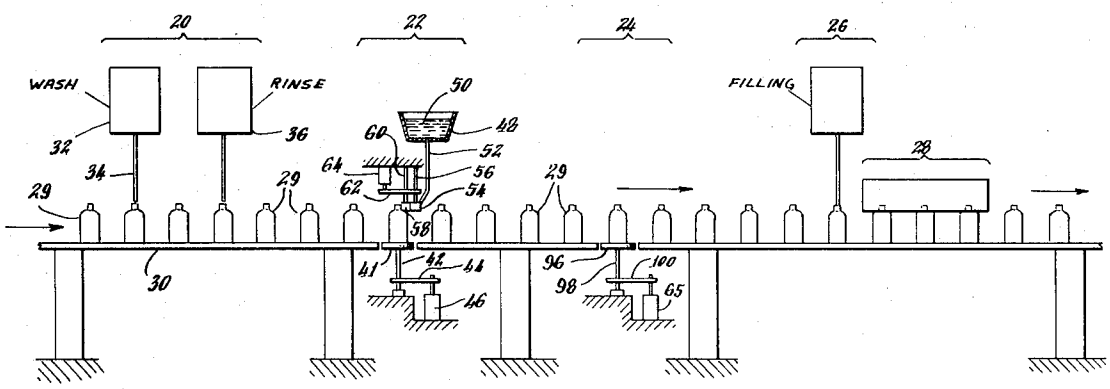
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Primary Examiner—James W. Lawrence
Assistant Examiner—Davis L. Willis
Attorney, Agent, or Firm—Kaufman & Kramer

[57] **ABSTRACT**

A method for examining the upper part of a glass vessel for defects comprises the steps of applying a fluorescent material to selected surfaces of the upper part of the vessel while inhibiting the introduction of the fluorescent material into voids or defects existing in coated surfaces, irradiating the coated surface with light having a frequency for exciting the fluorescent material, scanning the surface for discontinuities occurring in fluorescent radiation which corresponds to defects in the vessel, and providing an indication of the existence of such a discontinuity. The selected surfaces, in particular, comprise helically formed threads and the top surfaces of screw top beverage bottle. An apparatus in accordance with the invention is provided for effecting the examination of a glass vessel.

23 Claims, 17 Drawing Figures



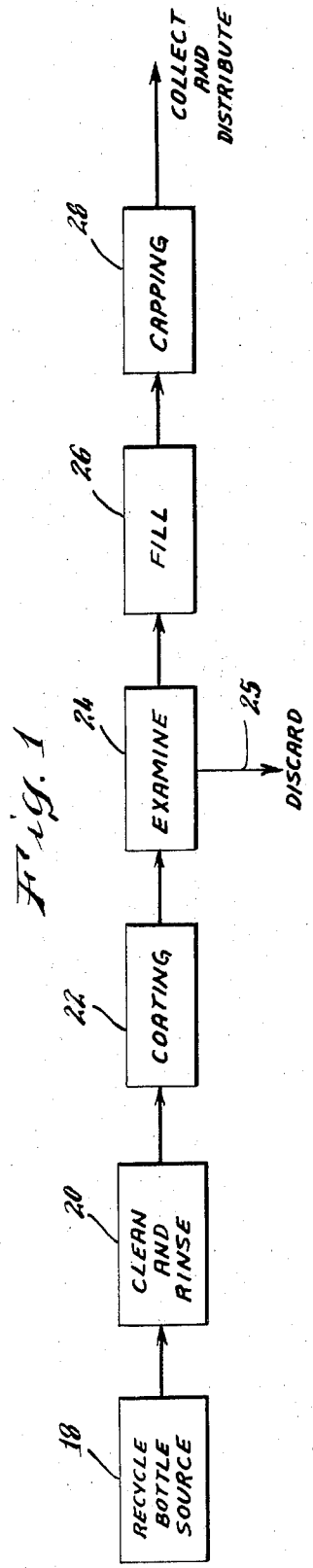

RECYCLE BOTTLE SOURCE
18
CLEAN AND RINSE
20
COATING
22
EXAMINE
24
25
DISCARD
FILL
26
CAPPING
28
COLLECT AND DISTRIBUTE

Fig. 1

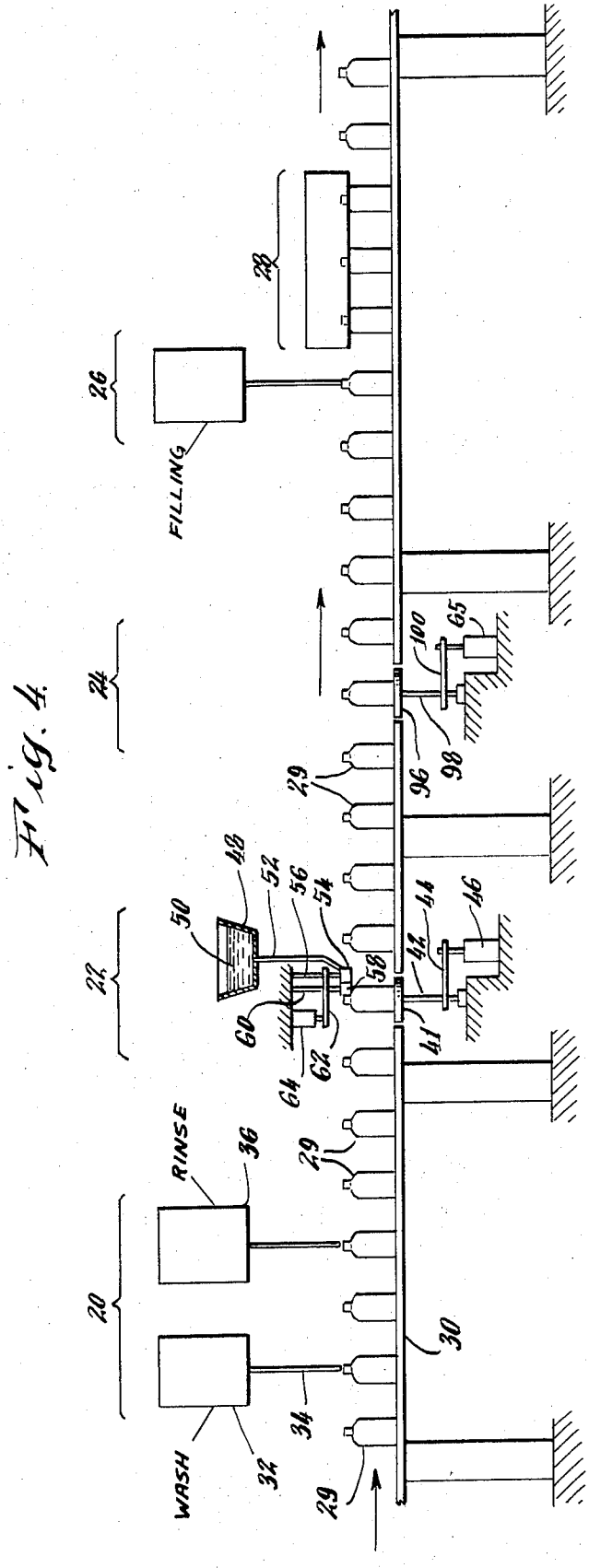

WASH
32
34
RINSE
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FILLING
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Fig. 4

Fig. 2b.

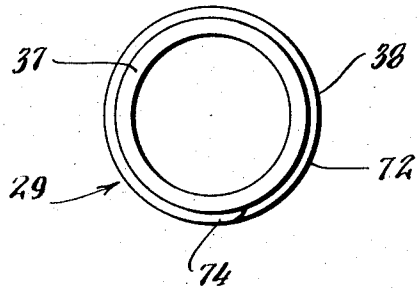


Fig. 3b.

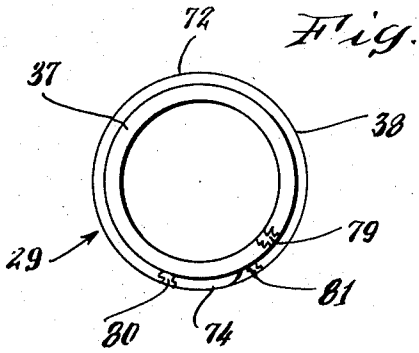


Fig. 2a.

