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(54) **OPTICAL COIN DISCRIMINATION SENSOR AND COIN PROCESSING SYSTEM USING THE SAME**

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See application file for complete search history.

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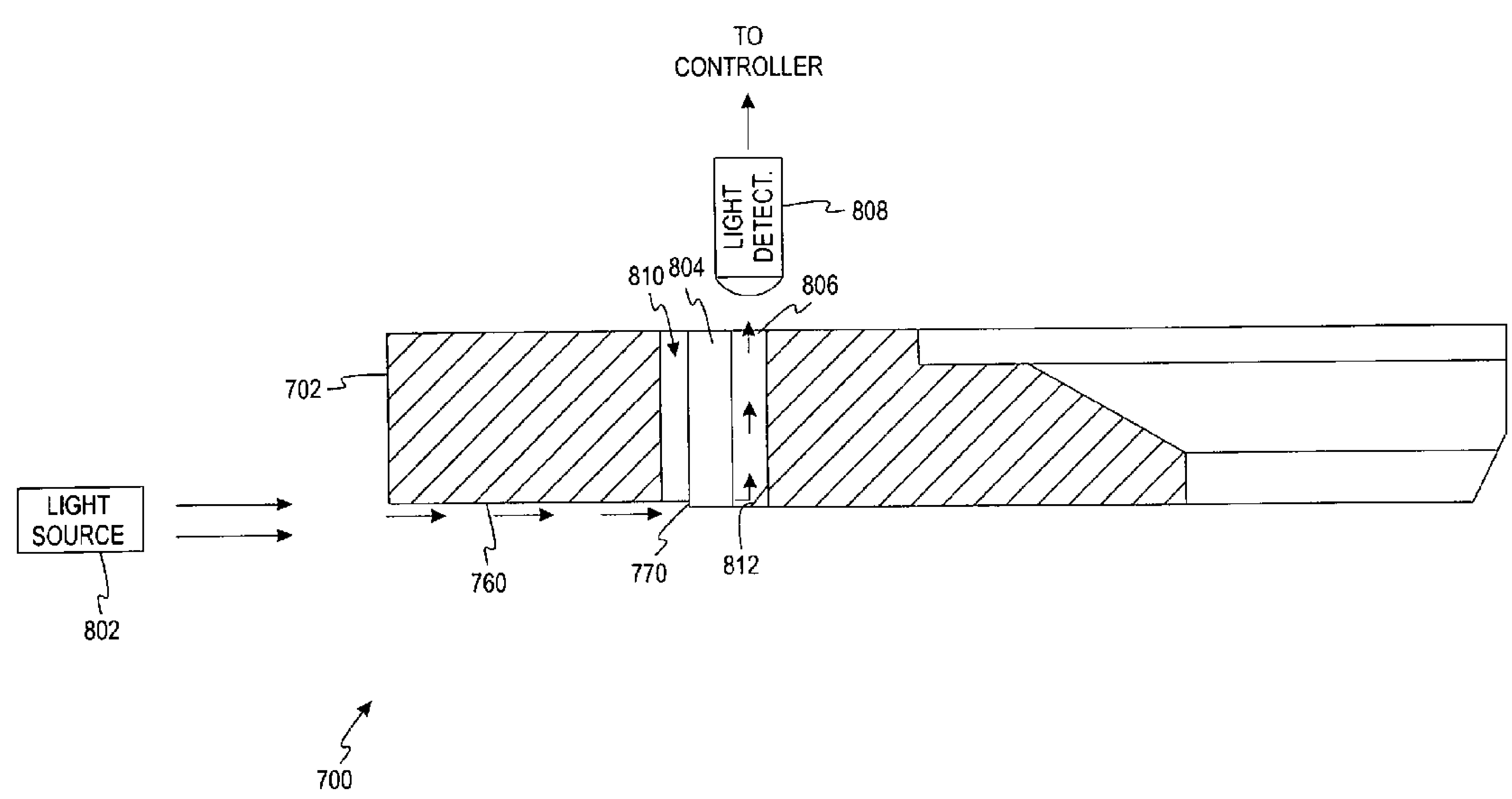
(57) **ABSTRACT**

According to one embodiment of the present invention, a method for determining the denomination of a coin with a disk-type coin processing system comprises moving a coin along a coin path with a rotatable disk, generating an encoder pulse for each incremental movement of the rotatable disk, directing a light beam transverse the coin path, detecting the light beam with a light detector, developing a signal at the light detector indicating the presence of a coin in the coin path, counting a number of encoder pulses occurring while developing the signal at the light detector, and comparing the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

34 Claims, 17 Drawing Sheets



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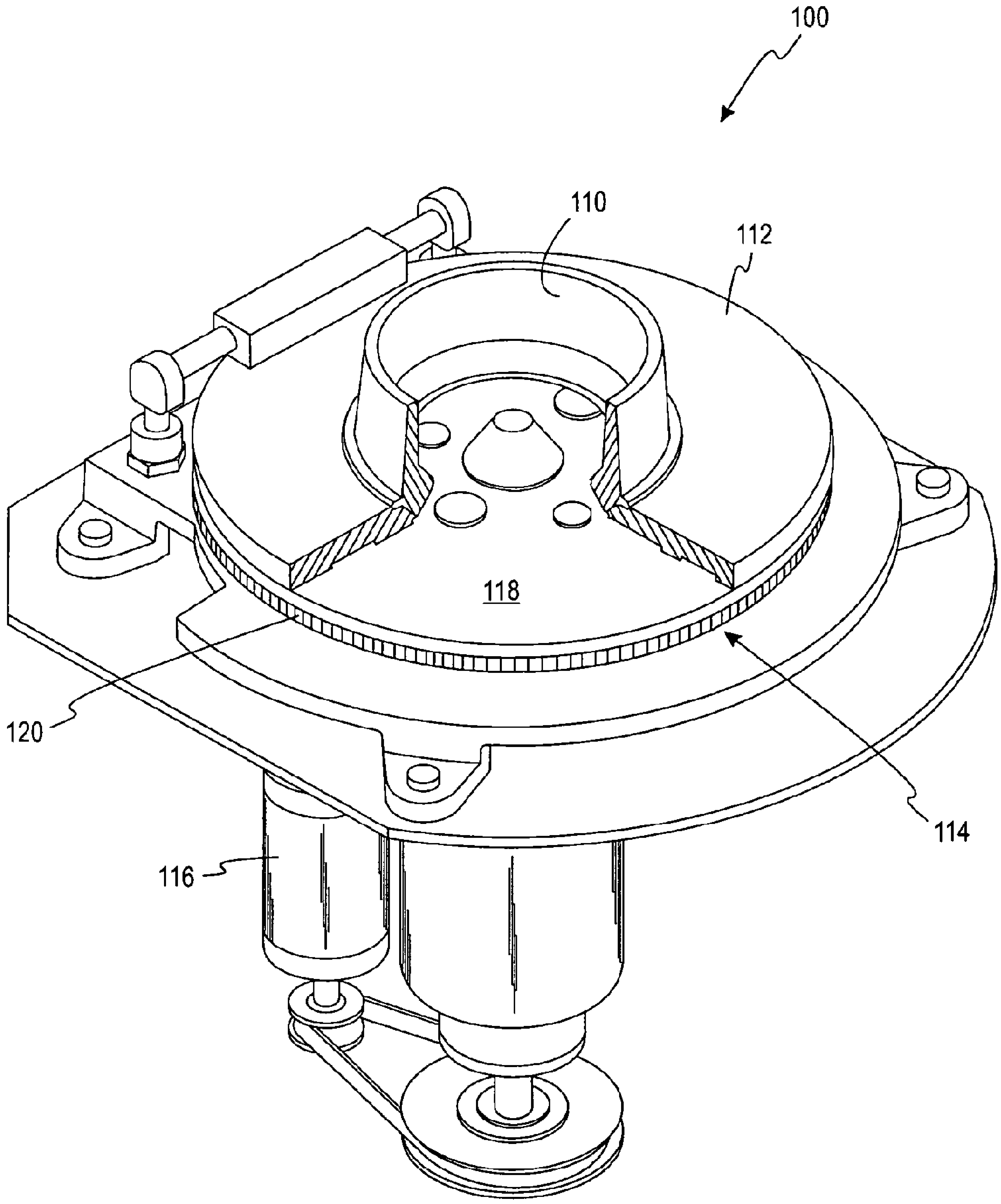


FIG. 1

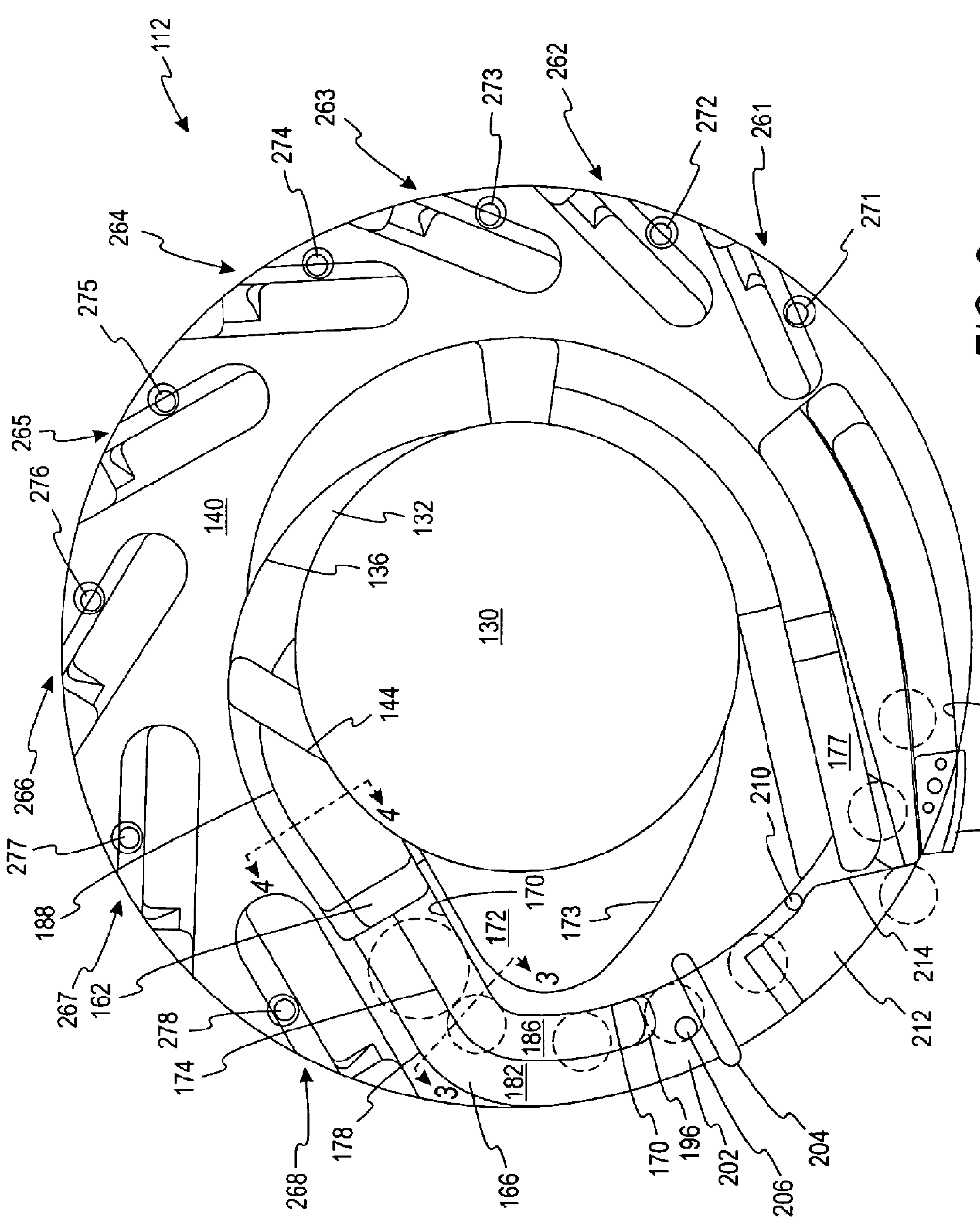

112
263
273
262
272
261
274
264
271
275
265
276
140
132
136
130
144
266
277
188
4
4
170
173
172
3
267
162
278
174
3
182
186
178
268
166
170
196
202
206
204
210
177
252
254
214
212