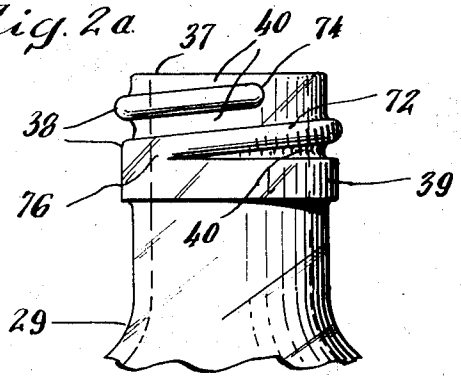


Fig. 3a.

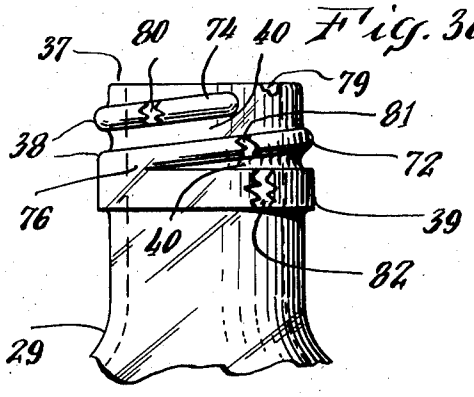
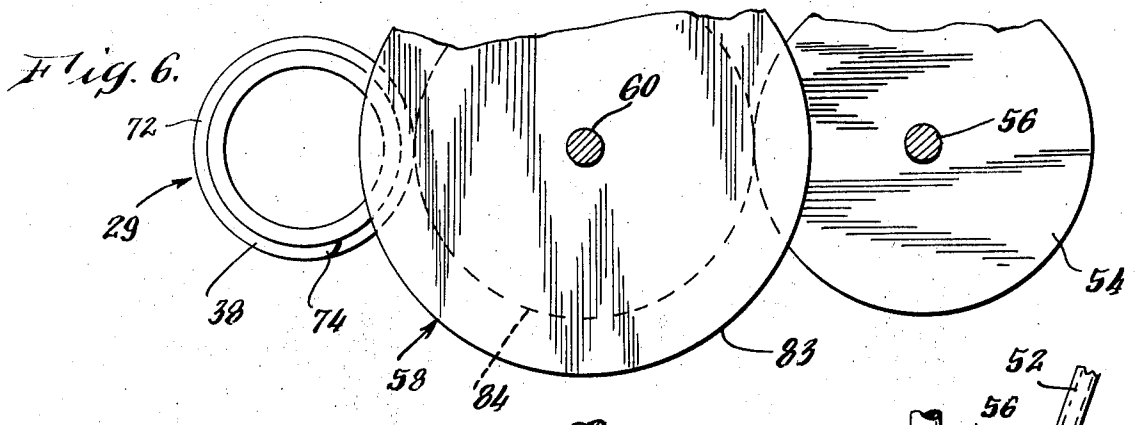


Fig. 6.



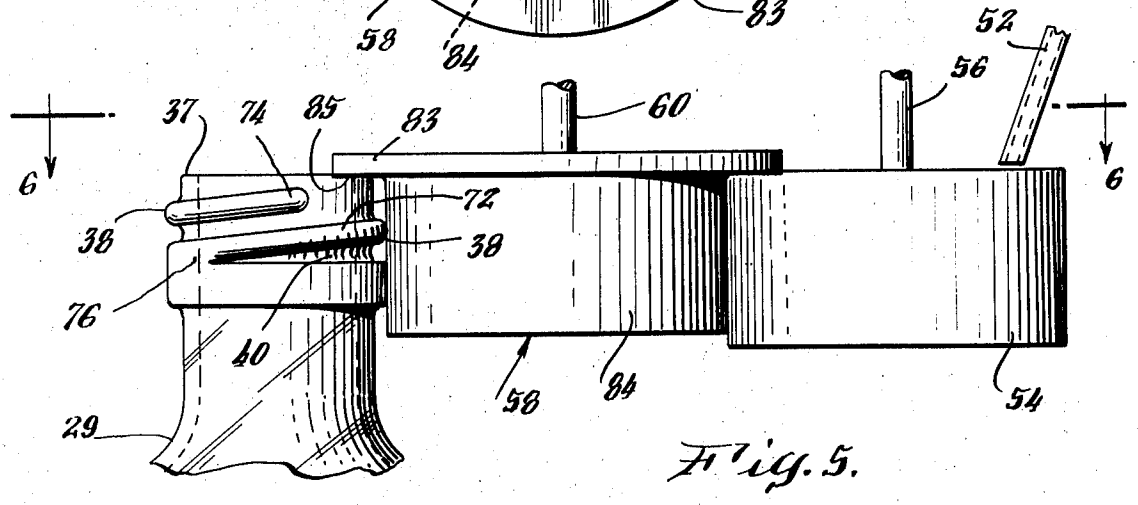


Fig. 5.

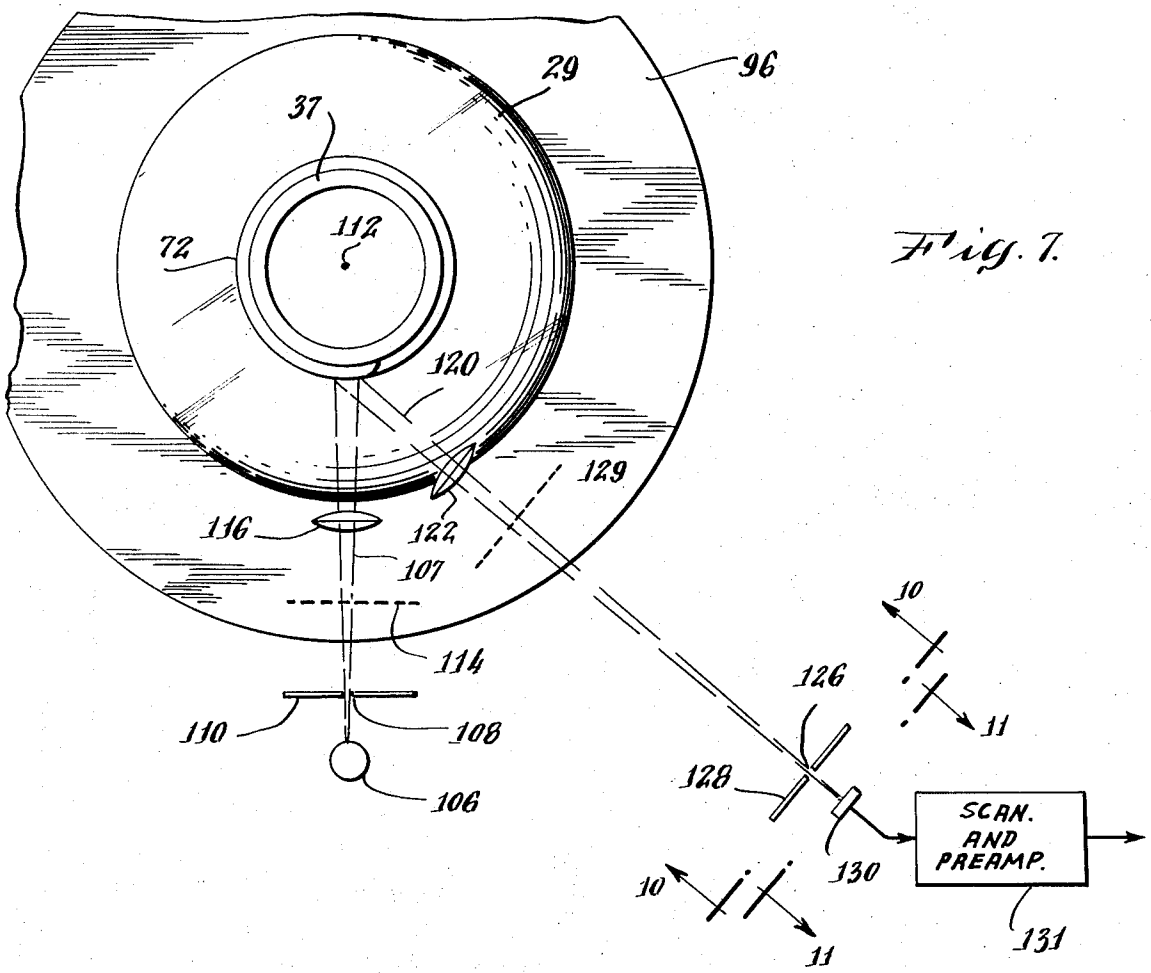

29
96
37
112
72
120
129
116
122
107
114
110
108
106
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126
128
130
SCAN. AND PREAMP.
131

Fig. 7.