FIG. 2

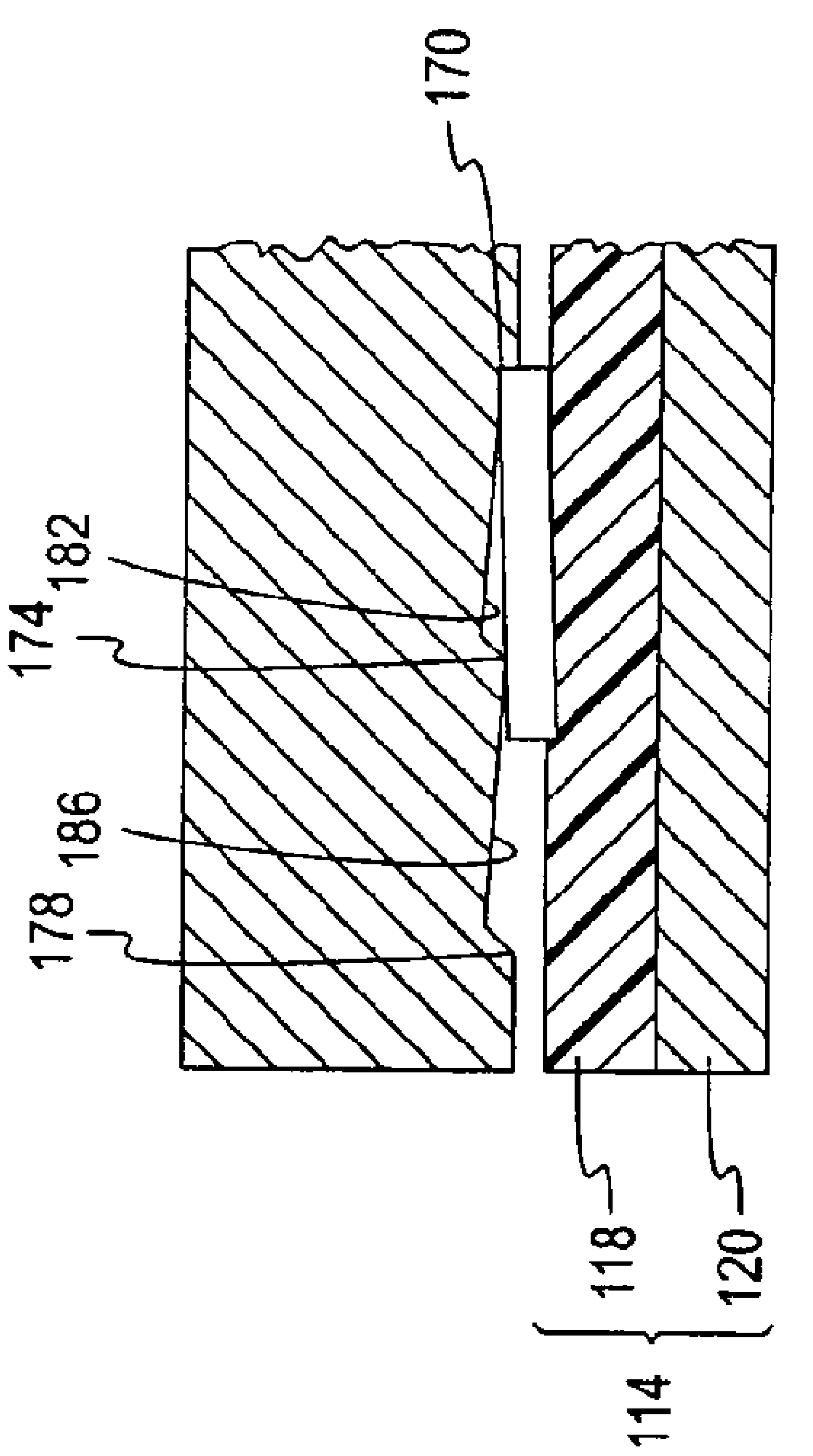


FIG. 3

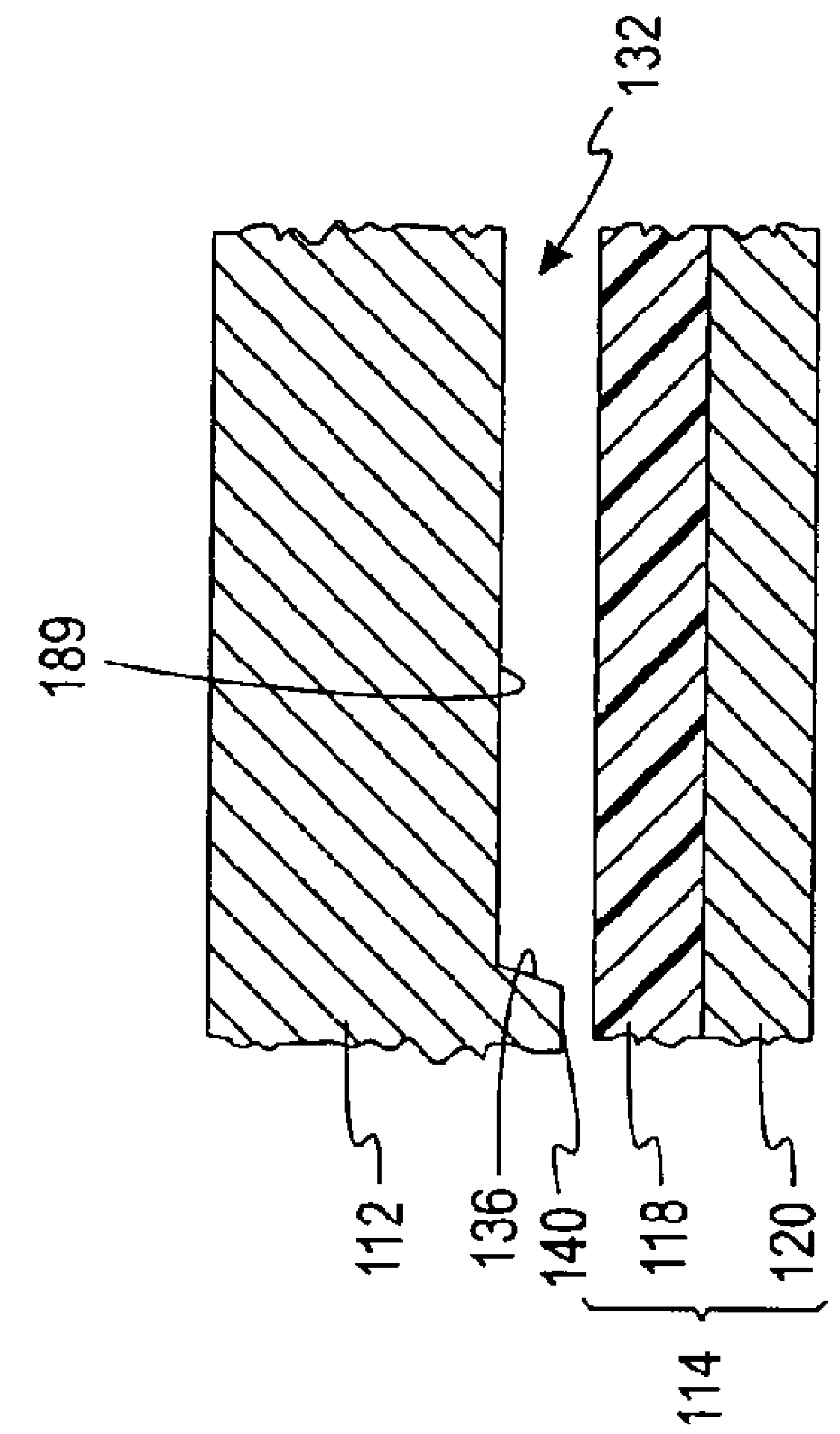


FIG. 4b

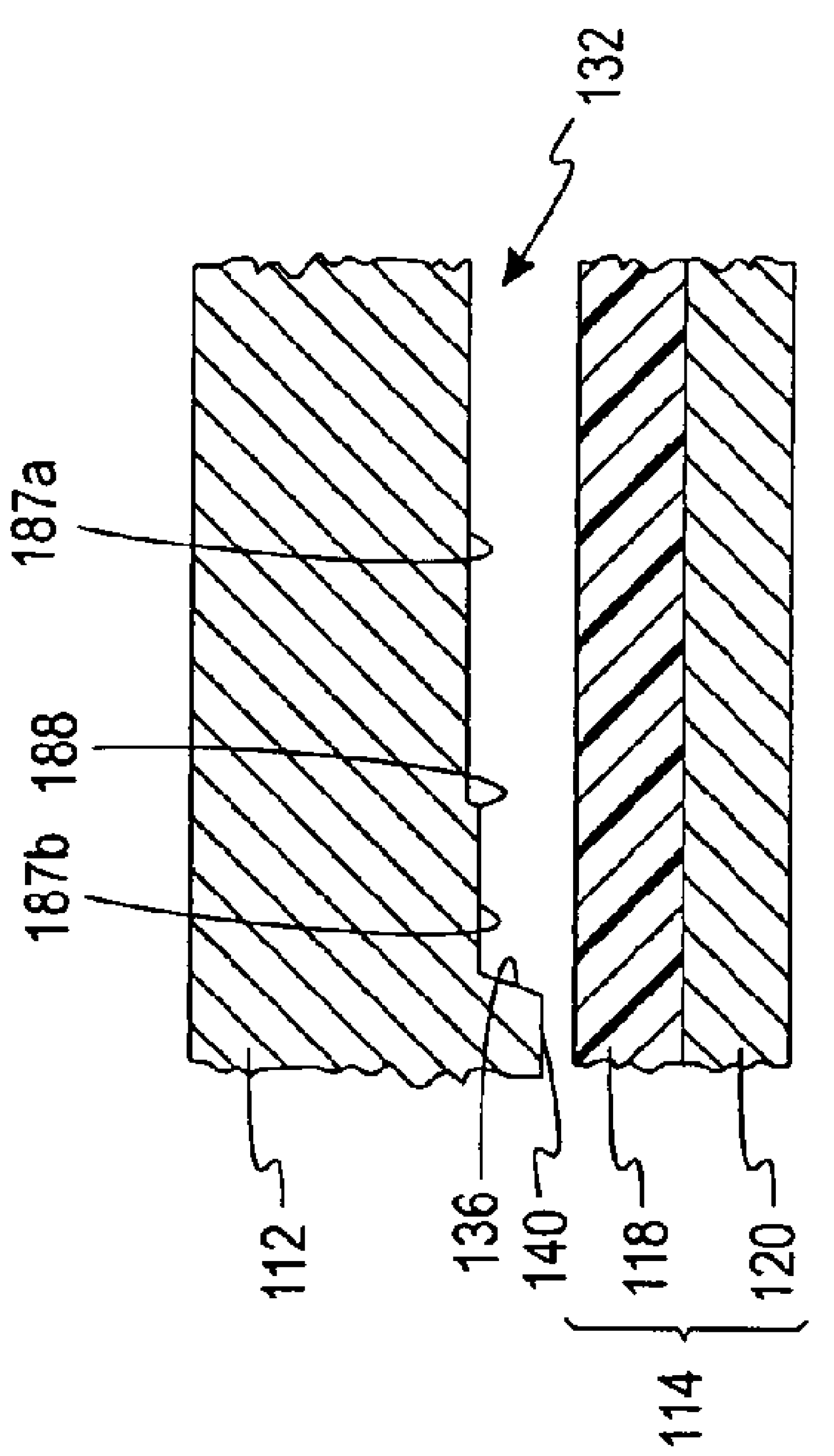


FIG. 4a

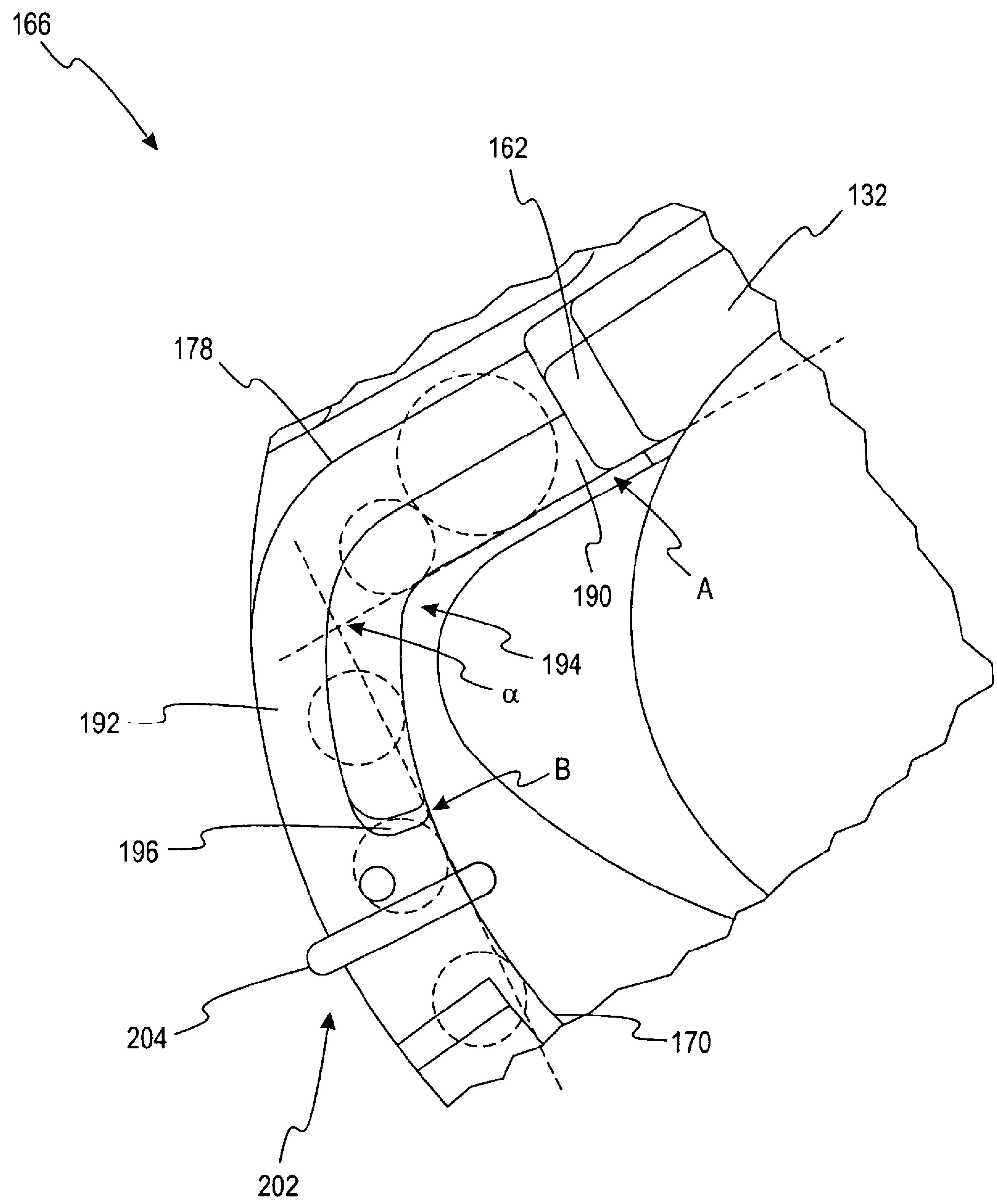


FIG. 5

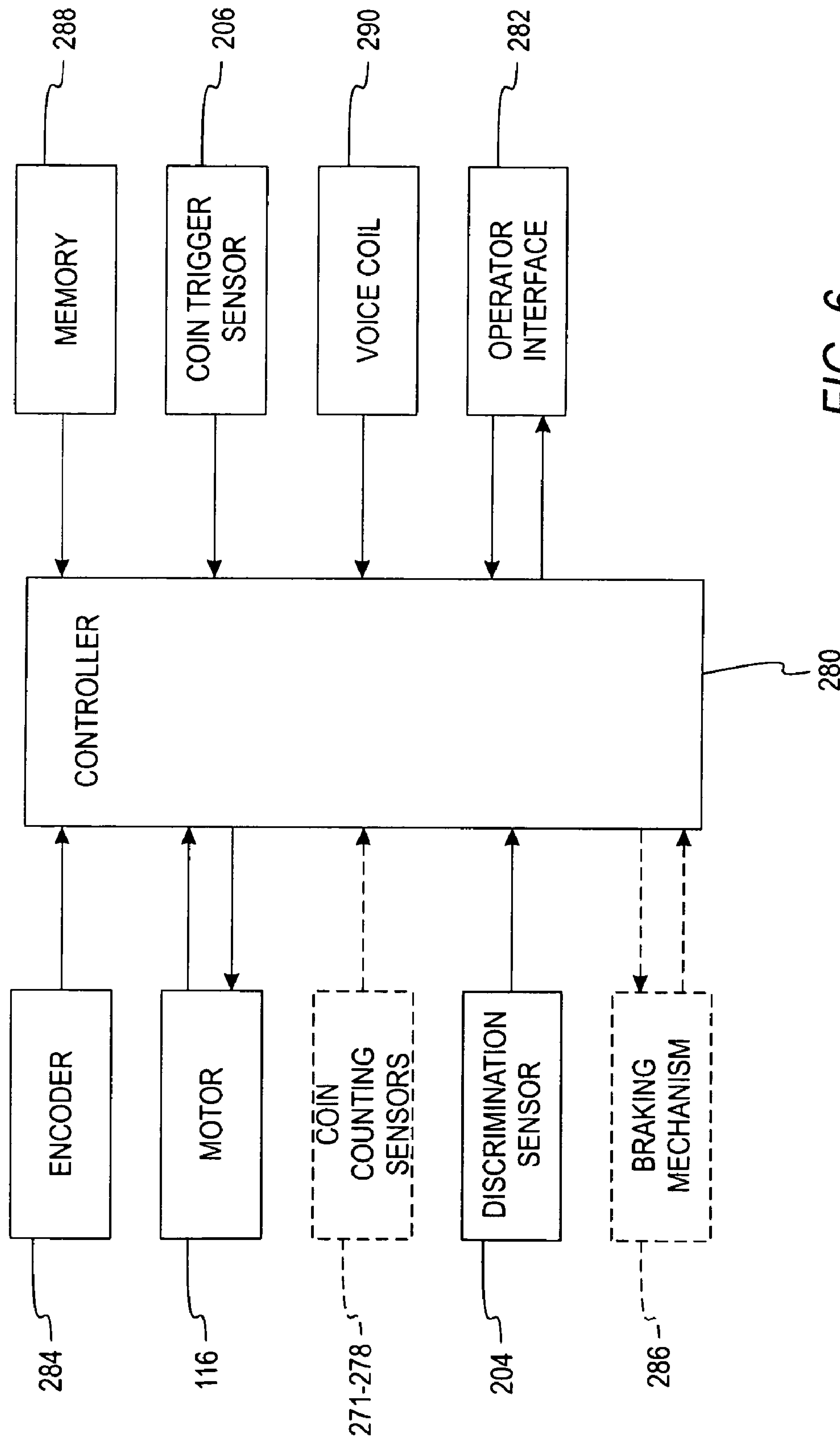

MEMORY
288
COIN TRIGGER SENSOR
206
VOICE COIL
290
OPERATOR INTERFACE
282
CONTROLLER
280
ENCODER
284
MOTOR
116
COIN COUNTING SENSORS
271-278
DISCRIMINATION SENSOR
204
BRAKING MECHANISM
286