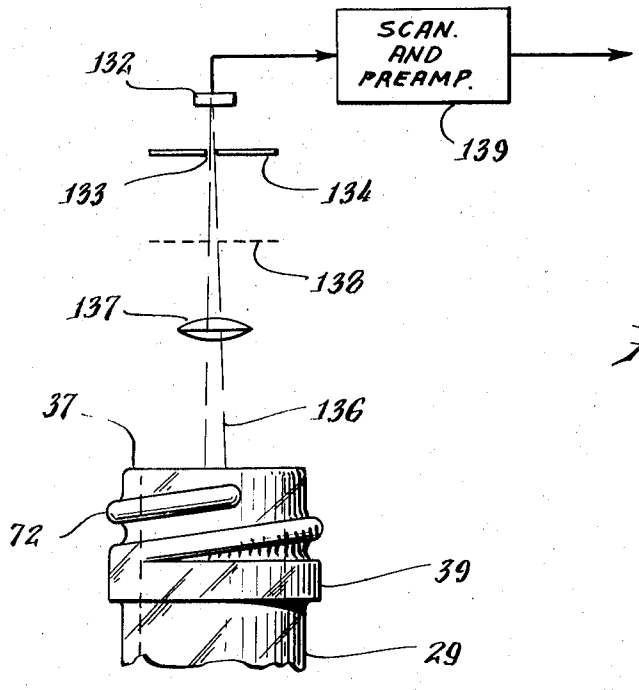
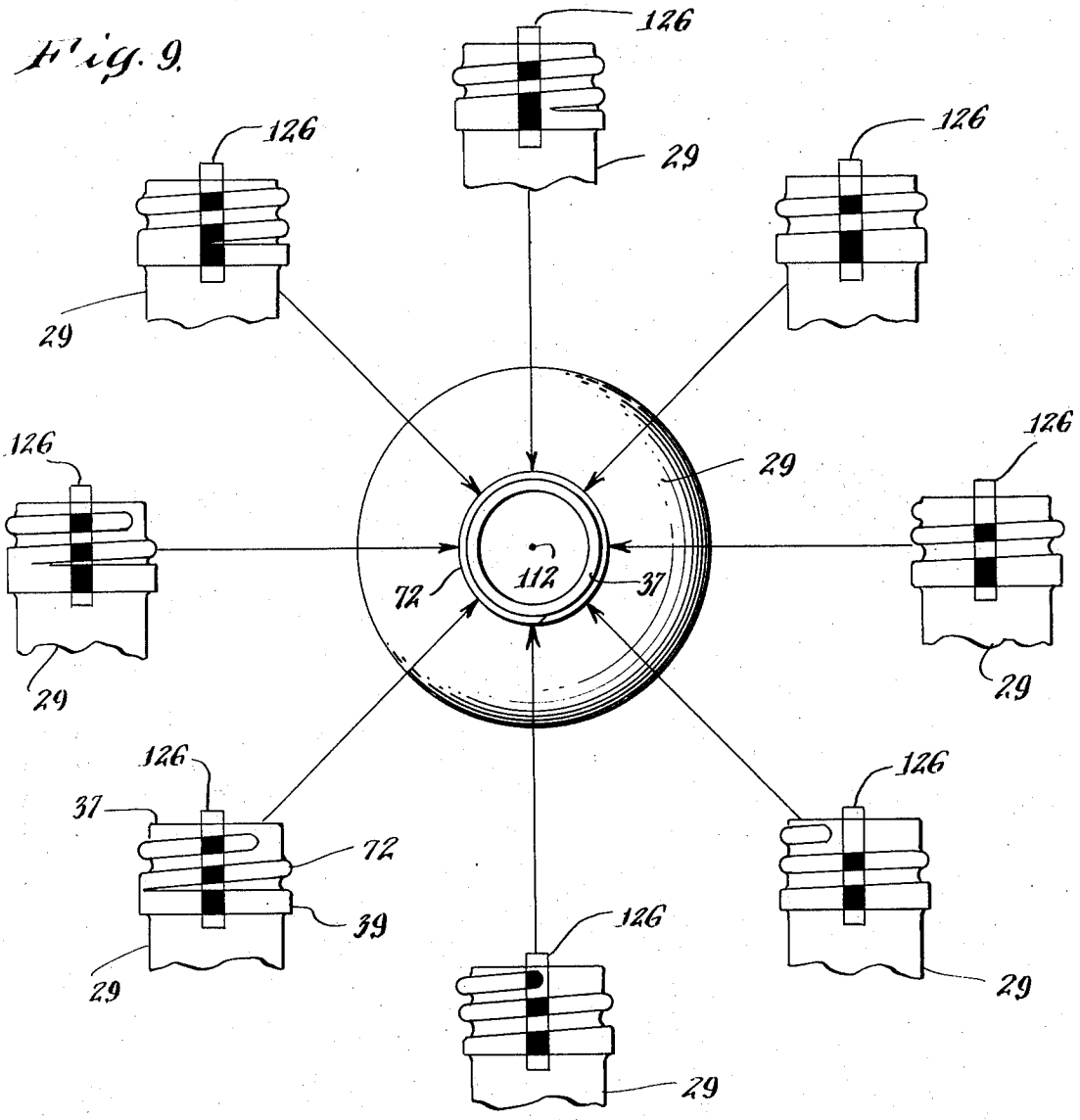

SCAN. AND PREAMP.
132
139
133
134
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137
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136
72
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29

Fig. 8.

Fig. 9.



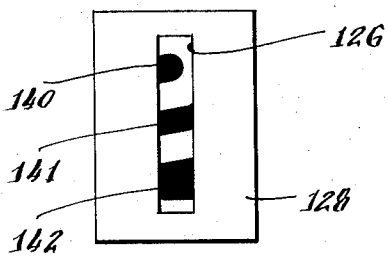


Fig. 10.

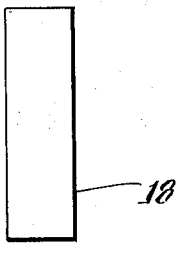


Fig. 12.

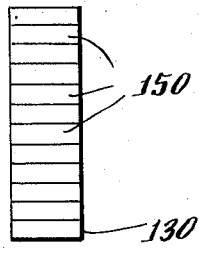
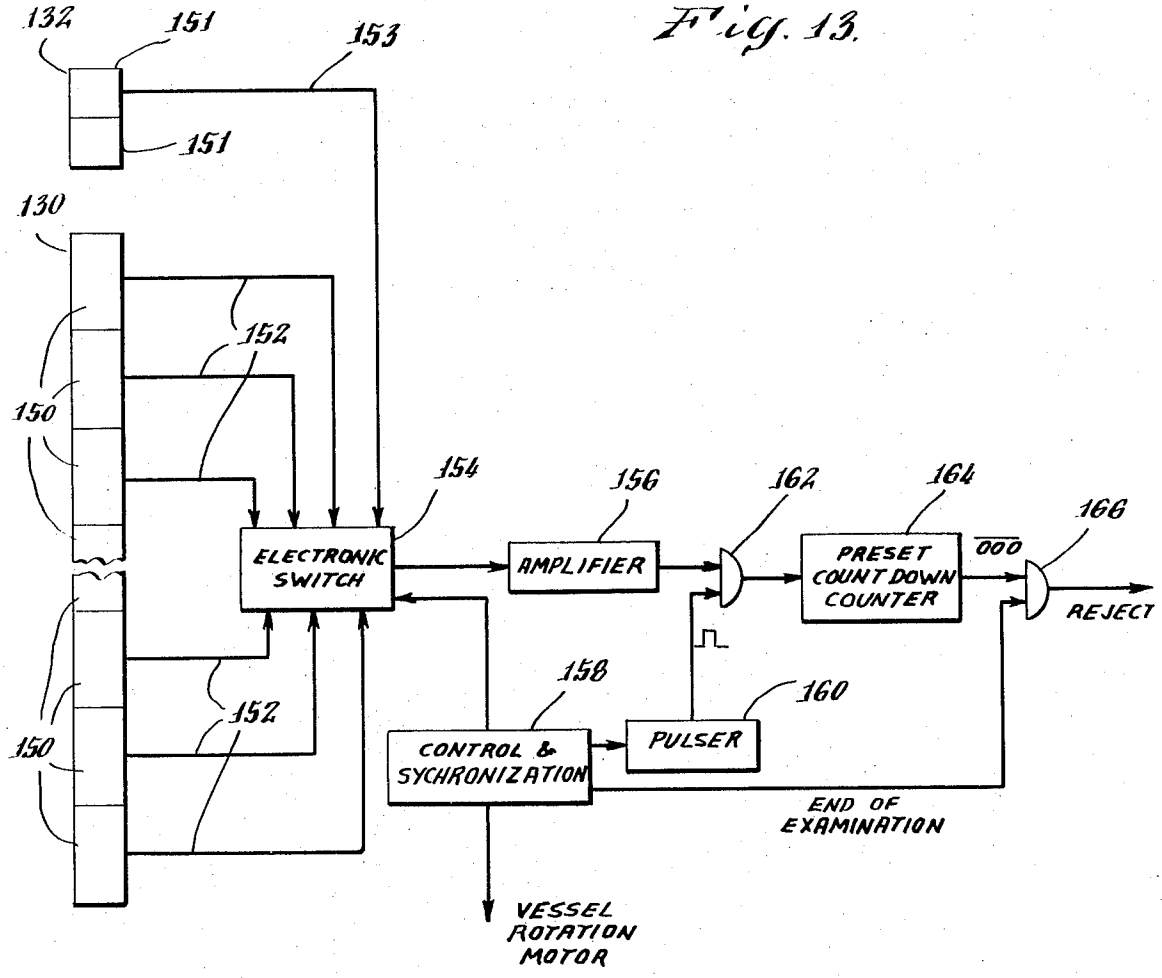


Fig. 11.

Fig. 13.


132
151
153
151
130
152
150
154
156
162
164
166
ELECTRONIC SWITCH
AMPLIFIER
PRESET COUNT DOWN COUNTER
000
REJECT
158
160
152
150
CONTROL & SYCHRONIZATION
PULSER
END OF EXAMINATION
VESSEL ROTATION MOTOR

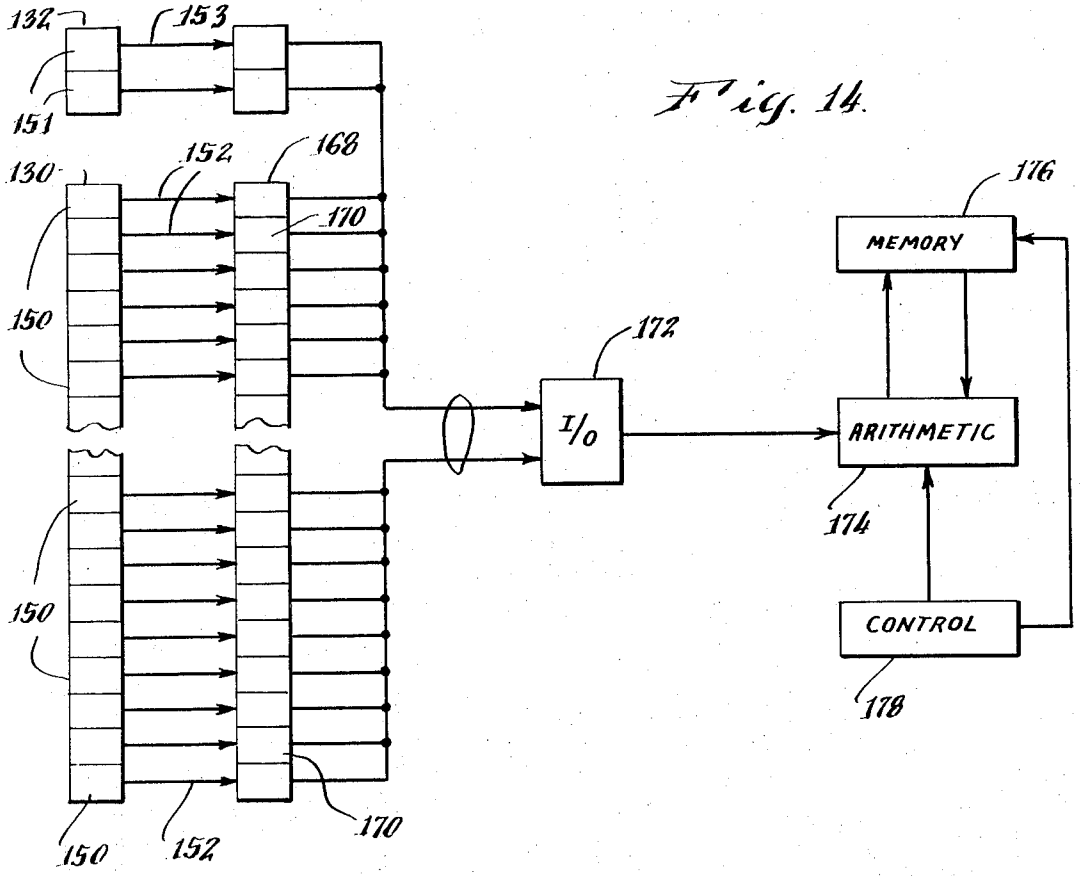

132
153
151
130
152
168
170
150
172
I/O
MEMORY
176
ARITHMETIC
174
CONTROL
178
150
150
152
170

Fig. 14.

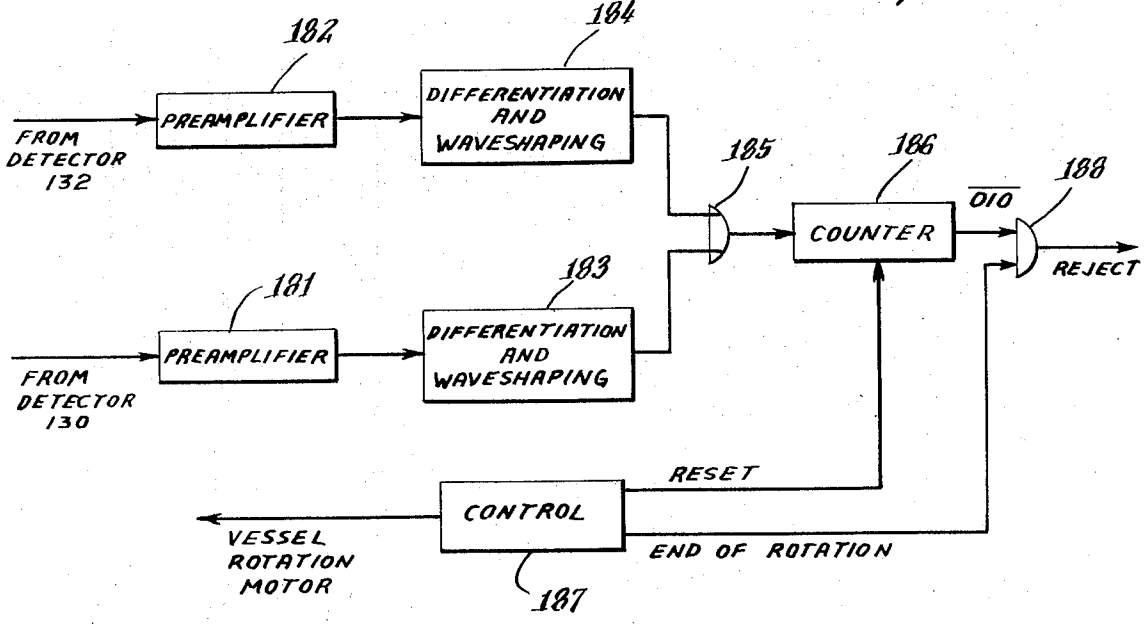

182
184
PREAMPLIFIER
DIFFERENTIATION AND WAVESHAPING
FROM DETECTOR 132
185
186
188
COUNTER
010
REJECT
181
183
PREAMPLIFIER
DIFFERENTIATION AND WAVESHAPING
FROM DETECTOR 130
RESET
CONTROL
VESSEL ROTATION MOTOR
END OF ROTATION
187

Fig. 15.

METHOD AND APPARATUS FOR THE EXAMINATION OF ARTICLES FOR DEFECTS

This invention relates generally to an improved method and apparatus for the examination of articles by fluorescent techniques. The invention relates more particularly to an improved method and apparatus for the detection with fluorescent techniques of defects occurring in glass beverage vessels and the like.