FIG. 6

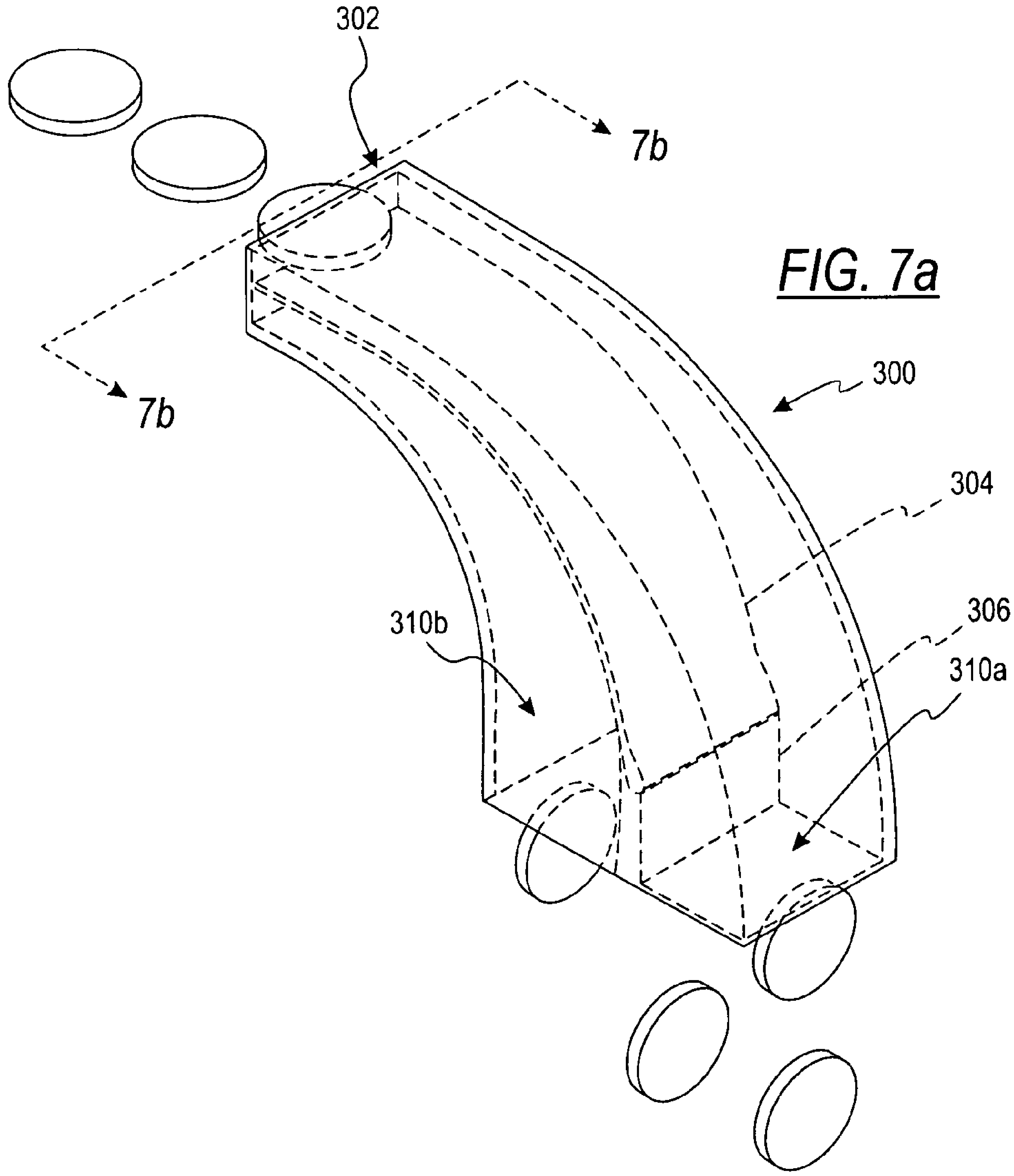

302
7b
7b
300
304
306
310b
310a

FIG. 7a

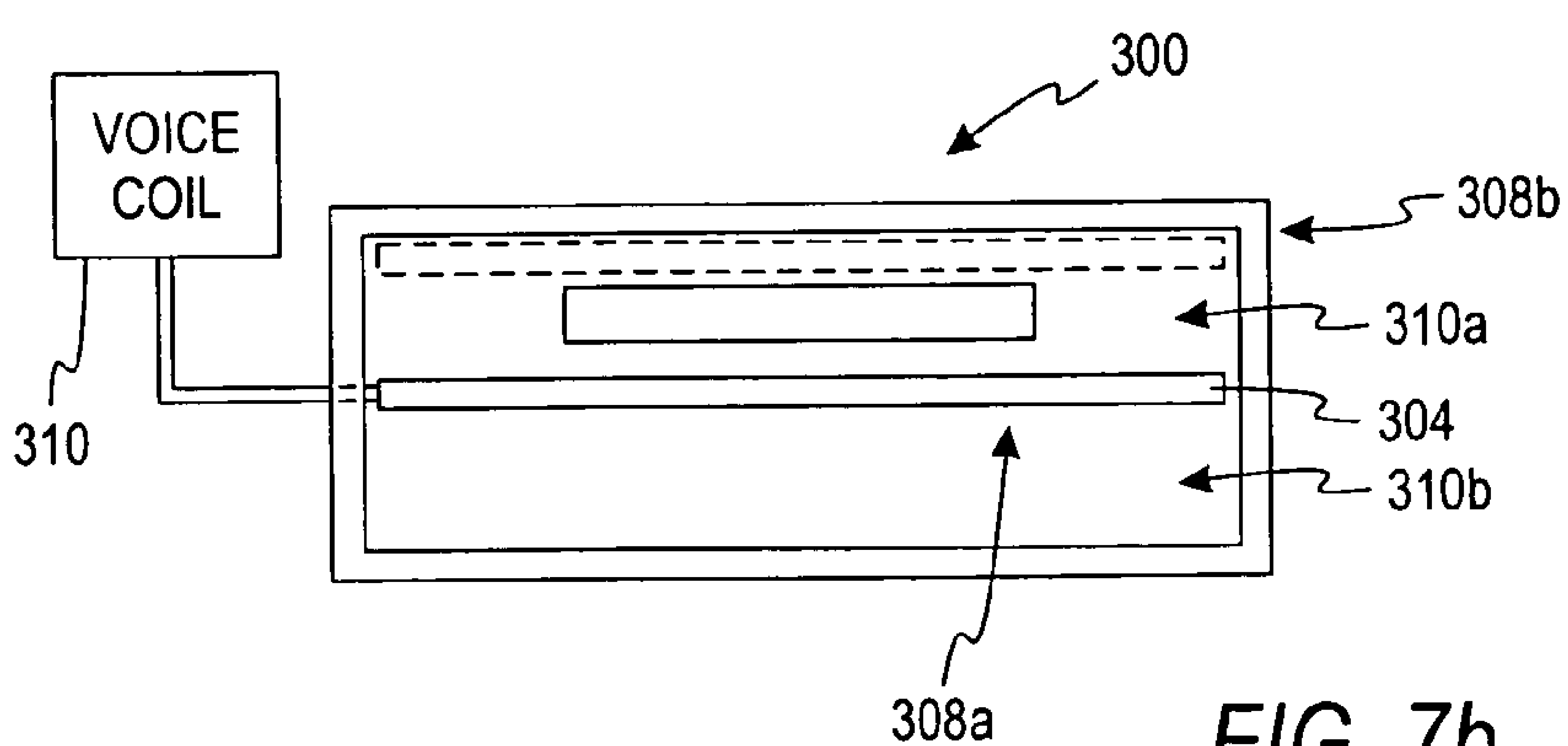

300
VOICE COIL
308b
310a
304
310b
310
308a

FIG. 7b

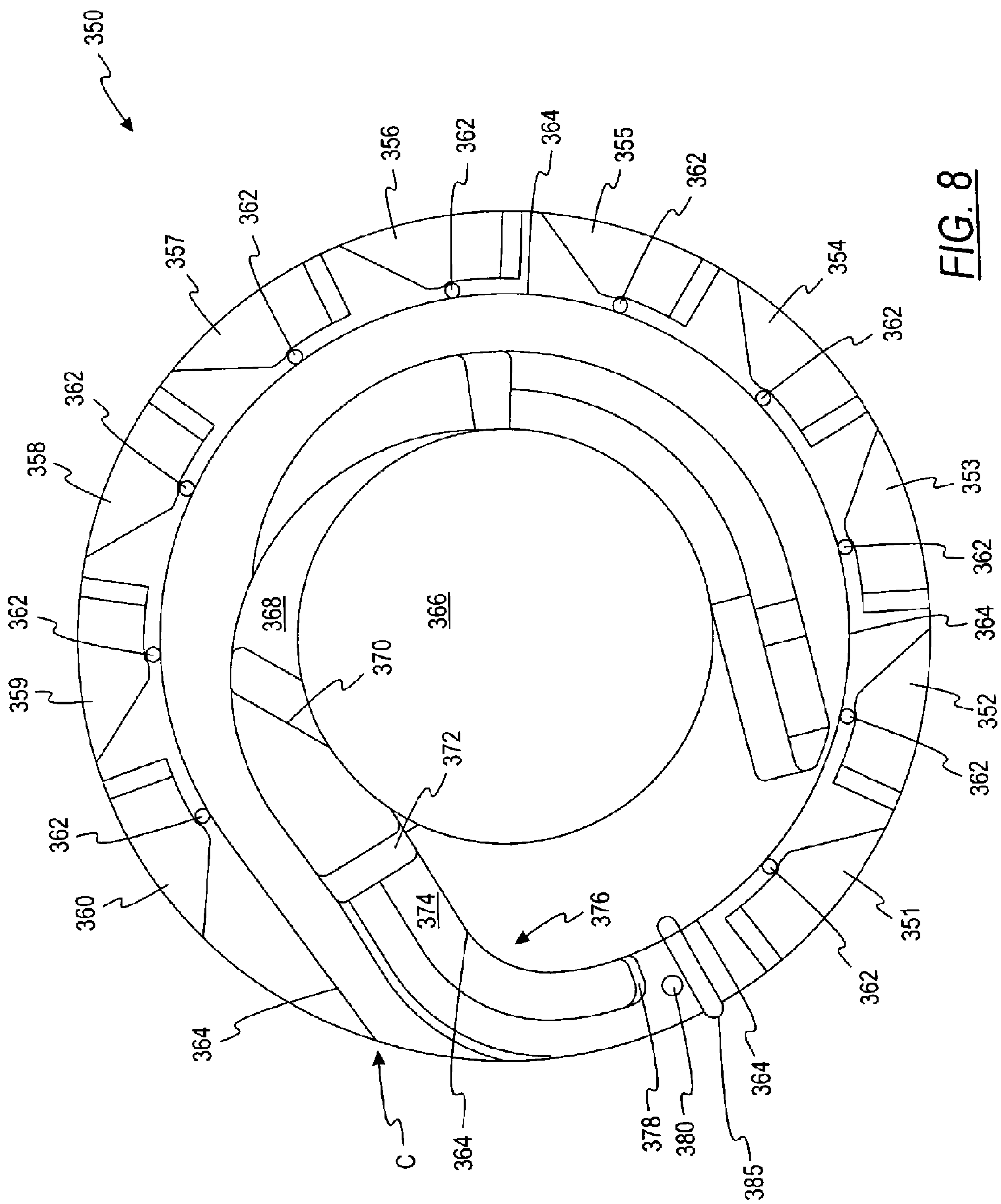
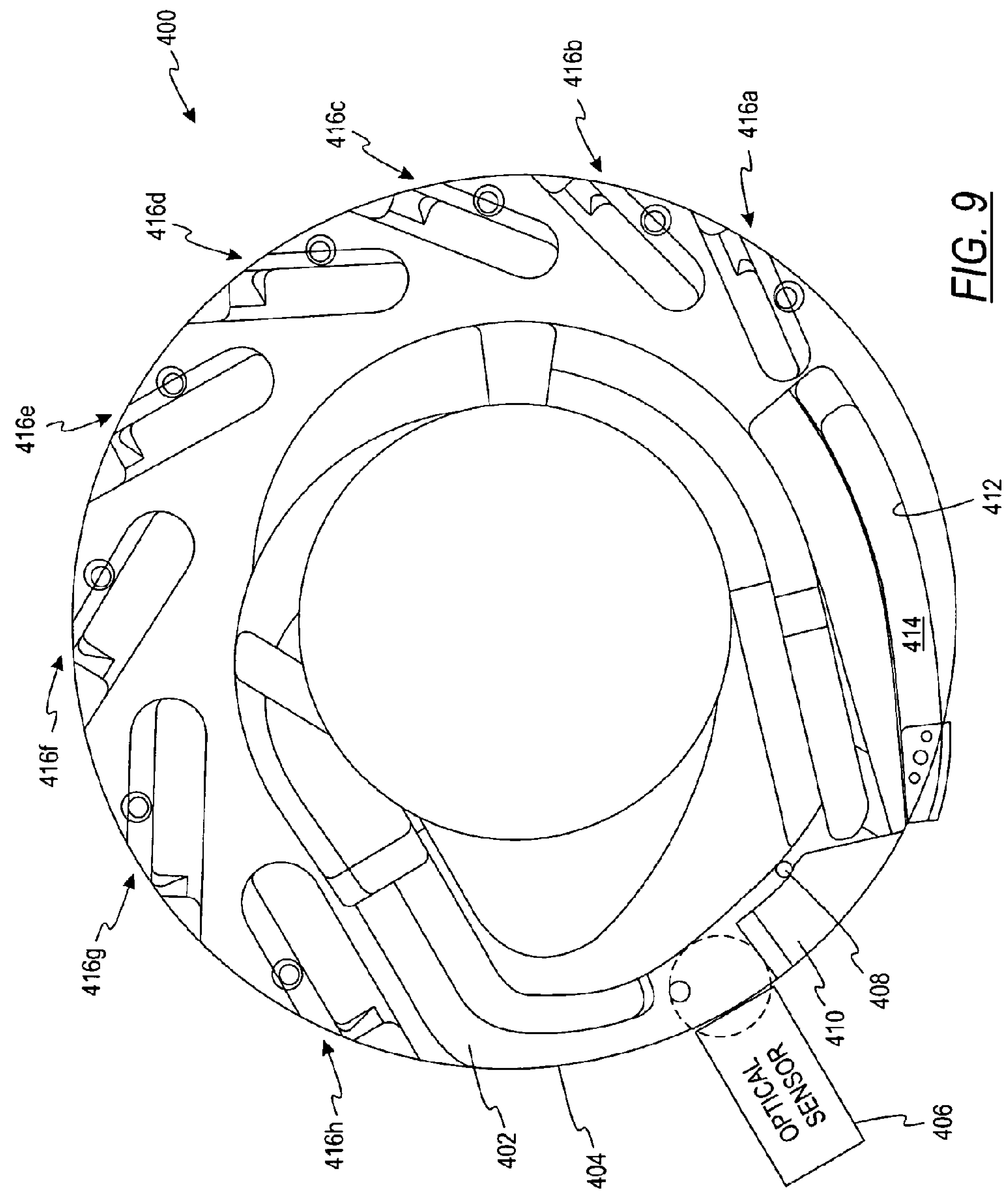

350
356
362
364
355
362
354
357
362
362
362
358
353
362
362
364
359
352
366
368
370
362
372
362
360
376
374
351
364
362
C
364
378
380
385
364

FIG. 8



400
416a
416b
416c
416d
416e
416f
416g
416h
412
414
408
410
OPTICAL SENSOR
406
404
402

FIG. 9

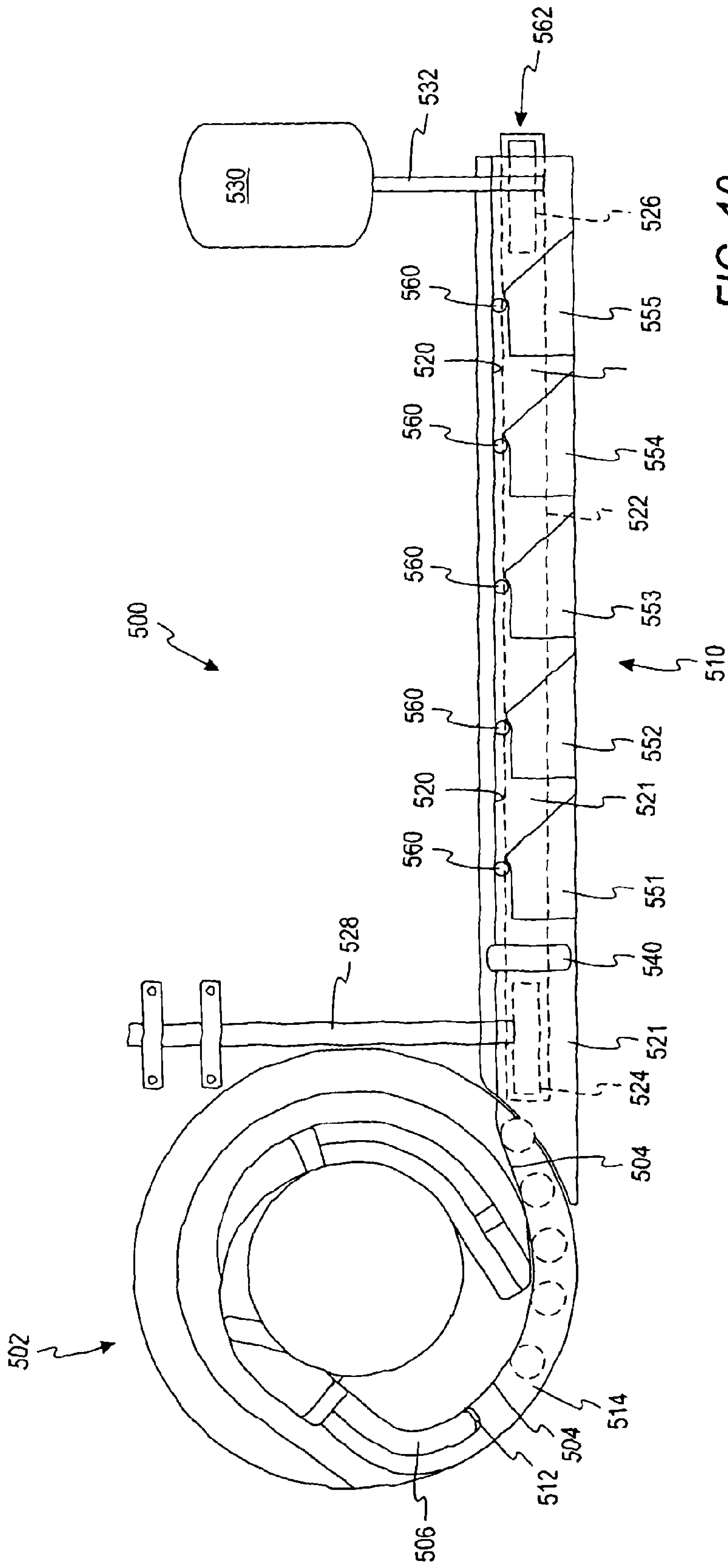

500
502
504
504
506
510
512
514
520
520
521
521
522
524
526
528
530
532
540
551
552
553
554
555
560
560
560
560
560
562