Fluorescent examination of articles for flaws or defects therein has principally been accomplished with a known technique referred to as the penetration technique. Examination with this technique is accomplished by coating a surface of an article with a fluorescent material, rinsing the fluorescent material from the surface and then irradiating the object with ultraviolet light. Defects in the article, such as hairline cracks and similar flaws which extend from the surface of the object and which are otherwise not visible to the naked eye, trap and retain the fluorescent material. Upon irradiation, the entrapped material fluoresces and reveals the presence and extent of any defects.

Various other procedures for the fluorescent examination of glass vessels are known. One such procedure requires the fabrication of a vessel being examined from a fluorescent material. Upon irradiation of the vessel, smooth surfaces of the vessel wall cause a uniform internal reflection of fluorescent radiation and a resulting confinement of the radiation within the vessel wall. The existence of a flaw however interrupts the uniformity of reflection and permits radiation to emanate from the flaw. This reflected radiation which escapes from the wall is then detected.

Another fluorescent examination technique has been employed for inspecting the interior of glass beverage bottles for residue and foreign objects. The interior of the bottle is washed with a fluorescent liquid and is then rinsed. Irregular surfaces of particles or a residue remaining in the bottle will retain or trap a portion of the fluorescent material and reveal its presence upon irradiation with ultraviolet light.

These known flourescent examination techniques can be impractical and costly, particularly when employed for beverage bottle examination. The penetration technique, for example, necessitates the removal or rinsing of the fluorescent material from the article before the existence of the defect can be sensed. There are instances however in which it is not feasible to rinse or remove the major portion of the fluorescent material. This is true in the recycling of glass beverage bottles. A large number of present day glass beverage bottles include integrally formed threads which engage a mating threaded bottle cap. Examination of the top surface of the bottle and the threads of a recycled bottle for defects is important for several reasons. The upper portion of a bottle often comes in contact with a users mouth and sharp edged voids and flaws can cause personal injury to the user. In addition, a defective bottle top surface can cause an incomplete seal resulting in the loss of carbonation and entry of bacterial growth when beverages contain sugar. In practice, large numbers of bottles are examined and in order to be economically feasible, the handling and examination of the bottles should occur at a relatively high rate such as, for example, 10 bottles per second. However, it is found that recycling equipment which is provided for washing and rinsing the bottles and for conveying bottles between various operating stations at these relatively high rates can itself cause damage to the bottles. While, in comparison with the total number of damaged returned bottles, this process results in a relatively low percentage of damage to bottles, nonetheless, the risk of personal injury to a user from a defective bottle thread dictates that all defective bottles be detected and discarded.

It is therefore preferable to examine the bottle threads after the principal recycling and cleaning steps have been performed and immediately before refilling of the bottles. At this stage of the process, however, fluorescent examination by techniques such as the penetration technique which provides for coating with a fluorescent material and then rinsing the material from the surface of the bottle will substantially reduce the reprocessing rate and can render the reprocessing examination costly. Alternatively, the fabrication of bottles from a fluorescent material is limiting and can be prohibitively expensive. Furthermore, detection arrangements employed with prior fluorescent sources for the examination of articles have suffered from reflections and refractions which interferred with the accuracy of detection.

Accordingly, it is an object of this invention to provide an improved method and apparatus for inspecting articles by fluorescent examination techniques.

Another object of the invention is to provide an improved method and apparatus for examining an article by fluorescent techniques wherein a fluorescent material which is deposited upon a surface of the article remains on the surface during the examination.

Another object of the invention is to provide a method and apparatus for fluorescent examination of an article wherein a fluorescent material which is deposited upon the article for purposes of examination of the article remains on the article after examination.

Another object of the invention is to provide an improved method of fluorescent examination of articles wherein the article acts as a fluorescent light source and having an improved defect detection arrangement which is substantially nonsusceptible to reflection of incident exciting light.

Another object of the invention is to provide a method of fluorescent examination of articles which are compatible with digital information handling techniques.

Still another object of the invention is to provide a relatively high speed and relatively low cost method and apparatus for the examination of screw threads and upper bottle surfaces on a screw top glass bottle.

A further object of the invention is to provide an improved method and apparatus for the examination of recycled glass bottles for defects which may occur in the bottle.

In accordance with the general features of this invention, a fluorescent material is deposited on the surface of an article being examined and is inhibited from introduction into voids or defects extending into the article from the surface. The article surface is subsequently irradiated at a frequency for exciting the deposited fluorescent material and discontinuities occurring in fluorescent radiation along the surface corresponding to defects in the surface are detected and indicated.

In accordance with more particular features of this invention, a method for examining the upper part of a glass vessel for defects comprises the steps of applying

a fluorescent material to selected surfaces of the upper part of the vessel with an applicator having a firmness which inhibits entry of the fluorescent material into voids or defects existing in the article and extending into the vessel from the selected surfaces, irradiating the coated surface with light having a frequency for exciting the fluorescent material, scanning the surface for discontinuities occurring in fluorescent radiation which correspond to defects in the vessel, and providing an indication of the existence of such a discontinuity. The selected surfaces, in particular, comprise the integrally formed threads and top surface of a screw top beverage bottle.

In accordance with more particular features of the invention, the fluorescent material comprises a substance which is adapted for human consumption and which may remain on the bottle after examination.

These and other objects and features of the invention will become apparent with reference to the following specification and to the drawings wherein:

FIG. **1** is a flow chart illustrating the process of this invention;

FIG. **2***a* is an elevation view of an upper portion of a screw thread glass beverage bottle illustrating an integrally formed non-defective screw thread and top bottle surfaces.

FIG. **2***b* is a plan view of the bottle of FIG. **2***a;*

FIG. **3***a* is an elevation view of an upper portion of a screw thread glass beverage bottle illustrating an integrally formed defective screw thread and a defective top bottle surface;

FIG. **3***b* is a plan view of the bottle of FIG. **3***a;*

FIG. **4** is a diagram of a bottle recycling and examination apparatus constructed in accordance with features of this invention;

FIG. **5** is a side view of an apparatus for depositing a fluorescent material on a screw thread surface and a top bottle surface of a glass beverage bottle;

FIG. **6** is a view taken along line **6—6** of FIG. **5**;

FIG. **7** is a schematic plan view of a part of an examination station of the apparatus of FIG. **4**;

FIG. **8** is a schematic elevation view of another part of the examination station of the apparatus of FIG. **4**;

FIG. **9** is a view of an upper portion of a screw top glass bottle illustrating the thread configuration for different orientations of the bottle with respect to a detector means as the vessel is rotated about its axis;

FIG. **10** is a view taken along lines **10—10** of FIG. **7** and illustrating an aperture disc of the detection means of FIG. **7**;

FIG. **11** is a view taken along line **11—11** of FIG. **7** and illustrating the surface of a segmented photodetector upon which fluorescent radiation from the bottle impinges;

FIG. **12** is a view illustrating an alternative form of photodetector;

FIG. **13** is a schematic diagram in block form of a circuit means for digitally sensing and indicating a defect in a bottle under examination;

FIG. **14** is a schematic diagram in block form of an alternative circuit means for digitally sensing and indicating a defect in a bottle under examination; and

FIG. **15** is a schematic diagram in block form of an alternative circuit means for providing analog sensing and for indicating a defect in a bottle under examination.

FIG. **1** illustrates the steps employed in accordance with features of this invention. While the present invention will be described with respect to the recycling of glass bottles, the invention is also applicable to the examination of newly manufactured bottles as well as to the examination of other types of articles. Bottles for recycling are derived from a source **18** and are conveyed in sequence to a cleaning and rinsing station **20,** a coating station **22** at which an upper portion of the bottles is coated with a fluorescent material, and to an examination station **24** where the bottles coated with fluorescent material are examined for defects. When a determination is made that a bottle is defective, the bottle is discarded. The discard occurs by bypassing the bottle to a discard conduit represented by line **25** before the bottle is filled at a subsequent station **26.** Alternatively, and in view of the relatively low proportion of defective bottles encountered, it is less costly at times in terns of equipment and processing rate to fill a defective bottle and then discard the bottle. Non-defective bottles which are filled at station **26** are conveyed to a station **28** where they are capped. The bottles are then collected for distribution.

FIG. **4** illustrates an apparatus for carrying out the described bottle recycling process. Recycled bottles **20** are transported by a conventional bottle conveying means **30** from the source **18** (FIG. **1**) to the cleaning and rinsing station **20** at which location the bottles are scoured under pressure with a detergent wash. The wash is derived from a source and pump means **32** and is introduced into the bottles by a suitable conduit means **34.** The detergent is pumped from the bottle through the conduit **34** at this location and the bottle then is conveyed to a rinsing location. A clear rinse is derived from a rinse source and pump means **36** at the rinsing station and is pumped into and then flushed from the bottle at this location. The equipment for performing the washing and rinsing steps is conventional.

As indicated hereinbefore, recycling of bottles is preferably accomplished at a relatively high transport rate. For example, the bottles are in practice stepped past a station at a rate of about 10 bottles per second. Because of this relatively high rate and the possibility of damage to the bottles from the equipment itself, it is preferable to examine the bottles for defects after cleaning and immediately prior to the beverage filling step.

The fluorescent material coating station **22** provides for depositing a fluorescent material on the top surface **37** of the bottle wall (FIG. **2***a*), on the outer surface or ridge **38** of the helical screw threads, and on a cap locking shoulder segment **39** while inhibiting deposition of the material in voids or defects which may exist in the top surface **37** in the screw thread **38,** in voids or defects in the shoulder segment **39,** and in valleys and spaces **40** extending between the threads. The fluorescent material coating station of FIG. **4** is shown to include a rotatable turntable **41** which is mounted to a drive shaft **42.** The drive shaft **42** is coupled by a drive belt **44** to a drive shaft of a motor **46.** A bottle **29** is stepped onto the turntable **44** and is rotated at a predetermined speed upon energization of the motor **46.** Although the turntable **41** is illustrated as supporting a single bottle for rotation, multiunit turntables can be provided which are adapted for rotating a plurality of bottles simultaneously. The coating station **22** further

includes a reservoir **48** containing a fluorescent material **50** which is conveyed by gravity feed, for example, through a conduit **52** to a transfer applicator **54.** The transfer applicator **54** is rotatably mounted on a shaft **56** and is positioned in contact with an applicator **58** which is similarly rotatably mounted on a shaft **60.** These shafts are coupled by a drive belt **62** to a drive shaft of a motor **46.** The applicator **58** is positioned for contacting selected surfaces **37, 38** and **39** of the bottle being coated and is driven at a rate for providing that the outer surface of the applicator **58** and these selected surfaces of the bottle are transported at the same rate. Stepping of the conveyor **30** and energization and de-energization of the drive motor **46** is controlled and synchronized by conventional means, not illustrated.

Reference is made to FIGS. **2, 3, 5** and **6** for a more detailed view and description of the applicator and the bottle **29.** While there is illustrated a screw cap bottle closure, the invention is equally applicable to "twist off," "crown caps," and other forms of bottle closures. An upper part of a bottle **29** is shown to include an integrally formed helically configured glass screw thread **72** having a thread starting segment **74** and a thread terminating segment **76** which terminates at the cap shoulder **39.** The valley areas or spaces **40** extending between the segments of the screw threads are generally planar. In comparison with the non-defective bottle of FIG. **2***a*, FIG. **3***a* illustrates a top surface **37** having a chipped out defect **79,** a screw thread **72** having defects **80** and **81** and a shoulder **39** having a defect **81.** These defects and flaws can have relatively sharp edges and can result in personal injury. In addition the flaw **79** in the top surface **37** can cause the loss of a seal between a cap and the bottle and result in a loss of carbonation in the case of carbonated beverages and in the growth of bacteria with sugar containing beverages.

In coating the selected surfaces **37, 38** and **39,** it is important for proper detection of defects to inhibit the coating of the valley bottle surface **40** and the defects **79, 80, 81** and **82.** The applicator is dimensioned so that the applicator body itself cannot enter these voids or valleys. It is further achieved by providing an applicator **58** which is formed of a material which is capable of transporting the fluorescent material on its surface yet exhibits a stiffness which, when in contact with selected surfaces will not extend into voids or defects and will not contact the surface **40.** One such suitable applicator comprises a cylinder **58** which is formed of rubber. Suitable rubbers comprise butyl, styrene butadiene, polybutadiene, polyisoprene and natural rubber. Another suitable applicator comprises a cloth faced rubber inking pad. The applicator **58** (FIG. **5**) is generally cylindrically shaped and includes a segment **83** of relatively larger diameter than another segment **84.** A lower surface **85** of the segment **83** extends over, contacts and deposits the fluorescent material **50** on the bottle top surface **37.** An outer surface of the segment **84** contacts and deposits fluorescent material on the ridge or edge surface **38** of the thread **72** and on the shoulder **39.** The transfer applicator **54** is fabricated of a material which is capable of receiving the fluorescent material **50** from the reservoir **48** and applying it by surface contact to the lower surface of the segment **83** and to the outer surface of the segment **84** of the applicator **58.** One such material for handling a liquid fluorescent material comprises relatively soft sponge rubber.

As indicated, the valley surfaces **40** preferably should not be coated with the fluorescent material. Coating of this surface undesirably increases the complexity of the detection means as will become apparent from a consideration of particular detector means, hereinafter. However, the planar surface **40** as well as other planar surfaces on similar or different articles may be coated with the fluorescent material when the detector means is adapted for an analysis of this surface. With respect to the detector means discussed hereinafter, this can be accomplished by presetting a counter to an appropriate count or by establishing a digital "signature" for a non-defective article surface.

The fluorescent material **50** preferably exists in the liquid state although powdered fluorescent materials may also be coated in accordance with this invention. The fluorescent material employed for coating recycled beverage bottles preferably comprises a substance which is suitable for human consumption and thereby advantageously eliminates any personal hazard and the need for washing of the material from the coated surfaces after the detection step. While a large number of fluorescent substances existing in the liquid state and which are suitable for human consumption are known, liquids comprising solutions of a vehicle or solvent and relatively small concentrations of quinine in particular have been found to be suitable for this application. The liquid may comprise any suitable solvent for quinine such as sodium alginate and water. A carbonated water beverage containing quinine and sold under the trade names of "Quinine Water" distributed by the Schwepps Corporation and a similar beverage distributed by the Cott Corporation comprises a liquid fluorescent material suitable for human consumption. Other suitable materials which need not be rinsed are eosin in water, esculin in water or alcohol, and fluorescin in water. In addition, in those instances when it is practical to rinse the coated material from the article other suitable fluorescent materials comprise anthrocene in alcohol, naphthalene-red in alcohol, resorsin blue in water and rhodamine in water.

After coating of selected surfaces, a bottle is transported by the conveyor **30** from the turntable **41** to the examination station **24.** At the examination station **24,** the bottle is rotated past a stationary sensing means, illustrated in FIGS. **7** and **8,** which detects discontinuities in fluorescent radiatin along the length of the surface being examined. The sensing station is shown in FIG. **4** to include a turntable **96** which is mounted on a rotatable drive shaft **98.** The drive shaft **98** is coupled by a drive belt **100** to the drive shaft of the electric motor **65** causing rotation at a predetermined speed of a bottle **29** which is positioned on the turntable.

The discontinuity detection means of FIG. **7** includes means for irradiating the upper part of a bottle **29** and for detecting a discontinuity in the fluorescent radiation from the selected surface as the bottle is rotated past the sensing station. The radiation means comprises an ultraviolet light source **106** from which a light beam **107** is projected through a slit **108** in an aperture plate **110.** The slit **108** has a principal dimension extending in a direction substantially parallel to a longitudinal axis **112** of the bottle **29.** The light beam **107** is transmitted through a filter **114** which is adapted for passing with minimum attenuation those light components occurring in the UV band and for eliminating visible light. The light beam **107** is focused by a lens **116** onto a seg-

ment of the upper bottle extending from the shoulder **39** to and including the upper surface **37.** Scanning for discontinuities is provided by rotating the bottle and sequentially positioning segments of the bottle for impingement by the light beam.

Coated surfaces upon which the beam **107** impinges fluoresce and the bottle thus acts as a light source. This fluorescent radiation, represented by the beam **120,** is focused by a lens **122** on a slit **126** in an aperture plate **128.** A filter **129** is positioned in the path of this beam and is adapted for restricting the transmission of light to those components occurring within the light spectrum of the fluorescing material and for eliminating UV light. The use of the filters **114** and **129** greatly enhances the signal noise characteristic of the detection means. A photodetector **130** is positioned behind the plate **128** and is aligned with the slit **126.** An electrical signal having an amplitude proportional to the intensity of the impinging light beam is generated by the photodetector and is coupled to a scanning and preamplifying means **131** discussed hereinafter. With the exceptions enumerated hereinafter, a non-defective bottle generates substantially continuous fluorescent radiation and provides a substantially continuous output signal from the photodetector as the bottle is rotated. However, defects in the selected surfaces result in an interruption in fluorescent radiation and a corresponding interruption in the continuity of the electrical signal. The amplified signal is coupled, as indicated in detail hereinafter, to circuit means for an analysis of the photodetector signal and a determination and indication of the existence of a defect in the bottle.