FIG. 10

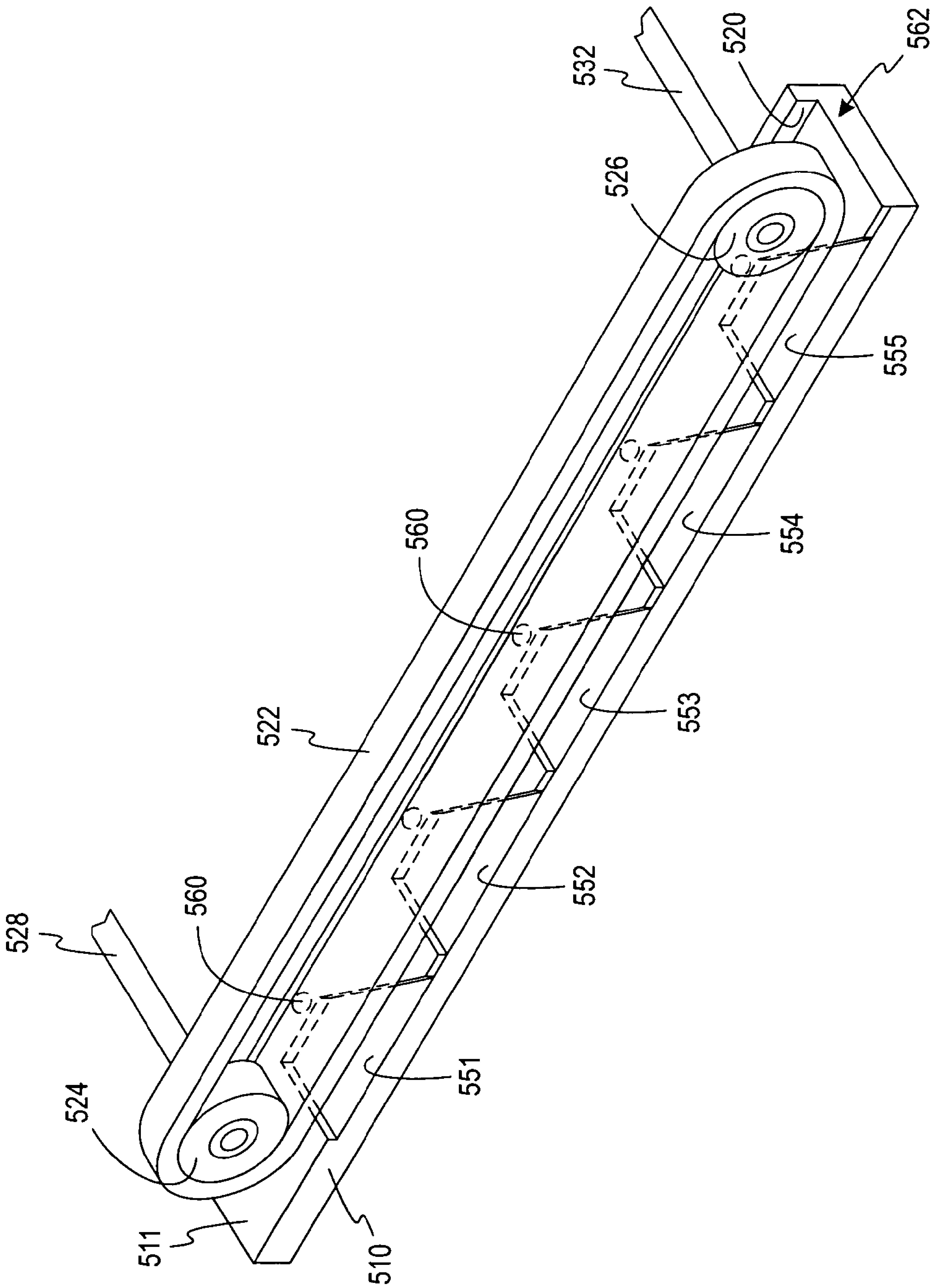


FIG. 11

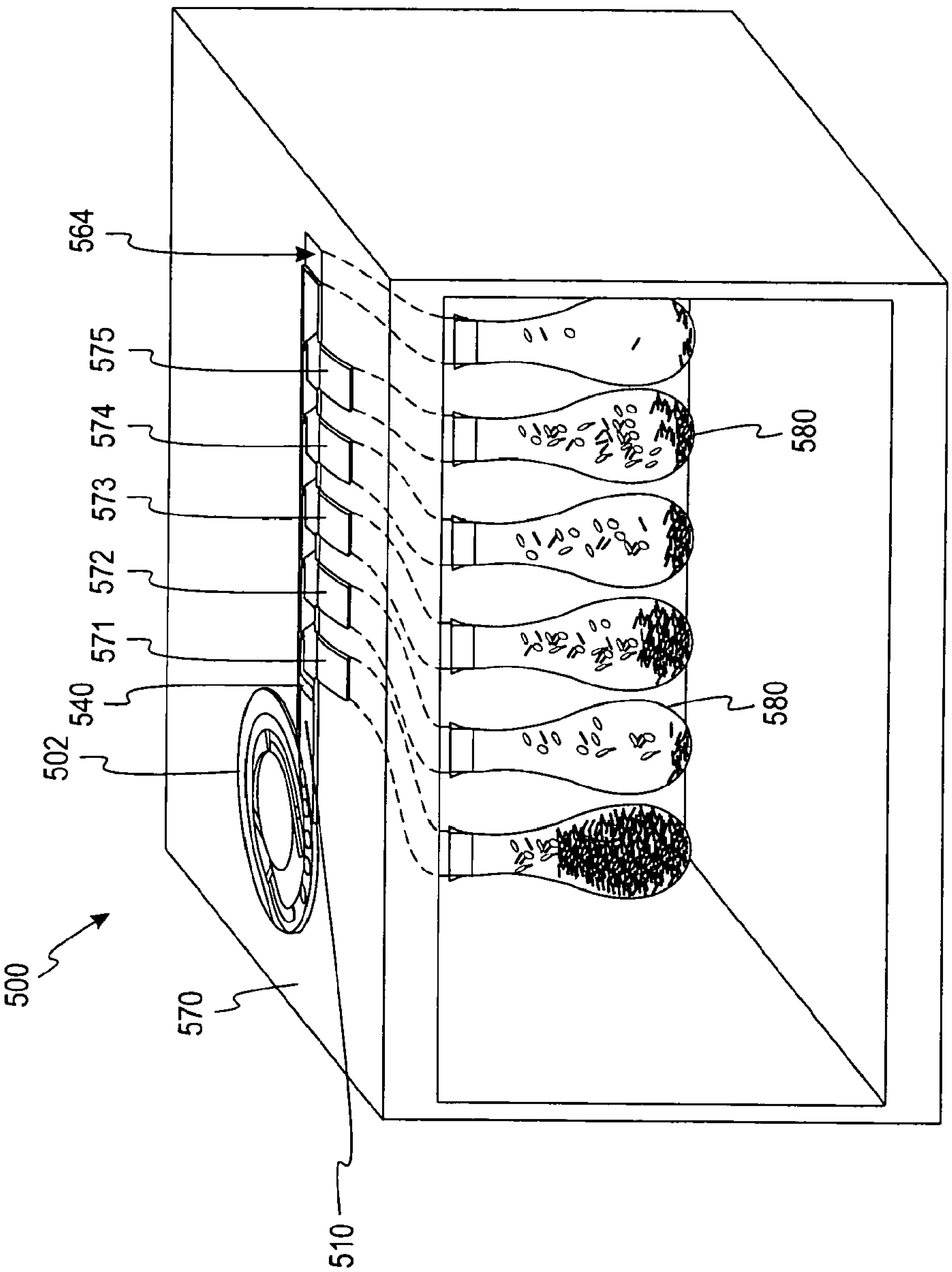


FIG. 12

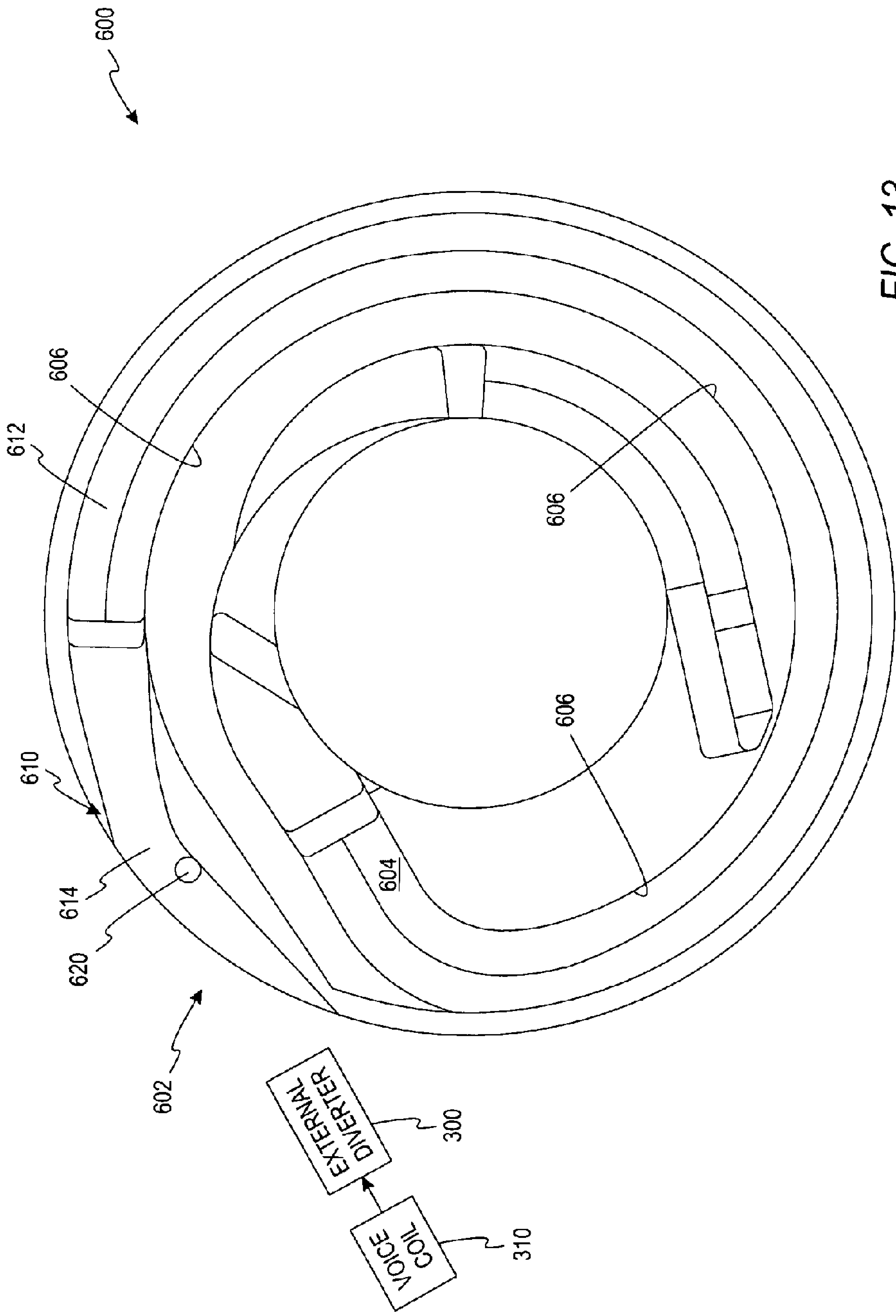

600
606
612
606
606
610
614
620
604
602
EXTERNAL DIVERTER
300
VOICE COIL
310

FIG. 13

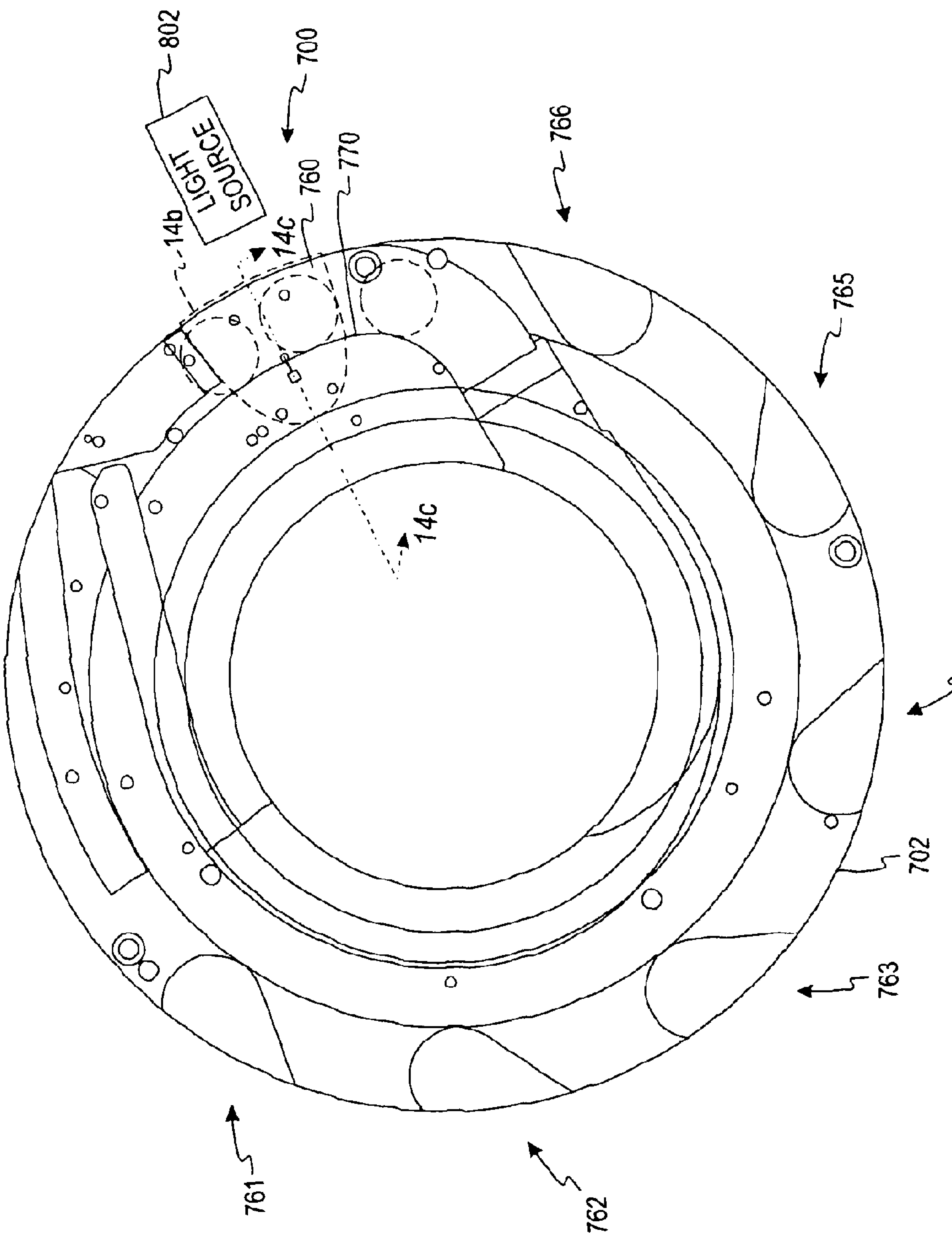

802
LIGHT SOURCE
700
766
14b
14c
760
770
14c
765
764
702
763
761
762

FIG. 14a

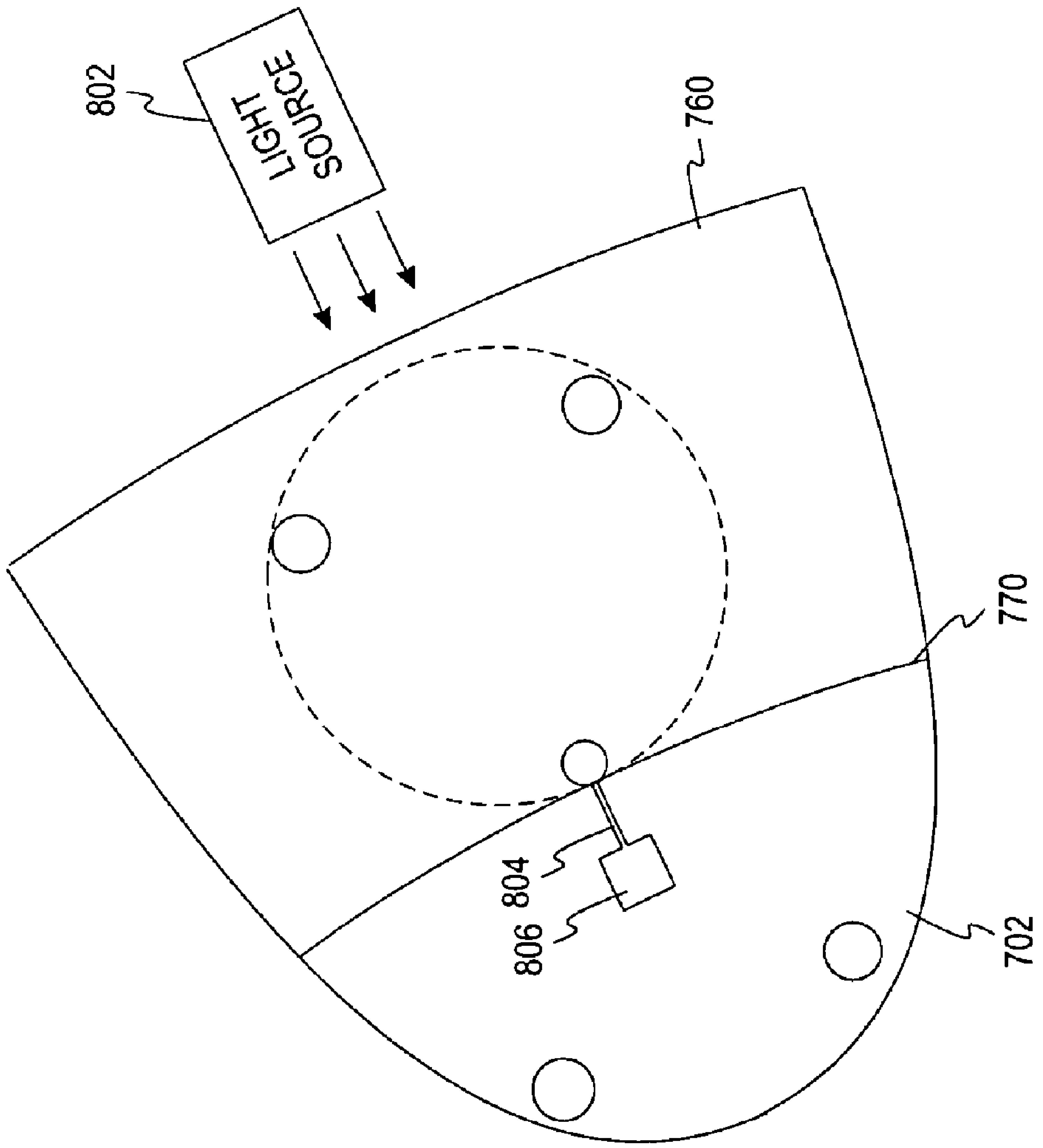


FIG. 14b

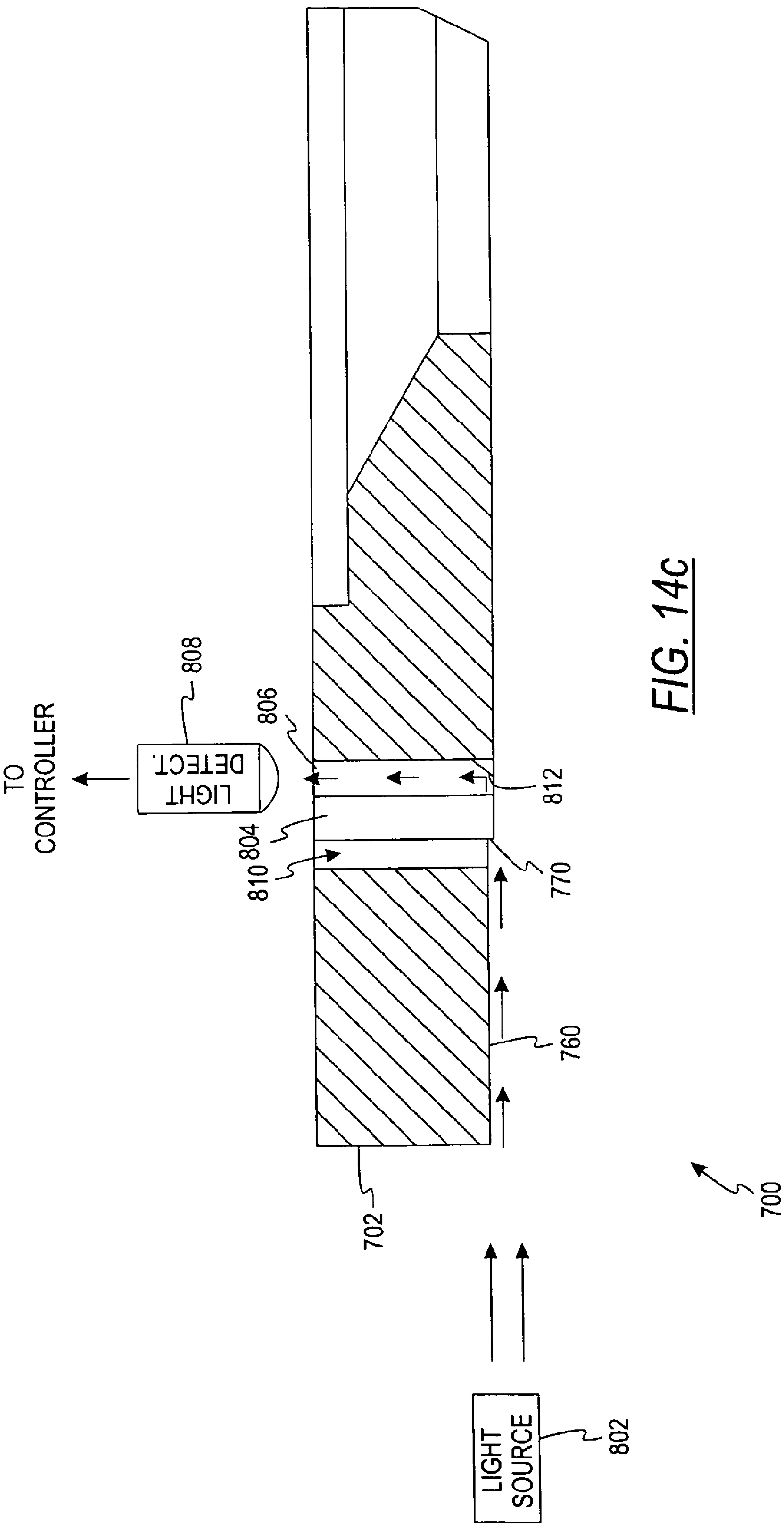

TO CONTROLLER
LIGHT DETECT.
808
806
812
804
810
770
760
702
700
LIGHT SOURCE
802

FIG. 14c

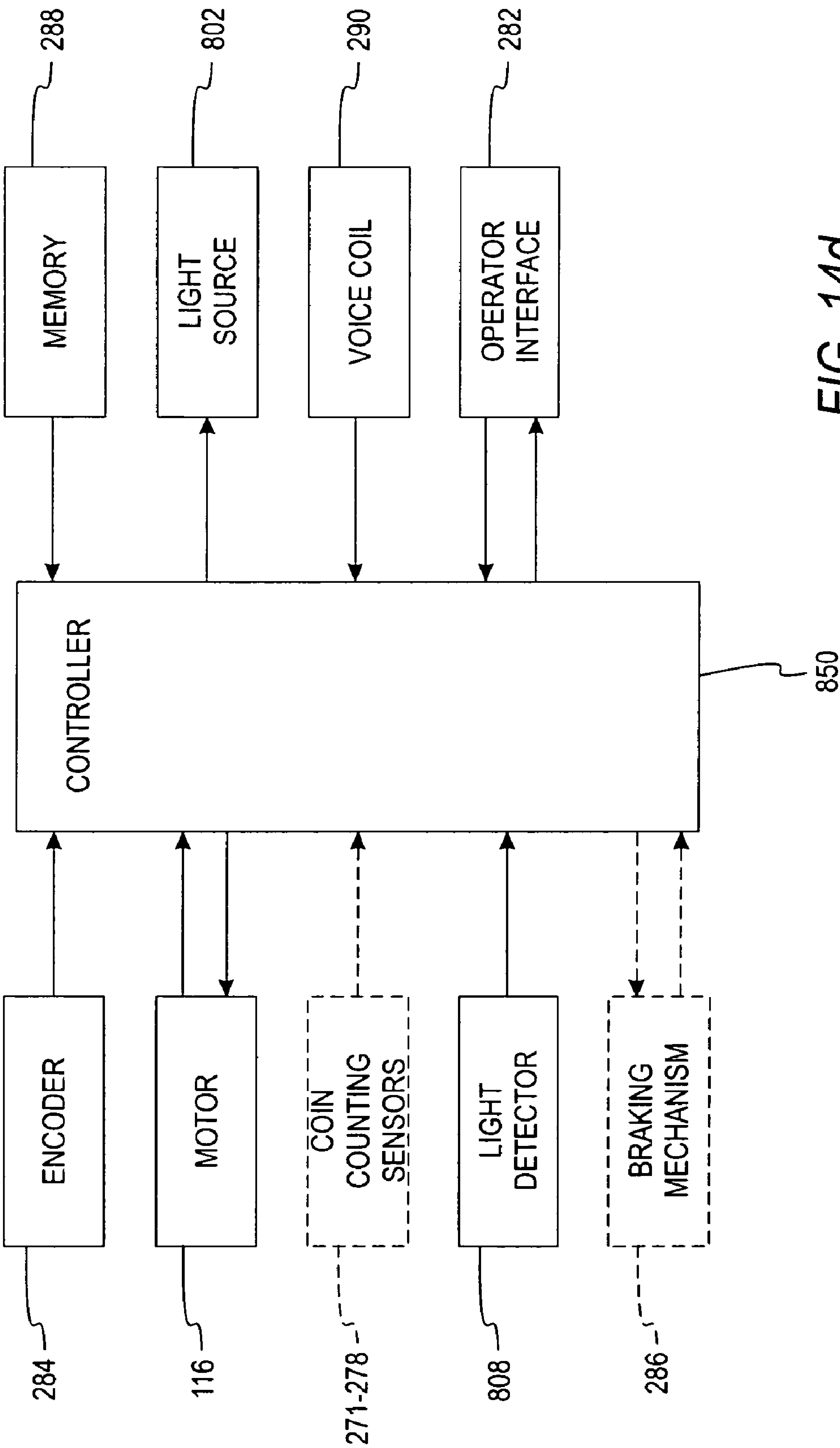

288
MEMORY
802
LIGHT SOURCE
290
VOICE COIL
282
OPERATOR INTERFACE
CONTROLLER
850
ENCODER
284
MOTOR
116
COIN COUNTING SENSORS
271-278
LIGHT DETECTOR
808
BRAKING MECHANISM
286

FIG. 14d

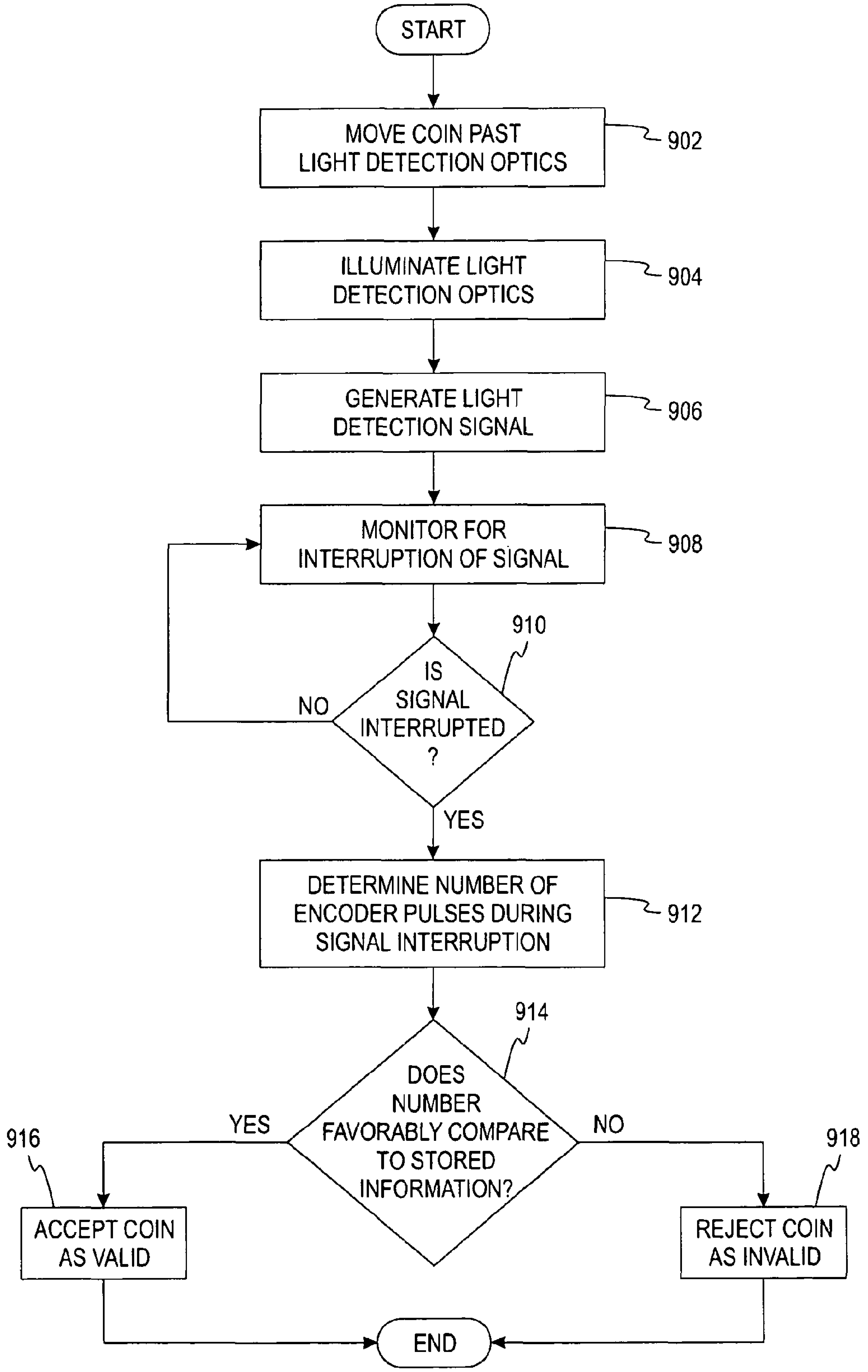

START
MOVE COIN PAST LIGHT DETECTION OPTICS
902
ILLUMINATE LIGHT DETECTION OPTICS
904
GENERATE LIGHT DETECTION SIGNAL
906
MONITOR FOR INTERRUPTION OF SIGNAL
908
910
IS SIGNAL INTERRUPTED ?
NO
YES
DETERMINE NUMBER OF ENCODER PULSES DURING SIGNAL INTERRUPTION
912
914
DOES NUMBER FAVORABLY COMPARE TO STORED INFORMATION?
YES
NO
916
ACCEPT COIN AS VALID
918
REJECT COIN AS INVALID
END

FIG. 15

OPTICAL COIN DISCRIMINATION SENSOR AND COIN PROCESSING SYSTEM USING THE SAME

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. Nos. 10/095,164 and 10/095,256, each of which is incorporated herein by reference in its entirety. U.S. patent application Ser. No. 10/095,164 is entitled "Disc-Type Coin Processing Device Having Improved Coin Discrimination System" and was filed on Mar. 11, 2002 *now U.S. Pat. No. 6,755,730*. U.S. Pat. No. 10/095,256 is entitled "Sensor and Method For Discriminating Coins of Varied Composition, Thickness and Diameter" and was filed on Mar. 11, 2002 *now U.S. Pat. No. 6,892,871*.

FIELD OF THE INVENTION

The present invention relates generally to coin sensors and coin processing systems and, more particularly, to an optical coin sensor that discriminates between coins that discriminates among coins of different denominations.

BACKGROUND OF THE INVENTION

Generally, disc-type coin sorters sort coins according to the diameter of each coin. Typically, in a given coin set such as the United States coin set, each coin denomination has a different diameter. Thus, sorting coins by diameter effectively sorts the coins according to denomination.

Disc-type coin sorters typically include a resilient pad (disposed on a rotating disc) that rotates beneath a stationary sorting head having a lower surface positioned parallel to the upper surface of the resilient pad and spaced slightly therefrom. The rotating, resilient pad presses coins upward against the sorting head as the pad rotates. The lower surface of sorting head includes a plurality shaped regions including exit channels for manipulating and controlling the movement of the coins. Each of the exit channels is dimensioned to accommodate coins of a different diameter for sorting the coins based on diameter size. As coins are discharged from the sorting head via the exit channels, the sorted coins follow respective coin paths to sorted coin receptacles where the sorted coins are stored.

It is desirable in the sorting of coins to discriminate between valid coins and invalid coins. Use of the term "valid coin" refers to coins of the type to be sorted. Use of the term "invalid coin" refers to items being circulated on the rotating disc that are not one of the coins to be sorted. For example, it is common that foreign or counterfeit coins (e.g., slugs) enter the coin sorting system. So that such items are not sorted and counted as valid coins, it is helpful to detect and discard these "invalid coins" from the coin processing system. In another application wherein it is desired to process (e.g., count and/or sort) only U.S. quarters, nickels and dimes, all other U.S. coins including dollar-coins, half-dollar coins and pennies are considered "invalid." Additionally, coins from all other coins sets including Canadian coins and Euro coins, for example, would be considered "invalid" when processing U.S. coins. Finally, any truly counterfeit coins (i.e., a slug) are always considered "invalid" in any application. In another application it may be desirable to separate Canadian coins from U.S. coins for example. Therefore, in that application all authentic U.S. coins are considered invalid, and all non-authentic U.S. coin, Canadian coins, and all coins from other coin sets (e.g., Euro coins) are considered invalid.

Typically, prior-art disc-type coin sorters include a discrimination sensor disposed within each exit channel for discriminating between valid and invalid coins as coins enter the exit channels. In such systems, therefore, coins entered the exit channel and are then discriminated. An invalid coin having a diameter that enables it to pass into an exit channel moves past the discrimination sensor. The discrimination sensor detects the invalid coin and a braking mechanism is triggered to stop the rotating disc before the invalid coin is moved out of the exit channel. A diverter, disposed within the coin path external, or internal, to the sorting head, moves such that a coin entering the coin path is diverted to an invalid coin receptacle. The sorting head is then jogged (electronically pulsed) causing the disc to incrementally rotate until the invalid coin is discharged from the exit channel to the coin path where it is diverted to a invalid coin receptacle. The diverter is moved back to its home position such that coins now entering the coin path are directed to the coin receptacles for valid coins. The coin sorter is then restarted and the disc begins to rotate at the normal sorting rate of speed.

One drawback associated with this type of prior art discrimination technique is the downtime consumed by the aforementioned stopping, jogging and restarting of the rotatable disc to remove the invalid coin. This process often takes approximately five seconds per invalid coin. Initially, this may appear to be a relatively insignificant amount of time; however, this time can add up to a significant amount of time in the processing of bulk coins.

Furthermore, because the rotatable disc rapidity breaks and stops so that an invalid coin is not ejected from a coin exit channel before the diverter is moved to route invalid coins to a reject receptacle, the overall speed (i.e., the number of rotations of the rotatable disc per minute) is limited. Additionally, this type prior art discrimination technique results in more "wear and tear" on the breaking system and motor.

Accordingly, a need exists for a coin processing machine that can discriminate invalid coins at a high-rate of speed.

SUMMARY OF THE INVENTION

According to one embodiment of the present invention, a method for determining the denomination of a coin with a disk-type coin processing system comprises moving a coin along a coin path with a rotatable disk, generating an encoder pulse for each incremental movement of the rotatable disk, directing a light beam transverse the coin path, detecting the light beam with a light detector, developing a signal at the light detector indicating the presence of a coin in the coin path, counting a number of encoder pulses occurring while developing the signal at the light detector, and comparing the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

The above summary of the present invention is not intended to represent each embodiment, or every aspect, of the present invention. Additional features and benefits of the present invention will become apparent from the detailed description, figures, and claims set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a coin processing system, according to one embodiment of the present invention, with portions thereof broken away to show the internal structure.

FIG. **2** is a bottom view of a sorting head for use with the system of FIG. **1**.

FIG. **3** is a cross-sectional view of the sorting head shown in FIG. **2** taken along line **3**-**3**.

FIG. **4**a is a cross-sectional view of the sorting head shown in FIG. **2** taken along **4**-**4**.

FIG. **4**b is a cross-sectional view of an alternative embodiment of that which is shown in FIG. **4**a.

FIG. **5** is an oversize view of a queuing channel of the sorting head shown in FIG. **2**.

FIG. **6** is a functional block diagram of the control system for the a coin processing system shown in FIG. **1**.

FIG. **7**a is a perspective view of an external diverter according to one alternative embodiment of the present invention.

FIG. **7**b is a front end view of the external diverter shown in FIG. **7**a taken along line **7**b-**7**b.

FIG. **8** is a bottom view of a programmable sorting head that can be used with the coin processing system of FIG. **1** instead of the sorting head shown in FIG. **2**.

FIG. **9** is a bottom view of a sorting head and an external optical sensor that can be used with the coin processing system of FIG. **1** instead of the sorting head shown in FIG. **2**.

FIG. **10** is a top view of a programmable power rail coin processing system according to one alternative embodiment of the present invention.

FIG. **11** is a perspective view of a rail and an endless belt for use with the programmable power rail coin processing system of FIG. **10**.

FIG. **12** is a perspective view of the programmable power rail coin processing system of FIG. **10** disposed within a cabinet according to one an alternative embodiment of the present invention.

FIG. **13** is a bottom view of a sorting head having a single coin exit station that can be used with the coin processing system of FIG. **1** instead of the sorting head shown in FIG. **2**.

FIG. **14**a is a bottom view of a sorting head according to one embodiment of the present invention for use with the system of FIG. **1**.

FIG. **14**b is an enlarged view of a portion of the sorting head of FIG. **14**a taken along line **14**b showing an optical coin discrimination sensor according to one embodiment of the present invention.

FIG. **14**c is a cross-section view of the sorting head of FIG. **14**a taken along line **14**c showing an optical coin discrimination sensor according to one embodiment of the present invention.

FIG. **14**d is a functional block diagram of the control system for the a coin processing system shown in FIG. **1** using the sorting head of FIG. **14**a. and an optical coin discrimination sensor according to one embodiment of the present invention.

FIG. **15** is a flow chart illustrating a method for processing coins with the sorting head of FIGS. **14**a-c and an optical coin discrimination sensor according to one embodiment of the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments will be shown byway of example in the drawings and will be desired in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Turning now to the drawings and referring first to FIG. **1**, a disc-type coin processing system **100** according to one embodiment of the present invention is shown. The coin processing system **100** includes a hopper **110** for receiving coins of mixed denominations that feeds the coins through a central opening in an annular sorting head **112**. As the coins pass through this opening, they are deposited on the top surface of a rotatable disc **114**. This rotatable disc **114** is mounted for rotation on a shaft (not shown) and driven by an electric motor **116**. The disc **114** typically comprises a resilient pad **118**, preferably made of a resilient rubber or polymeric material, bonded to the top surface of a solid disc **120**. While the solid disc **120** is often made of metal, it can also be made of a rigid polymeric material.