Fluorescent radiation from the top surface **37** is similarly sensed, as illustrated in FIG. **8,** by focusing the fluorescent radiation on a photodetector **132.** The photodetector **132** is positioned behind a slit **133** in an aperture plate **134.** The beam **136** of fluorescent radiation is focused by a lens **137** onto the detector **132.** An optical filter **138** having transmission characteristics for passing the spectrum generated by the fluorescent radiation and similar to that of filter **129** of FIG. 7 is positioned in the path of the beam **136.** An output signal from the detector **132** is coupled to a preamplifier **139** for amplification and coupling to circuit means for analyzing the detector signals.

The operation of the error determination circuit means of FIGS. **13, 14** and **15** will be more fully appreciated by a consideration of the character of the fluorescing surfaces under examination. FIG. **10** which is a view of the output aperture plate **128** and the slit **126** formed therein illustrate that the coated fluorescent material is positioned at three locations along the length of the slit. An upper shaded segment **140** represents fluorescent radiation emanating from the uppermost thread segments while the segments **141** and **142** represent fluorescent radiation emanating respectively from a lower thread segment located at a different vertical position on the bottle and from the shoulder segment **39.** The pattern illustrated in FIG. **10** represents the fluorescent radiation pattern presented to the detector **130** for one rotational position of a bottle. As the bottle is rotated, the helical configuration of the thread **72** causes the thread segments **140** and **141** to assume different vertical locations in the slit. The fluorescent segments **140** and **141** therefore appear to be moving vertically within the slit. Since a bottle is rotated at a substantially constant angular velocity, the segments **140** and **141** will appear to move in a vertical direction at a substantially uniform rate. However, at the thread starting segment **74** (FIG. **2**) and at the thread terminating segment **76,** discontinuities will appear to occur. The discontinuities represent the rotational orientation of the bottle and are not indicative of a defect in the screw thread. They must be accounted for in the analysis of the photodetector output. In FIG. **9,** the slit **126** is superimposed on the screw threads in order to illustrate the variations in the screw thread patterns which will be presented to the photodetector at different rotational orientations of a bottle about its longitudinal axis. The shoulder segment **142** and the flat top surface segment **37** do not exhibit a variation along the length of the slits **126** and **132,** respectively, and the fluorescent radiation emanating from these slits will remain at stationary locations within their respective slits. It is noted that the presentation of the fluorescing surfaces represents bits of information which conveniently lend themselves to analysis by digital techniques.

Defects which may occur in the selected surfaces being examined can have varying widths along the length of the thread, depending upon the type and severity of the defect. Typically, bottles having defects on the order of one-half millimeter or greater along the length of the surface in the general direction of rotation are considered potentially dangerous and should be detected and discarded. The width of the slit is preferably about ½ millimeter at the bottle top and the length of the slit **126** extends from the bottom of the shoulder **39** to the surface **37.** The length of the slit **133** extends for about the thickness of the bottle wall near the surface **37.**

FIG. **13** illustrates a circuit arrangement for handling data provided by the detectors **130** and **132.** The photodetectors **130** and **132** are segmented along their length into a plurality of insulated segments **150** and **151,** respectively, each of which provides an independent output voltage on an associated output line **152** and **153** respectively. The output of the photodetectors is then scanned by a high speed electronic switch **154** which cyclically and sequentially couples each of the photodetector segments to a preamplifier **156.** The switching operation of the electronic switch **154** is controlled by a control and synchronizing means **158** which also synchronizes an output signal from a pulse generator **160.** The pulse generator **160** provides an output pulse which is coupled to an AND gate **162** along with the output from the preamplifier **156.** The occurrence of an output signal from the preamplifier **156** indicates that the segment which is coupled to the preamplifier at a particular point of time in the scanning cycle by the electronic switch **154** is being impinged by fluorescent radiation from a segment of the coated surface. Upon the occurrence of an output signal from the preamplifier **156,** the pulse generator **160** will enable the AND gate **162** and provide a pulse output to a preset countdown counter **164.** This counter is preset to a value representative of the number of counts which would be provided by a bottle having no defects in the surface examined and therefore no discontinuities in fluorescent radiation as the bottle is rotated. This preset count is adjusted to account for the discontinuities caused by the thread segments **74** and **76** as discussed hereinbefore. The initial rotational orientation of a bottle on the table **96** (FIG. **4**) need not proceed from a same reference location on each bottle

in this form of operation since the number of counts for a non-defective bottle are known and since only the total count is being examined and compared with the total count of a nondefective bottle. Initiation and termination of rotation of a bottle at the examination station is controlled by the control and synchronizing means **158** which provides an output control signal for controlling excitation of the motor **65** (FIG. **4**) and provides an output signal, which indicates termination of rotation and of the examination, to an AND gate **166.** The rotation of a non-defective bottle will result in the countdown of the preset counter to a predetermined count such as a binary zero state. An absence of one or more pulses to the counter **164** will result in a binary count differing from the predetermined final count and will enable an AND gate **166** and initiate a bottle reject operation. The reject operation comprises for example the actuation of a mechanical gate, not shown, which diverts the transport of a defective bottle either before or after filling with a beverage to a discard bin.

FIG. **14** illustrates an alternative form of circuit means for digitally examining the condition of coated selected surfaces of a screw top bottle. The photodetector **130** is, similiar to FIG. **13,** divided into a plurality of segments **150,** each of which is mutually insulated and each of which has an output line **152** for coupling an associated photodetector segment to a preamplifier strip **168.** The preamplifier strip includes a plurality of preamplifing stages **170** equal in number to the photodetector segments **150** and each of which is associated with one of the photodetector segments. This arrangement provides for a binary presentation in parallel of the state of each of the photodetector segments **150** as the bottle rotates. This information is coupled in parallel through an input/output terminal **172** to the arithmatic section **174** of a small scale wired program computer. The binary information presented by the photodetector **130** at each rotational position of the bottle is coupled to the computer and is stored in a memory system **176.** There is previously stored in the memory system **176** a pattern, configuration or "signature" of a bottle known to be non-defective. This information or signature is provided by examining a bottle known to be non-defective in order to generate signal patterns which are then stored as reference data. Data from a bottle under examination and which is temporarily stored in memory **176** is then transferred to the arithmetic unit **174** for comparison with the "signature" or data from a non-defective bottle.

It is noted that the data derived from a bottle under examination is stored without respect to a predetermined orientation. In order to compare the sample data with the reference data, the sample data is convolved with the reference data. The results of each signal are added and the arithmatic unit **174** searches for a maximum value. A starting point for comparison is then set equal to the sample position of maximum value. Having thus established the start position, the reference data and the sample are compared signal by signal and any differences can be associated with bottle defects.

FIG. **15** illustrates an analog detection circuit arrangement for detecting discontinuities in fluorescent radiation from selected surfaces. A photodetector suitable for use with the arrangement of FIG. **15** is illustrated in FIG. **12.** This photodetector comprises a unitary strip **180** which is exposed to fluorescent radiation along the entire length of the aperture slit. The total instantaneous output power of the photodetector is proportional to the area of the fluorescent radiation impingement on the photodetector strip. As the bottle is rotated, the output power will vary in accordance with the area of the coated surface which provides fluorescent radiation. A non-defective bottle will provide substantially smooth and gradual changes in output power. A defective bottle however will cause relatively sharp discontinuities in the power level which are detected by the arrangement of FIG. **15.** In addition, the discontinuities of the thread segments **74** and **76** will cause relatively sharp discontinuities in the output power level. During one revolution of a non-defective bottle, there will be two relatively short discontinuities in the output power.