According to one embodiment, coins are initially deposited by a user in a coin tray (not shown) disposed above the coin processing system **100** shown in FIG. **1**. The user lifts the coin tray which funnels the coins into the hopper **110**. A coin tray suitable for use in connection with the coin processing system **100** is described in detail in U.S. Pat. No. 4,964,495 entitled “Pivoting Tray For Coin Sorter,” which is incorporated herein by reference in its entirety.

As the disc **114** is rotated, the coins deposited on the resilient pad **118** tend to slide outwardly over the surface of the pad **118** due to centrifugal force. As the coins move outwardly, those coins which are lying flat on the pad **118** enter the gap between the surface of the pad **118** and the sorting head **112** because the underside of the inner periphery of the sorting head **112** is spaced above the pad **118** by a distance which is about the same as the thickness of the thickest coin. As is further described below, the coins are processed and sent to exit stations where they are discharged. The coin exit stations may sort the coins into their respective denominations and discharge the coins from exit channels in the sorting head **112** corresponding to their denominations.

Referring now to FIG. **2**, the underside of the sorting head **112** is shown. The coin sets for any given country are sorted by the sorting head **112** due to variations in the diameter size. The coins circulate between the sorting head **112** and the pad **118** (FIG. **1**) on the rotatable disc **114** (FIG. **1**). The coins are deposited on the pad **118** via a central opening **130** and initially enter the entry channel **132** formed in the underside of the sorting head **112**. It should be keep in mind that the circulation of the coins in FIG. **2** appears counterclockwise as FIG. **2** is a view of the underside of the sorting head **112**.

An outer wall **136** of the entry channel **132** divides the entry channel **132** from the lowermost surface **140** of the sorting head **112**. The lowermost surface **140** is preferably spaced from the pad **118** by a distance that is slightly less than the thickness of the thinnest coins. Consequently, the initial outward radial movement of all the coins is terminated when the coins engage the outer wall **136**, although the coins continue to move more circumferentially along the wall **136** (in the counterclockwise directed as viewed in FIG. **2**) by the rotational movement imparted to the coins by the pad **118** of the rotatable disc **114**.

In some cases, coins may be stacked on top of each other—commonly referred to as “stacked” coins or “shingled” coins. Some of these coins, particularly thicker coins, will be under pad pressure and cannot move radially outward toward wall **136** under the centrifugal force. Stacked coins which are not against the wall **136** must be recirculated and stacked coins in contact against the wall **136** must be unstacked. To unstack the coins, the stacked coins encounter a stripping notch **144** whereby the upper coin of the stacked coins engages the stripping notch **144** and is channeled along the stripping notch **144** back to an area of the pad **118** disposed below the central opening **130** where the coins are then recirculated. The vertical dimension of the stripping notch **144** is slightly less the thickness of the thinnest coins so that only the upper coin is contacted and stripped. While the stripping notch **144** prohibits the further circumferential movement of the upper coin, the lower coin continues moving circumferentially across stripping notch **144** into the queuing channel **166**.

Stacked coins that may have bypassed the stripping notch **144** by entering the entry channel **132** downstream of the stripping notch **144** are unstacked after the coins enter the queuing channel **166** and are turned into an inner queuing wall **170** of the queuing channel **166**. The upper coin contacts the inner queuing wall **170** and is channeled along the inner queuing wall **170** while the lower coin is moved by the pad **118** across the inner queuing wall **170** into the region defined by surface **172** wherein the lower coin engages a wall **173** and is recirculated. Other coins that are not properly aligned along the inner queuing wall **170**, but that are not recirculated by wall **173**, are recirculated by recirculating channel **177**.

As the pad **118** continues to rotate, those coins that were initially aligned along the wall **136** (and the lower coins of stacked coins moving beneath the stripping notch **144**) move across the ramp **162** leading to the queuing channel **166** for aligning the innermost edge of each coin along the inner queuing wall **170**. In addition to the inner queuing wall **170**, the queuing channel **166** includes a first rail **174** and a second rail **178** that form the outer edges of stepped surfaces **182** and **186**, respectively. The stepped surfaces **182**, **186** are acutely angled with respect to the horizontal. The surfaces **182** and **186** are sized such that the width of surface **182** is less than that of the smallest (in terms of the diameter) coins and the width of surface **184** is less than that of the largest coin.

Referring for a moment to FIG. **3**, a small diameter coin (e.g., a dime or a 1¢ Euro coin) is shown pressed into pad **118** by the first rail **174** of the sorting head **112**. The rails **174**, **178** are dimensioned to be spaced away from the top of the pad **118** by a distance less than the thickness of the thinnest coin so that the coins are gripped between the rail **174**, **178** and the pad **118** as the coins move through the queuing channel **166**. The coins are actually slightly tilted with respect to the sorting head **112** such that their outermost edges are digging into the pad **118**. Consequently, due to this positive pressure on the outermost edges, the innermost edges of the coins tend to rise slightly away from the pad **118**.

Referring back to FIG. **2**, the coins are gripped between one of the two rails **174**, **178** and the pad **118** as the coins are rotated through the queuing channel **166**. The coins, which were initially aligned with the outer wall **136** of the entry channel **130** as the coins moved across the ramp **162** and into the queuing channel **166**, are rotated into engagement with inner queuing wall **170**. Because the queuing channel **166** applies a greater amount of pressure on the outside edges of the coins, the coin are less likely to bounce off the inner queuing wall **170** as the radial position of the coin is increased along the inner queuing wall **170**.

Referring to FIG. **4**a, the entry region **132** of the embodiment of the sorting head **112** shown in FIG. **2** includes two stepped surfaces **187**a, **187**b forming a rail **188** therebetween. According to an alternative embodiment of the sorting head **112**, the entry channel **132** consists of one surface **189** as shown in FIG. **4**b.

Referring now to FIG. **5**, there is shown an oversized view of the queuing channel **166** of FIG. **2**. It can be seen that the queuing channel **166** is generally "L-shaped." The L-shaped queuing channel **166** is considered in two segments—a first upstream segment **190** and a second downstream segment **192**. The upstream segment **190** receives the coins as the coins move across the ramp **162** and into the queuing channel **166**. The coins enter the downstream segment **192** as the coins turn a corner **194** of the L-shaped queuing channel **166**. As the pad **118** continues to rotate, the coins move along the second segment **192** and are still engaged on the inner queuing wall **170**. The coins move across a ramp **196** as the coins enter a discrimination region **202** and a reject region having a reject channel **212** for off-sorting invalid coins, which are both located towards the downstream end of the second segment **192**. The discrimination region includes a discrimination sensor **204** for discriminating between valid and invalid coins and/or identifying the denomination of coins.

The queuing channel **166** is designed such that a line tangent to the inner queuing wall **170** of the L-shaped queuing channel **166** at about the point where coins move past the ramp **196** into the discrimination region **202** (shown as point A in FIG. **5**) forms an angle alpha (α) with a line tangent to the inner queuing wall **170** at about the point where coins move over ramp **162** into the queuing channel **166** (shown as point B in FIG. **5**). According to one embodiment of the present invention, the angle alpha (α) is about 100°. According to alternative embodiments of the coin processing system **100**, the angle alpha (α) ranges between about 90° and about 110°.

As the pad **118** continues to rotates, the L-shape of the queuing channel **166** imparts spacing to the coins which are initially closely spaced, and perhaps abutting one another, as the coins move across the ramp **162** into the queuing channel **166**. As the coins move along the first upstream segment **190** of the queuing channel **166**, the coins are pushed against inner queuing wall **170** and travel along the inner queuing wall **170** in a direction that is transverse to (i.e., generally unparallel) the direction in which the pad **118** is rotating. This action aligns the coins against the inner queuing wall **170**. However, as the coins round the corner **194** into the second downstream segment **192** of the queuing channel **166**, the coins are turned in a direction wherein they are moving with the pad (i.e., in a direction more parallel to the direction of movement of the pad). A coin rounding the corner **194** is accelerated as the coin moves in a direction with the pad; thus, the coin is spaced from the next coin upstream. Put another way, the first segment **190** receives coins from the entry channel **132** and the second segment **192** is disposed in a position that is substantially more in direction of movement of said rotatable disc **114** for creating an increased spacing between adjacent coins. Accordingly, the coins moving through the second segment **192** are spaced apart. According to one embodiment of the present invention, the coins are spaced apart by a time of approximately five milliseconds when the sorting head **112** has an eleven inch diameter and the pad **118** rotates at a speed of approximately three hundred revolutions per minute (300 r.p.m.). According to an alternative embodiment, the coins are spaced apart by a distance of less than about two inches when the sorting head **112** has an eleven inch diameter and the pad **118** rotates at a speed of about 350 r.p.m.

Referring back to FIG. **2**, as the coins move into the discrimination region **202** of the second segment **194**, the coins move across ramp **196** and transition to a flat surface of the discrimination region **202** as the pad **118** continues to rotate. Put another way, the two stepped surfaces **182**, **186** of the queuing channel **166** transition into the flat surface of the discrimination region **202** towards the downstream end of the second segment **194**. The pad **118** holds each coin flat against the flat surface of the discrimination region **202** as the coins are moved past the discriminator sensor **204** in the downstream second segment **194**.

The sorting head **112** includes a cutout for the discrimination sensor **204**. The discrimination sensor **204** is disposed just below the flat surface of the discrimination region **202**. Likewise, a coin trigger sensor **206** is disposed just upstream of the discrimination sensor **204** for detecting the presence of a coin. Coins first move over the coin trigger sensor **206** (e.g., a photo detector or a metal proximity detector) which sends a signal to a controller indicating that a coin is approaching the coin discrimination sensor **204**.

According to one embodiment, the coin discrimination sensor **204** is adapted to discriminate between valid and invalid coins. As discussed in the Background Section, use of the term "valid coin" refers to coins of the type to be sorted. Use of the term "invalid coin" refers to items being circulated on the rotating disc that are not one of the coins to be sorted. Any truly counterfeit coins (i.e., a slug) are always considered "invalid." According to another alternative embodiment of the present invention, the coin discriminator sensor **204** is adapted to identify the denomination of the coins and discriminate between valid and invalid coins.

Coin discrimination sensors suitable for use with the disc-type coin sorter shown in FIGS. **1** and **2** are describe in detail in U.S. Pat. Nos. 5,630,494 and 5,743,373, both of which are entitled "Coin Discrimination Sensor And Coin Handling System" and are incorporated herein by reference in their entries. Another coin discrimination sensor suitable for use with the present invention is described in detail in copending U.S. patent application Ser. No. 10/095,256 (Attorney Docket No. 47171-00361USPT) entitled "Sensor And Method For Discriminating Coins Of Varied Composition, Thickness, And Diameter," filed on Mar. 11, 2002, which is incorporated herein by reference.

As discussed above according to one alternative embodiment of the present invention, the discrimination sensor **204** discriminates between valid and invalid coins. Downstream of the discrimination sensor **204** is a diverting pin **210** disposed adjacent inner queuing wall **170** that is movable to a diverting position (out of the page as viewed in FIG. **2**) and a home position (into the page as viewed in FIG. **2**). In the diverting position, the diverting pin **210** directs coins off of inner queuing wall **170** and into a reject channel **212**. The reject channel **212** includes a reject wall **214** that rejected coins abut against as they are off-sorted to the periphery of the sorting head **112**. Off-sorted coins are directed to a reject area (not shown). Coin that are not rejected (i.e., valid coins) eventually engage an outer wall **252** of a gauging channel **250** where coins are aligned on a common radius for entry into the coin exit station area as is described in greater detail below.

According to one embodiment of the present invention, the diverting pin **210** is coupled to a voice coil (not shown) for moving the diverting pin between the diverting position and the home position. Using a voice coil in this application is a nontraditional use for voice coils, which are commonplace in acoustical applications as well as in servo-type applications. Typically, a discrete amount of voltage is applied to the voice coil for moving the windings of the voice coil a discrete amount within the voice coil's stroke length—the greater the voltage, the greater the movement. However, the Applicants have discovered that the when the voice coil is "flooded" with a positive voltage, for example, the voice coil rapidly moves the diverting pin **210** coupled thereto to the diverting position (i.e., the end of the voice coil's stroke length) within a very short time period that is less than the time it takes for the coins to move from the discrimination sensor **204** to the diverter pin **210** when increased spacing is encountered due to the queuing channel. The voice coil is then flooded with a negative voltage for rapidly moving the diverting pin **210** windings back to its home position.

A voice coil suitable for use with the present invention is described in U.S. Pat. No. 5,345,206, entitled "Moving Coil Actuator Utilizing Flux-Focused Interleaved Magnetic Circuit," which is incorporated herein by references in its entirety. As an example, a voice coil manufactured by BEI, Technologies, Inc. of San Francisco, Calif., model number LA15-16-024A, can move an eighth-inch (⅛ in) stroke (e.g., from the home position to the diverting position) in approximately 1.3 milliseconds, which is a speed of about 0.1 inch per millisecond, and can provide approximately twenty pounds of force in either direction. Other voice coils are suitable for use with the coin sorting system of FIG. **2**.

Other types of actuation devices can be used in alternative embodiments of the present invention. For example, a linear solenoid or a rotary solenoid may be used to move a pin such as diverting pin **210** between a diverting position and a home position.

As the pad **118** continues to rotate, those coins not diverted into the reject channel **212** continue along inner queuing wall **170** to the gauging region **250**. The inner queuing wall **170** terminates just downstream of the reject channel **212**; thus, the coins no longer abut the inner queuing wall **170** at this point and the queuing channel **166** terminates. The radial position of the coins is maintained, because the coins remain under pad pressure, until the coins contact an outer wall **252** of the gauging region **252**. According to one embodiment of the present invention, the sorting head **112** includes a gauging block **254** which extends the outer wall **252** beyond the outer periphery of the sorting head **112**. The gauging block **254** is useful when processing larger diameter coins such as casino tokens, $1 coins, 50¢ pieces, etc. that extend beyond he outer periphery of the sorting head **112**. According to the embodiment of the sorting head **112** shown in FIG. **2**, the gauging channel **250** includes two stepped surfaces to form rails similar to that described above in connection with the queuing channel **166**. In alternative embodiments, the gauging channel **250** does not include two stepped surfaces.

The gauging wall **252** aligns the coins along a common radius as the coins approach a series of coin exit channels **261**-**268** which discharge coins of different denominations. The first exit channel **261** is dedicated to the smallest coin to be sorted (e.g., the dime in the U.S. coin set). Beyond the first exit channel **261**, the sorting head **112** shown in FIG. **2** forms seven more exit channels **261**-**268** which discharge coins of different denominations at different circumferential locations around the periphery of the sorting head **112**. Thus, the exit channels **261**-**268** are spaced circumferentially around the outer periphery of the sorting head **112** with the innermost edges of successive channels located progressively closer to the center of the sorting head **112** so that coins are discharged in the order of increasing diameter. The number of exit channels can vary according to alternative embodiments of the present invention.

The innermost edges of the exit channels **261**-**268** are positioned so that the inner edge of a coin of only one particular denomination can enter each channel **261**-**268**. The coins of all other denominations reaching a given exit channel extend inwardly beyond the innermost edge of that particular exit channel so that those coins cannot enter the channel and, therefore, continue on to the next exit channel under the circumferential movement imparted on them by the pad **118**. To maintain a constant radial position of the coins, the pad

118 continues to exert pressure on the coins as they move between successive exit channels **261-268**.

According to one embodiment of the sorting head **112**, each of the exit channels **261-268** includes a coin counting sensor **271-278** for counting the coins as coins pass though and are discharged from the coin exit channels **261-268**. In an embodiment of the coin processing system utilizing a discrimination sensor capable of determining the denomination of each of the coins, it is not necessary to use the coin counting sensors **271-278** because the discrimination sensor **204** provides a signal that allows the controller to determine the denomination of each of the coins. Through the use of the system controller (FIG. **6**), a count is maintained of the number of coins discharged by each exit channel **261-268**.

FIG. **6** illustrates a system controller **280** and its relationship to the other components in the coin processing system **100**. The operator communicates with the coin processing system **100** via an operator interface **282** for receiving information from an operator and displaying information to the operator about the functions and operation of the coin processing system **100**. The controller **280** monitors the angular position of the disc **114** via an encoder **284** which sends an encoder count to the controller **280** upon each incremental movement of the disc **114**. Based on input from the encoder **284**, the controller **280** determines the angular velocity at which the disc **114** is rotating as well as the change in angular velocity, that is the acceleration and deceleration, of the disc **114**. The encoder **284** allows the controller **280** to track the position of coins on the sorting head **112** after being sensed. According to one embodiment of the coin processing system **100**, the encoder has a resolution of 2000 pulses per revolution of the disc **114**.

Furthermore, the encoder **284** can be of a type commonly known as a dual channel encoder that utilizes two encoder sensors (not shown). The signals that are produced by the two encoder sensors and detected by the controller **280** are generally out of phase. The direction of movement of the disc **114** can be monitored by utilizing the dual channel encoder.

The controller **280** also controls the power supplied to the motor **116** which drives the rotatable disc **114**. When the motor **116** is a DC motor, the controller **280** can reverse the current to the motor **116** to cause the rotatable disc **114** to decelerate. Thus, the controller **270** can control the speed of the rotatable disc **114** without the need for a braking mechanism.

If a braking mechanism **280** is used, the controller **280** also controls the braking mechanism **286**. Because the amount of power applied is proportional to the braking force, the controller **280** has the ability to alter the deceleration of the disc **114** by varying the power applied to the braking mechanism **286**.

According to one embodiment of the coin processing **100**, the controller **280** also monitors the coin counting sensors **271-278** which are disposed in each of the coin exit channels **261-268** of the sorting head **112** (or just outside the periphery of the sorting head **112**). As coins move past one of these counting sensors **271-278**, the controller **280** receives a signal from the counting sensor **271-278** for the particular denomination of the passing coin and adds one to the counter for that particular denomination within the controller **280**. The controller **280** maintains a counter for each denomination of coin that is to be sorted. In this way, each denomination of coin being sorted by the coin processing system **100** has a count continuously tallied and updated by the controller **280**. The controller **280** is able to cause the rotatable disc **114** to quickly terminate rotation after a "n" number (i.e., a predetermined number) of coins have been discharged from an exit channel, but before the "n+1" coin has been discharged. For example, it may be necessary to stop the discharging of coins after a predetermined number of coins have been delivered to a coin receptacle, such as a coin bag, so that each bag contains a known amount of coins, or to prevent a coin receptacle from becoming overfilled. Alternatively, the controller **280** can cause the system to switch between bags in embodiments having more than one coin bag corresponding to each exit channel.

The controller **280** also monitors the output of coin discrimination sensor **204** and compares information received from the discrimination sensor **204** to master information stored in a memory **288** of the coin processing system **100** including information obtained from known genuine coins. If the received information does not favorably compare to master information stored in the memory **288**, the controller **280** sends a signal to the voice coil **290** causing the diverting pin **210** to move to the diverting position.

According to one embodiment of the coin processing system **100**, after a coin moves past the trigger sensor **206**, the coin discrimination sensor **204** begins sampling the coin. The discrimination sensor **204** begins sampling the coins within about 30 microseconds ("μs") of a coin clearing the trigger sensor **206**. The sampling ends after the coin clears a portion or all of the discrimination sensor **204**. A coin's signature, which consists of the samples of the coin obtained by the discrimination sensor **204**, is sent to the controller **280** after the coin clears the trigger sensor **206** or, alternatively, after the coin clears the discrimination sensor **204**. As an example, when the coin processing system **100** operates as a speed of 350 r.p.m. and the sorting head **112** has a diameter of eleven inches, it takes approximately 3900 μs for a 1¢ Euro coin (having a diameter of about 0.640 inch) to clear the trigger sensor **206**. A larger coin would take more time.

The controller **280** then compares the coin's signature to a library of "master" signatures obtained from known genuine coins stored in the memory **288**. The time required for the controller **280** to determine whether a coin is invalid is dependant on the number of master signatures stored in the memory **288** of the coin processing system **100**. According to one embodiment of the present invention, there are thirty-two master signatures stored in the memory **288**, while other embodiments may include any practical number of master signatures. Generally, regardless of the number of stored signatures, the controller **280** determines whether to reject a coin in less than 250 μs.

After determining that a coin is invalid, the controller **280** sends a signal to activate the voice coil **290** for moving the diverting pin **210** to the diverting position. As shown in FIG. **2**, the diverting pin **210** is located about 1.8 inches downstream from the trigger sensor **206** on the eleven inch sorting head. Assuming an operating speed of 350 r.p.m., for example, the controller **280** activates the voice coil **290** within about 7300 μs from the time that the coin crosses the trigger sensor **206**. As discussed above, the voice coil **290** is capable of moving the diverting pin **210** approximately an ⅛ inch in about 1300 μs.

Therefore, assuming an eleven inch sorting disk, an operational speed of 350 r.p.m. and a trigger sensor **206**, discrimination sensor **204** and a diverting pin **210** arrangement as shown in FIG. **2**, about 11000 μs (11 milliseconds) elapses from the time a coin crosses the trigger sensor **206** until the diverting pin **210** is lowered to the diverting position. Thus, the diverting pin **210** is located less than about two inches downstream of the trigger sensor **206**. Accordingly, the spacing between coins crossing the trigger sensor **206** is less than about two inches.

Once the diverting pin **210** is moved to the diverting position, the diverting pin **210** remains in the diverting position until a valid coin is encountered by the discrimination sensor **204** according to one embodiment of the present invention. This reduces wear and tear on the voice coil **190**. For example, the diverting pin **210** will only be moved to the diverting position one time when three invalid coins in a row are detected, for example, in applications involving a heavy mix of valid and invalid coins. If the fourth coin is determined to be a valid coin, the diverting pin **210** is moved to its home position. Further, according to some embodiments of the coin processing system **100**, the diverting pin **210** is moved to the home position if the trigger sensor **206** sensor does not detect a coin within about two seconds of the last coin that was detected by the trigger sensor **206**, which can occur when a batch of coins being processed in nearing the end of the batch. This reduces wear and tear on the pad **118**, which is rotating beneath the diverting pin **210**, because the diverting pin **210** and the rotating pad **118** are in contact when the diverting pin **210** is in the diverting position.

Because of the spacing imparted to the coins via the L-shaped queuing channel **166**, it is not necessary to slow or stop the machine to off-sort the invalid coins. Rather, the combination of the increased spacing and fast-activating voice coil **290** contribute to the ability of the coin sorter system illustrated in FIGS. **1** and **2** to be able to discriminate coins on the fly.

The superior performance of coin processing systems according to one embodiment of the present invention is illustrated by the following example. Prior art coin sorters, such as those discussed in the Background Section where is was necessary to stop and then jog the disc to remove an invalid coin, that utilized an eleven inch sorting disc were capable of sorting a retail mix of coins at a rate of about 3000 coins per minute when operating at a speed for about 250 r.p.m. (A common retail mix of coins is about 30% dimes, 28% pennies, 16% nickels, 15% quarters, 7% half-dollar coins, and 4% dollar coins.) The ability to further increase the operating speed of these prior art devices is limited by the need to be able to quickly stop the rotation of the disc before the invalid coin is discharged as is discussed in the Background Section. According to one embodiment of the coin processing system **100** of FIGS. **1** and **2**, the system **100** is cable of sorting a retail mix of coins at a rate of about 3300 coins per minute when the sorting head **112** has a diameter of eleven inches and the disc is rotated at about 300 r.p.m. According to another embodiment of the present invention, the coin processing system **100** is capable of sorting a "Euro financial mix" of coins at rate of about 3400 coins per minute, wherein the sorting head **112** has a diameter of eleven inches and the disc is rotated at about 350 r.p.m. (A common Euro financial mix of coins made up of about 41.1% 2 euro coins, about 16.7% 1 euro coins, about 14.3% 50¢ Euro coins, about 13.0% 20¢ Euro coins, about 11.0% 10¢ Euro coins, about 12.1% 5¢ coins and about 8.5% 1¢ Euro coins.)

In one embodiment of the coin processing system **100**, the coin discrimination sensor **210** determines the denomination of each of the coins as well as discriminates between valid and invalid coins, and does not include coin counting sensors **271-278**. In this embodiment, as coins move past one the discrimination sensor **204**, the controller **280** receives a signal from discrimination sensor **204**. When the received information favorably compares to the master information, a one is added to a counter for that particular determined denomination within the controller **280**. The controller **280** has a counter for each denomination of coin that is to be sorted. As each coin is moved passed the discrimination sensor **204**, the controller **280** is now aware of the location of the coin and is able to track the angular movement of that coin as the controller receives encoder counts from the encoder **284**. Therefore, referring back to the previous coin bag example, the controller **280** is able to determined at the precise moment at which to stop the rotating disc **114** such that the "nth" coin is discharged from a particular output channel **261-286**, but the "n+1" coin is not. For example, in an application requiring one thousand dimes per coin bag, the controller counts number of dimes sensed by the discrimination sensor **204** and the precise number of encoder counts at which it should halt the rotation of the disc **114**—when the 1000th dime is discharged from the coin exit channel, but not the 1001st dime.

Referring now to FIGS. **7**a and **7**b, an external diverter **300** for use with an alternative embodiment of coin processing system **100** is shown. A plurality of external diverters **300** are arranged circumferentially around the sorting head **112** such that an inlet **302** of each external diverter **300** is disposed adjacent to each exit channel **261-268** for receiving coins discharged therefrom. The external diverters are used for separating valid and invalid coins according to one alternative embodiment of the coin processing system **100** in place of the voice coil **290** and pin **210**. In another alternative embodiment, the diverter **300** works in connection with the voice coil **290** and pin **210** and functions to separate valid coins into two batches, rather than to separate invalid from valid coins.

The external diverter **300** includes an internal partition **304** that pivots about a base **306** between a first position **308**a and a second position **308**b wherein coins are directed down a first coin path **310**a and a second coin path **310**b, respectively. The internal partition **304** is coupled to a voice coil **310** for rapidly moving the internal partition **304** between the first and second positions **308**a, b. In an alternative embodiment, the external diverter **300** is constructed such that the internal partition **304** moves from side-to-side (not up and down) to route coins between the two coin paths **310**a, b.

According to one alternative embodiment of the coin processing system **100**, the external diverters **300** are used in place of the diverting pin **210** (FIG. **2**) for discriminating between valid and invalid coins. When an invalid coin is sensed by discrimination sensor **204** (FIG. **2**), the controller **280** (FIG. **6**) activates the voice coil **310** of the external diverters so that the invalid coin is directed down a second coin path **310**b. The controller **280**, with input from the encoder **284**, is able to track the angular position of the invalid coin around the sorting head **112** as the pad **118** rotates. For each exit channel **261-268** and each corresponding external diverter **300**, the controller **280** activates the voice coil **310** after a coin preceding the identified invalid coin has moved passed the exit channel **261-268**, but before the identified invalid coin has reached the exit channel **261-268**. For example, if the invalid coin has a diameter appropriate for the first exit channel **261**, the invalid coin will be discharged from the first exit channel **261** into the second coin path **310**b of the external diverter **300**. The controller **280** sends a signal to the voice coil **310** to return internal partition **304** of the external diverter to the first position **308**a before the coin immediately following the invalid coin reaches the first exit channel. The controller **280** repeats this sequence for each external diverter disposed around the sorting head. According to another alternative embodiment of the coin processing system **100**, the controller is able to determine the diameter of each of the invalid coins using one or more sensors in the discrimination region **202** including the discrimination sensor **204**; therefore, the controller **204** only activates the external diverter **300** of the exit channel **261-268** that is appropriate for the determined diameter of the invalid coin.

According to one alternative embodiment of the coin processing system **100**, the external diverters **300** are used in connection with the sorting head of FIG. **2** which includes the diverting pin **210** (FIG. **2**). The diverting pin **210** is used to off-sort invalid coins as described in connection with FIG. **2**. The external diverters are used to separate the valid coins into two different batches. For example, in some applications the coin processing system **100** uses dual bag holders for each denomination and a predetermined number of coins discharged to each coin bag. The controller **280** maintains of a count of the coins discharged from each output receptacle and activates the external diverter **300** for routing coins to a second bag before the next coin is discharged from the corresponding exit channel **261-286**. Again, because the controller **280** is tracking the angular movement of the disc **114** via the encoder **284**, the controller **280** knows the precise moment that an identified valid coin is going to reach and be discharged from an exit channel.

Again, the generally L-shaped queuing channel **166** imparts a spacing to the coins allowing the coin processing system **100** to utilize the external diverters **300**, which are rapidly actuated by the voice coils, on the fly. Accordingly, it is not necessary to slow or stop the rotating disc **144** when off-sorting invalid coins or routing coins down an alternate coin path.

Referring now to FIG. **8**, a programmable sorting head **350** is shown for use in an alternative embodiment of the coin processing system **100** of FIG. **1**. Very generally, the exit channels **351-360** of the programmable sorting head **350** are substantially the same size so that coins of any denomination can be discharged out of any exit channel **351-360**. Thus, the programmable sorting head **350** does not sort coins on the basis of diameter size; rather, coins are discriminated on the basis of information obtained from a discrimination sensor and are selectively distributed from the sorting head **350**. Each of the exit channels **351-360** function similar to that of the reject channel **212** of FIG. **2**. A diverting pin **362** is disposed adjacent each exit channel **351-360** and moves downward (out of the page in FIG. **8**) to a diverting position for ejecting coins off of an inner queuing wall **364** into the corresponding exit channel **351-360**.

The programmable sorting head **350** operates in a manner similar to the sorting head **112** described in connection with FIG. **2**. Coins that are deposited on the rotating pad **118** via a central opening **366** in the programmable sorting head **350** initially enter an entry channel **368**. As the pad **118** continues to rotate, coins are moved past a stripping notch for stripping stacked coins and then across a ramp, for increasing the pad pressure, into a queuing channel **374** having an inner queuing wall **364**. In the embodiment of the programmable sorting head **350** depicted in FIG. **8**, the queuing channel **374** includes three stepped surfaces and three rails (as opposed to two stepped surfaces and two rails for the sorting head **112** in FIG. **2**). Alternatively, the queuing channel **374** consists of one surface.

The queuing channel **374** of the programmable sorting head **350** is L-shaped for imparting a spacing to the coins as the coins are moved past the corner **376** of the L-shaped queuing channel **374**. The L-shaped queuing channel **374** of FIG. **8** imparts spacing to adjacent coins in the same manner as does the L-shaped queuing channel **166** described in connection with FIG. **2**. Coins turning the corner **376** of the queuing channel **374** are accelerated and spaced-apart and engage the inner queuing channel wall **364**. As the pad **118** continues to rotate, the coins aligned along wall **364** are move across a ramp **378** which transitions the coins to a flat surface for moving the coins past a coin trigger sensor **380** and a coin discrimination sensor **382**.

The coin discrimination sensor **382** is adapted to discriminate between valid and invalid coins and to determine the denomination of each of the coins passing under the sensor **382**. The function of the trigger sensor **380** and the discrimination sensor **382** is similar to that described in connection with FIG. **2**. By processing input from the sensors **380**, **382** and the encoder **284**, the controller **280** tracks the angular position of each coin and is able to calculate the precise time to active a voice coil coupled to a pin **362** disposed adjacent to an exit channel **362**. For example, if the coin discrimination sensor **382** determines that a coin is a dime and the coin sorting system is operating pursuant to a mode wherein dimes are to be off-sorted at the first exit channel **351**, the pin **362** is lowered to the diverting position after the coin preceding the dime is moved past the first exit channel **351**, but before the dime reaches the first exit channel. As the pad continues to rotates, the dime contacts the pin **362** and is knocked off the inner wall **365** into the first exit channel **351**. The controller **280** raises the pin **362** before the next coin reaches the first exit channel **351**. Put another way, the time to retract the pin **362** is less tan the time for the next coin to pass the pin **362** due to the increased spacing imparted to the coins by the L-shaped queuing channel **374**.

In various alternative embodiments of the coin processing system **100** utilizing the programmable sorting head **350** ("the programmable processing system"), the programmable processing system operates pursuant to many predefined modes of operation and user-defined modes of operation. For example, the first exit channel **351** can operate as a reject chute for off-sorting invalid coins. In another embodiment, none of the exit channels **351-360** serve as reject chutes; rather, invalid coins are moved along wall **364** around the sorting head **350** and follow wall **364** off the sorting head at a point "C" where the coins are discharged to another off-sort area. In another application such as in the processing of coins obtained from vending machines, the first three exit channel **351-353** are used to sort nickels, dimes and quarters, respectively, until a predetermined number of coins of a denomination are delivered to the respective exit channel **351-353**. Then the controller causes nickels, dimes and quarters to be off-sorted at the fourth, fifth and sixth exit channels **354-356**, respectively, and so on. Accordingly, after a predetermined number of nickels have been discharged by the first exit channel **351**, nickels are then off-sorted at the fourth exit channel **354**, and then the by the seventh exit channel **357**. No more than the predetermined number of coins are discharged from the exit channels **351-359** and the subsequent exit channel assigned to nickels, for example, is not utilized until the previous exit channel assigned to nickels has discharged a predetermined number of coins.

In another embodiment of the present invention, the programmable coin processing system operates pursuant to a mode of operation wherein the first ten coin denominations detected by the coin discrimination sensor **382** are the coin denominations assigned to the ten exit channels **351-360**, respectively, and all other coins are off-sorted by following wall **364** off the sorting head **350** at point "C." As is readily apparent, the programmable sorting system can be utilized in pursuant to a myriad of modes of operation in alternative embodiments of the system.

In another embodiment of the present invention, the programmable coin processing system is utilized to separate coins from a plurality of coin sets—British pound coins, French Franc coins, German Deutschmark coins, U.S. coins, Italian Lira coins, Canadian coins and Euro coins, for example. The programmable coin processing system causes coins of each coin set to be distributed to one of the ten exit channels **351-360**, while off-sorting other "invalid" coins. The programmable coins sorter can be linked to an external network which provides currency exchange rates so that the system can calculate the real-time value of all the coins processed from the different coin sets from different countries.

In FIG. **9**, an alternative embodiment of a sorting head **400** is shown for use with the coin processing system **100** of the present invention. While it will be recognized that the sorting head **400** is similar to the sorting head **112** shown in FIG. **2**, the alternative embodiment to be discussed in connection with FIG. **9** is also applicable to a programmable coin sorting system such as that described in connection with FIG. **8**.

The sorting head **400** is similar to that of FIG. **2** in that it is designed to impart spacing to adjacent coins; however, the queuing channel **402** is designed to move coins so that the outside edge of each of the coins extends beyond an outer periphery **404** of the sorting head **400** as the coins move past an optical sensor **406** for discriminating the coins. According to one embodiment, the optical sensor **406** is adapted to discriminate between valid and invalid coins. In another alternative embodiment, the optical sensor **406** is adapted to discriminate between valid and invalid coins and to identify the denomination of coins. The optical sensor **406** can comprise a photodetector, a charge-coupled device (CCD) detector, a metal oxide semiconductor (MOS) array, a line array, a camera, a scanning laser or other type of optical sensor according to various alternative embodiments.

The radial position of the queuing channel **402** is moved outward a distance such that the diameter of the smallest coin to be processed (e.g., the dime in the U.S. coin set) is moved beyond the outer periphery **404** of the sorting head **400** to obtain optical information from the coin. According to one embodiment, the coins must extend beyond the outer periphery **404** of the sorting head **400** at least about 0.010 inch (approximately 0.25 mm) for obtaining the optical information from the coin. A controller of the coin processing system **100** then processes the optical information obtained from each coin by the optical sensor **404**. As the pad continues to rotate, the coin is brought back within the outer periphery **404** of the sorting head **400** as the coin moves past a diverting pin **408** and reject channel **410** similar to that described in connection with FIG. **2**. Invalid coins are rejected via the reject channel **410** while valid coins are moved into engagement with an outer wall **412** of a gauging channel **414** for aligning the coins along a common radius as the coins approach the exit channels **416**a-h.