The output from the photodetectors **130** and **132** which are arranged as the nonsegmented unit of FIG. **12** are coupled to preamplifiers **181** and **182,** respectively. Signal outputs from these preamplifiers are in turn coupled to differentiating and wave shaping circuit arrangements **183** and **184,** respectively. Since the change in the power output level from the photodetectors for a non-defective bottle is relatively smooth and gradual, there will be no output from the differentiating and wave shaping circuit arrangements **183** and **184.** However, the relatively sharp discontinuities created by the thread segments **74** and **76** will result in two discontinuities and thus two output pulses from the differentiating and wave shaping circuit **183.** This output is coupled through an OR gate **185** to a binary counter **186.** A control means **187** controls the rotation of the vessel by initiating and terminating the energization of the rotating motor and in addition resets the counter **186** to a binary zero. During a rotational cycle of a non-defective bottle, the counter **186** will have a count of binary two, (i.e., **010**). An AND gate **188** is accordingly disabled and a reject signal is not generated. However, the existence of defects in the bottle surfaces being examined will result in sharp discontinuities in the fluorescent radiation and will result in one or more additional pulses creating a **$\overline{010}$.** This output signal along with the end of rotation signal from the control means **186** results in a reject signal output from the AND gate **188.**

Although this specification has specifically described fluorescent examination techniques with respect to recycling of screw thread glass bottles, the invention is equally applicable to the examination of defects in other types of bottles. For example, this invention may advantageously be utilized for an inspection of crowns on non-threaded bottle cap types of bottles. Newly manufactured as well as recycled vessels can be examined with this invention. Furthermore, the techniques described are applicable to the detection of surface defects in other articles.

There has thus been described an improved method and apparatus for examining articles for defects existing therein. These defects are advantageously detected by coating the surface under examination with a fluorescent material and inhibiting entry of the material into voids or defects, irradiating the coated surface causing fluorescence of the coated material and detecting discontinuities in the fluorescent radiation as the article is rotated.

While there has been described particular embodiments of the invention, it will be understood that modi-

fications may be made thereto without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A method for examining articles for the detection of voids which extend into the article from a surface of the article comprising the steps of:

Depositing a material on the surface of an article being examined and inhibiting the introduction of the material into voids extending into the article from the surface, said material adapted to fluoresce when irradiated with light energy of a predetermined spectrum;

Irradiating the surface of said article at the predetermined spectrum for exciting the fluorescent material and causing fluorescent radiation therefrom; and,

Detecting discontinuities occurring in fluorescent radiation along the surface thereof corresponding to voids in the surface.

2. The method of claim **1** wherein said fluorescent material is deposited on the surface and inhibited from introduction into the voids by applying the material with an applicator having a surface hardness which inhibits the applicator surface from extending into a void existing in the surface of the article.

3. The method of claim **2** wherein said coated surface is irradiated by scanning the coated surface with a light beam thereby causing sequential fluorescent radiation from the coated surface at a radiation detection means.

4. The method of claim **3** wherein said coated surface is scanned by providing relative motion between the light beam and the article.

5. The method of claim **4** wherein relative motion is provided between said article and said light beam by transporting said article about an axis of the article past a stationary light beam.

6. The method of claim **3** including projecting the light beam at the coated surface through an optical filter which transmits light of a limited frequency spectrum for exciting the coated material and projecting the fluorescent radiation at the detection means through an optical filter which transmits light of a limited frequency spectrum corresponding to the spectrum of fluorescent radiation of the excited fluorescent material.

7. The method of claim **6** wherein said fluorescent radiation is projected at said detection means and said detection means is scanned for generating electrical indications in digital form of the occurrence or the absence of fluorescent radiation from a selected surface of the article.

8. The method of claim **2** wherein said coated material comprises a solution of quinine in a solvent.

9. The method of claim **2** wherein said applicator is formed of rubber.

10. A method for examining a glass vessel for defects which extend from a surface of the vessel into the vessel comprising the steps of:

Applying a fluorescent material to a selected surface of the vessel with an applicator having a surface dimension and firmness which inhibit the entry of the applicator surface and the fluorescent material into a void existing in the surface;

Irradiating the coated surface with light having a frequency spectrum for exciting the fluorescent material and causing fluorescent radiation therefrom;

Scanning the coated surface by providing relative motion between the coated surface and said irradiating light;

Detecting discontinuities occurring in fluorescent radiation which correspond to a void in the vessel surface; and,

Providing an indication of the existence of the discontinuity.

11. The method of claim **10** wherein said vessel comprises a glass bottle and said selected surface comprises a top surface of the bottle.

12. The method of claim **10** wherein said vessel comprises a glass bottle and said selected surface comprises a helically shaped integral glass thread formed in an upper part of the bottle and which is adapted for engaging a closure cap for the bottle.

13. The method of claim **12** wherein said selected surface includes a shoulder segment integrally formed in an upper part of the bottle for sealing a bottle cap thereto.

14. A method for examining a glass beverage bottle for defects or flaws in an upper portion of the bottle, said upper portion including an integrally formed top wall surface and a helically shaped thread for engaging a closure member for the bottle comprising the steps of:

Coating a surface of the thread with a fluorescent material which is deposited on said surface by an applicator having a surface area and stiffness which inhibits the entrance of the applicator and the introduction of coating material into voids or flaws which extend from the surface of the thread into the body of the thread;

Projecting a narrow rectangular shaped beam of ultraviolet light at said upper portion of said bottle thereby causing fluorescent radiation to emanate from coated surfaces located within the relatively narrow area of beam impingement;

Rotating the bottle about a longitudinal axis thereof, past the light beam;

Directing the fluorescent radiation at a photo detection means for generating an electrical signal representative of beam impingement upon said photo detection means; and,

Analyzing an electrical output signal from said photo detection means for sensing discontinuities occurring in fluorescent radiation from said coated surface which correspond to a defect in the surface.

15. The method of claim **14** wherein said rectangular shaped beam is projected at said bottle for providing that a relatively longer dimension of said rectangular shaped beam is generally parallel to a longitudinal axis of said bottle.

16. The method of claim **15** wherein said photo detection means includes a photodetector which is segmented into a plurality of photo detector elements and said elements are sequentially scanned.

17. An apparatus for detecting surface voids existing in an article comprising:

Means for depositing a fluorescent material on a selected surface of an article being examined and for inhibiting the introduction of the material into a void extending into the article from said surface;

Means for irradiating said coated surface at a frequency for exciting the deposited fluorescent material thereby causing fluorescent radiation from said surface;

and,

Means for detecting a discontinuity occurring in fluorescent radiation along the surface corresponding to a void in the surface.

18. The apparatus of claim **17** wherein said fluorescent material comprises a solution of quinine in a vehicle.

19. An apparatus for examining the upper part of a glass vessel for voids occurring therein comprising:

Means for applying a fluorescent material to selected surfaces of the upper part of the vessel, said means including an applicator body in contact with said surface and having a dimension which is generally larger than the voids occurring in the vessel and having a surface hardness for inhibiting the entry of said applicator surface and the introduction of said material into said voids;

Means for scanning the coated surface with light having a frequency for exciting the fluorescent material; and,

Means for detecting discontinuities in fluorescent radiation corresponding to voids in the surface.

20. The apparatus of claim **19** wherein said means for scanning said selected surface and detecting discontinuities in fluorescent radiation comprises a source of ultraviolet light, means for providing relative motion between said light source and said vessel, means for projecting ultraviolet light from said source at said selected surface through an optical filter which transmits ultraviolet light and inhibits the transmission of visible light, a photodetector, means for projecting fluorescent radiation at said photodetector through an optical filter which transmits light within a limited frequency spectrum corresponding to the spectrum of the fluorescent radiation, said photodetector providing an output signal corresponding to voids in the selected surface.

21. The apparatus of claim **20** wherein said photodetector comprises a plurality of segmented photodetector elements and means are provided for sequentially scanning each of said elements for sensing the occurrence or non-occurrence of an electrical signal at said element.

22. The apparatus of claim **19** wherein said applicator is formed of rubber.

23. A method for examining recycled glass vessels comprising the steps of:

Conveying the vessels to a washing and rinsing station;

Washing and rinsing the vessels;

Conveying the vessels from the washing and rinsing station to a coating station;

Applying a fluorescent material to a selected surface of the vessel with an applicator having a surface dimension and firmness which inhibits the entry of the applicator surface and the fluorescent material into voids or defects existing in the surface;

Irradiating the coated surface with light having a frequency spectrum for exciting the fluorescent material and causing fluorescent radiation therefrom;

Scanning the coated surface by providing relative motion between the coated surface and said irradiating light;

Detecting discontinuities occurring in fluorescent radiation which correspond to a void in the vessel surface;

and

Discarding the vessels in which voids in the vessel surface were detected.

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