Turning now to FIG. **10**, a programmable power rail coin processing system **500** ("rail system **500**") is shown according to an alternative embodiment of the present invention. The rail system **500** includes a guide plate **502** similar to the sorting head **350** shown and described in connection with FIG. **8**. The guide plate **502** functions in substantially the same manner as the sorting head **350** in FIG. **8** by aligning coins, that are moved by a rotating disc, along an inner queuing channel wall **504** of a queuing channel **506**; however, the guide plate **502** does not sort the coins. Rather, the coins are sorted along a rail **510** as is described in greater detail below.

It should be noted that the while underside of the guide plate **502** is shown in FIG. **10**, the surface of the guide plate **502** shown in FIG. **10** faces downward while the rail **510** would face upward as shown in actual operation of the rail sorter **500**. As with the sorting head in FIGS. **2** and **8**, the queuing channel **506** of the guide plate **502** is generally L-shaped for imparting a spacing between adjacent coins. As the rotatable disc (similar to disc **114** of FIG. **1**) continues to rotate, the coins are moved over a ramp **512** on to a flat surface **514** and along a wall **504**. The guide plate **502** does not include any exit channels. Further, the guide plate **502** does not include a coin discrimination sensor as it can be disposed on the rail **510**. Rather, the coins continue along the inner queuing wall **504** and are moved onto the rail **510** and into engagement with a wall **520** of the rail **510** while the underside of each coin contacts a flat surface **521** of the rail **510**.

Referring also to FIG. **11**, an endless belt **522** that is looped around two pulleys **524**, **526** is disposed along the longitudinal axis of the rail **510** and is disposed above the rail **510** a distance less than the thickness of the thinnest coin. (Note that the endless belt **522** is depicted with a dashed-line in FIG. **10**.) The first pulley **524** rotates around a shaft **528** and the second pulley is driven by a motor **530** via another shaft **532**. The belt **522**, which is made out of a resilient material such as rubber, grips the coins as the upper surfaces of the coins come into contact with the belt **522** as the coins move from the guide plate **502** along the queuing wall **504** to the rail **510** and into engagement with the wall **520**. The belt **522**, which is in pressed engagement with the coins, moves the coins along the rail **510** while an underside of each coin slides along the flat surface **521** of the rail **510**. The transition between the guide plate **502** and the rail **510** should appear substantially seamless to the coins so as not to decrease the spacing between the coins. The endless belt **522** moves at a speed sufficient to maintain the spacing between adjacent coins as the coins move onto the rail **510** and come under control of the belt **522**. According to an alternative embodiment of the rail sorter **500**, the belt **522** moves at a speed sufficient to increase the spacing between adjacent coins and no L-shaped queuing channel would be needed to increase spacing between adjacent coins in such an embodiment.

As the belt **522** continues to rotate, coins are moved past a coin discrimination sensor **540** for discriminating between invalid and valid coins and for determining the denomination of the coins. A plurality of coin exit channels **551-555** are disposed in the rail **520** downstream of the coin discrimination sensor **540**. While five exit channels **551-555** are shown in the embodiment of the rail system **500** shown in FIG. **10**, the length of the rail **510** and the endless belt **522** can be extended (or reduced) to accommodate any reasonable number of exit channels. Also included along the rail **510** are a plurality of diverting pins **560** disposed adjacent each coin exit channel **551-526** for obstructing a coin moving along the wall **520** and forcing the coin into the corresponding exit channel. The diverting pins **560** each move from a home position, wherein the pins disposed slightly below the surface **521** of the rail, to a diverting position extending beyond the surface **521** of the rail **510** for engagement with coins. Each of the diverting pins **560** are moved from the home position to the diverting position and back to the home position by a voice coil, which provides the advantage of rapid actuation.

An encoder (not shown) is coupled to one of the two pulleys **524**, **526** and is interface with a controller of the rail system **500** for tracking the linear movement of the coins along the rail **510**. As discussed above in connection with FIG. **8**, the controller of the rail system **500** is interfaced with the coin discrimination sensor **540**, the diverter pins **560** and the encoder for selectively diverting coins into the plurality of exit channel **551-555**. Coins that are not selectively diverted into one of the plurality of exit channels **551-555** are moved off a downstream end **562** and fall into an invalid coin chute **564** (FIG. **12**). Alternatively, invalid coins are off-sorted via one of the coin exit channels **551-555**.

Similar to the sorting head depicted in FIG. **8**, the rail system **500** is programmable. Each exit channel **551-555** is sized to accommodate coins of most any diameter. Accordingly, the rail sorter can be programmed to selectively discharge coins of any denomination out of any of the exit channels **551-555**. For example, in one application, U.S. coins are sorted in order of increasing value—pennies, nickels, dimes, quarters, half dollar coins and dollar coins—rather than in order of increasing diameter.

Referring also to FIG. **12**, the rail system **500** is disposed within a cabinet **570** for housing the rail sorter **500**. (Note that the endless belt **522** and pulleys **524**, **526** are not shown FIG. **12**.) A plurality of coin tubes **571-575** are disposed along the rail **510** adjacent the exit channels **551-555** for receiving coins discharged from each of the exit channels **551-555** and routing the coins to coin receptacles such as coin bags **580** contained within the cabinet **570**. A sixth coin tube **576** routs coins from the invalid coin chute **564** to a coin receptacle disposed with the cabinet **570**.

The rail system **500** provides the advantage of presenting the coin bags **580** in a substantially liner fashion. Put another way, the exit channels **551-555** output coins in the same direction which facilities a substantially linear bag presentation. Therefore, an operator of the rail system **500** can easily access the coins bags **580** from the same side of the cabinet. In alternative embodiment of the rail sorter **500**, dual coin bag holders for holding two coins bags can be attached to the end of each coin tube. Dual bag holders allow the rail system **500** to route coins of a single denomination to two different bags; thus, once a predetermined number of coins have been routed to a first bag the coins of that denomination are routed to a second bag.

In an alternative embodiment of the rail system **500**, the guide plate **502** includes a discrimination region having a discrimination sensor and a reject channel as does the sorting head **112** of FIG. **2**. Accordingly, the discrimination sensor on the guide plate **502** discriminates between valid and invalid coins and/or determines the denomination of the coins and invalid coins are off-sorted via the reject channel. Thus, no discrimination sensor is needed on the rail in such an embodiment.

In yet another alternative embodiment of the rail system, the rail and guide plate are formed from the same piece of material such that they are integral components. The rotating pad and endless belt are disposed on the same side of the integral rail and pad—either the top-side or the bottom-side. Alternatively still, a large rotating pad can impart movement to the coins along the integral guide plate and pad.

Turning to FIG. **13**, a sorting head **600** having a single exit station **602** is shown for use in an alternative embodiment of the coin processing system **100**. The sorting head **600** operates in a similar manner as does the sorting heads described previously up until the point where the coins enter a queuing region **604** of the sorting head **600**. In the queuing channel **604**, the coins are aligned against an inner queuing wall **606**, which extends around a substantial portion of the sorting head **600**. At the downstream end, the queuing channel **604** includes a substantially "dog-leg-shaped" portion **610**, which includes an first upstream segment **612** and a second downstream segment **614**.

Similar to the generally L-shaped queuing regions described above in connection with FIGS. **2** and **8**, the dog-leg-shaped portion **610** imparts a spacing to adjacent coins moving from the first segment **612** to the second downstream segment **614**. As a pad (such as pad **118** of FIG. **1**) rotates, the coins are pushed against inner wall **606** and travel along the inner wall **606** in a direction that is transverse to the direction in which the pad is rotating. This action aligns the coin against the wall **606**. As the coins move from the first upstream segment **612** to the second downstream segment **614** of the queuing channel **166**, the coins are turned in a direction wherein they are moving with the pad, which imparts spacing between adjacent coins.

As the pad continues to rotate, the coins are moved past a discrimination sensor **620** disposed along the queuing channel **604** for discriminating between valid and invalid coins and/or identifying the denomination of coins. The coins continue along the inner queuing channel wall **606** until the pad rotation causes the coins to be discharged from the single exit station **602**. Note that that all coins entering the coin processing system described in connection with FIG. **13** thus far are discharged out of the single output channel **602**.

An external diverter **300** actuated by a voice coil **310**, such as described in connection with FIGS. **7**a, b, receives coins discharged from the single output receptacle **602**. A controller (not shown) monitors the output of the discrimination sensor **620** for selectively moving the internal partition **304** (FIGS. **7**a, b) between the first and second positions **308**a, b for routing coins to the first and second coins paths **310**a, b. Alternatively, the external diverter is actuated by a solenoid.

The coin processing system described in connection with FIG. **13** can be used in applications wherein it is desirable to separate coins into two batches. For example, it may be desired to process U.S. dimes into batches of 1000 dimes each. In another application, it may be desired to separate valid coins from invalid coins. In another application, it may be desired to separate a mixed batch of coins such as a mix of U.S. coins and Euro coins into their respective coin sets. According to an alternative embodiment of the coin processing system described in connection with FIG. **13**, the sorting head **600** includes a diverting pin and reject channel for off-sorting invalid coins prior to discharging valid coins from the single exit station **602**. Such an embodiment can be used in an application wherein it is desired to separate Euro coins from U.S. coins, but to also remove invalid coins (e.g., coins from other coin sets and/or counterfeit coins).

Turning now to FIGS. **14**a, **14**b, and **14**c, an optical coin discrimination senor **700** will be described. FIG. **14**a shows the underside of a sorting head **702**, which processes coins similar to that displayed in FIG. **2**. The optical coin discrimination sensor **700** and sorting head **702** may be used with the disc-type coin processing system **100** of FIG. **1** according to one embodiment of the present invention. Coins are processed with the sorting head **702** similar to that described in the FIG. **2**. As coins are aligned along the inner queuing wall **770** and moved along the queuing channel **766**, the coins are moved toward the optical coin discrimination sensor **700** as the pad **118** (FIG. **1**) continues to rotate. Exemplary coins are shown in dashed lines on the sorting head **702**. As the coins are moved past the discrimination sensor **700**, the discrimination sensor **700** is used to discriminate valid coins from invalid coins.

As the pad **118** continues to rotate, the coins are moved from the discrimination sensor **700** past the diverting pin **710** and the reject channel **714**. The diverting pin **710** moves from a home position to a diverting position for diverting coins from the queuing wall **770** into the reject channel **714**, as described above, in response to a coin being determined to be an invalid coin. Those coins not diverted from the queuing wall **770**—wherein the diverting pin **710** is maintained in the home position—continue along the queuing wall **770** and eventually past the plurality of exit channels **761-766** as discussed above in connection with FIG. **2**. In the sorting of coins from the U.S. coin set, for example, dimes are discharged from the first exit channel **761**, pennies are discharged from the second exit channel **762**, nickels are discharged from the third exit channel **763**, half-dollar coins are discharged from the fourth exit channel **764**, and dollar coins are discharged from the fifth exit channel **765**. The sorting head **702** may include more or less than six exit channels in alternative embodiments of the present invention depending on the particular application and the desired number of coins to be sorted. In other embodiments, the exit channels **761-766** of the sorting head **702** may be similarly sized and used in connection with a plurality of diverters similar to that discussed in connection with FIG. **8**, permitting the sorting head **702** to be used as a programmable sorting head.

The optical coin discrimination sensor includes a light source **802**, a first light guide **804**, a second light guide **806**, and a light detector **808**. Generally, the first and second light guides **802**, **804** receive light from the light source **802** and guide the received light to the light detector **808**. As a coin moves along the queuing channel **760** and past the first light guide **804**, the opaque nature of the coins (shown in dashed lines in FIG. **14**b) prevents the first light guide **804** from receiving the light emitted by the light source **802**. As discussed below, the blocking of the first light guide **804** causes an interruption in the light beam, which prevents light from the light source **802** from illuminating the light detector **808**, is used to discriminate that coin.

According to one embodiment of the present invention, the first light guide **804** is constructed of sapphire and is about 0.010 inch wide and about 0.150 inch deep. The first light guide may be constructed of another substantially optically clear material such as plastic or acrylic, for example, in alternative embodiments of the present invention. While only the bottom portion (as viewed in FIG. **14**c) of the first light guide **804** is used in receiving light and directing the received light to the second light guide **406**, the first light guide **804** has a length corresponding to the thickness of the sorting head **702** to facilitate the handling and placement of the first light guide **804** within the sorting head **702**.

The second light guide **806** is constructed of a substantially optically clear material such as plastic, acrylic, sapphire, etc. according to alternative embodiments of the present invention. The second light guide has an angled back surface **812** for directing light received from the first light guide **804** toward the light detector **808** as illustrated in FIG. **14**c. According to one embodiment of the present invention, the angled surface **812** is disposed at an about 45° angle relative to the horizontal. In alternative embodiments of the present invention, the first and second light guides **804**, **806** may be integral components such that they are constructed from the same piece of material.

The light path is shown in FIG. **14**c by a plurality of arrows. The path is generally horizontal from the light source **802** across the bottom surface of the sorting head **702** and through the first light guide **804** and into the second light guide **806**. Within the second light guide **806**, the light continues along a horizontal path (as viewed in FIG. **14**c) until contacting the angled surface **812** of the second light guide **806** at which point the light is upwardly directed by the angled surface **812** at an about 90° angle. The light continues in the upward direction through the second light guide **806**, which directs the light onto the light detector **808**. According to the illustrated embodiment, the detector **808** is disposed proximate to the output end of the second light guide **806**. In an alternative embodiment of the present invention, an optical fiber may be used to pipe light from the output end of the second light guide **806** to a detector disposed in a different location. The second light guide **806** has a cross section that is about 0.125 inch by 0.125 inch and has a length corresponding to the thickness of the sorting head **702** according to one embodiment of the present invention.

According to one embodiment of the present invention, the light source comprises a laser diode. The inventors have found a laser diode module commercially available from Optima Precision Inc. of West Linn, Oreg., Part No. DLM 2103-636, to be suitable for use in one embodiment of the present invention. This laser diode outputs light having a wavelength of about 623 nm. Other types of light sources may be used in alternative embodiments of the present invention such as, for example, semiconductive lamps, incandescent lamps, gas arc lamps, fluorescent lamps, or electrochemical lamps.

An aperture **810** in the sorting head **702** adjacent the first light guide **804** directs forced air from a nozzle (not shown) across the face of the first light guide **804** for removing debris that has accumulated during the processing of coins (e.g., dust, coin dust, oil, etc.) from the coin-contacting face of the first light guide **804**. Additionally, the contact of the coins against the face of the first light guide **804** also removes, or at least loosens, any debris.

Referring also to FIG. **14**d, a control system, including a controller **850**, for the coin processing system **100** using the sorting head **702** and optical coin discrimination sensor **700** is shown according to one embodiment of the present invention. The controller **850** controls the coin processing system **100** similar to that discussed above in connection with FIG. **6**. The controller **850** of coin processing system **100** employing the optical coin discrimination sensor **700** controls the motor **116** and is optionally coupled to coin counting sensors **271-278** disposed in each of the coin exit channels **271-766** (not shown in FIG. **14**a) and an optional braking mechanism **286**. Further, the controller **850** is coupled to a memory **288** and an operator interface **282** for receiving information from and displaying information to a user of the coin processing system **100**.

The controller **850** is also coupled to the encoder **284**, the light detector **808**, and the light source **802**. The controller activates the light source **802** when activating the motor **116** for processing the coins according to one embodiment of the present invention. The light detector **808** generates a light-detection signal indicative of receiving the light beam output by the light source **802**. The controller **850** receives the light-detection signal from the light detector **808**. A plurality of different types of optical light detectors can be used in alternative embodiments of the present including photodetectors, CCD arrays, etc. According to one embodiment of the present invention, the light detector is a phototransistor commercially available from Optek Technology, Inc. of Carrollton, Tex. (Part No. OP805SL).

In the operation of the coin processing system **100**, the controller's **850** receipt of the light-detection signal from the detector **808** informs the controller **850** that the first light guide **804** is not being covered by a passing coin. When a coin to be discriminated is moved passed the first light guide **804**, the coin covers the first light guide and, thus, prevents light from the light source **802** from illuminating the light detector **808** during which the detector **808** does not output a light-detection signal indicating the detector **808** is detecting light.

According to one embodiment of the present invention, the light detector **808** outputs a voltage corresponding to the level of received light. If the signal drops blow a predetermined threshold voltage, the controller **850** determines that the light detector **808** is blocked by a passing coin. When the signal rises above the predetermined threshold, the controller **850** determines that the light detector **808** is not being blocked by a passing coin. A voltage comparator (not shown) electrically disposed between the light detector **808** and the controller **850** can be used to compare the signal generated by the light detector **808** to the predetermined threshold.

In another embodiment of the present invention, the detector **808** outputs an analog light-detection signal that is digitized by an analog-to-digital converter prior to being sent to the controller **850**. The controller **850** samples this digitized signal at a rate on the order of tens of thousands of times per second depending on the resolution of the encoder **284** and the rotational speed of the disc **114**. The sampled digitized signal is then compared by the controller **850** to a predetermined threshold value to determine whether a coin is blocking the light detector.

During the operation of the coin processing system **100**, the controller **850** is also receiving pulses (e.g., encoder counts) from the encoder **284**. As discussed above, each pulse from the encoder represents an incremental movement of the disc **114** (FIG. **1**) that is rotating beneath the sorting head **702**. According to one embodiment of the present invention, the encoder **284** has a resolution of about 20,000 pulses per revolution of the disk **114**. In the illustrated embodiment of the sorting head **702** (FIG. **14**a), the sorting head **702** has a diameter of about 11 inches and the input end of the first light guide **804** that receives light form the light source **802** is disposed about 4.44 inches from the center of the sorting head **702**. This translates to each coin moving a distance of about 0.0014 inch past the first light guide **804** for each encoder pulse given the above-discussed specifications accordingly to one embodiment of the present invention.

Using the number of encoder pulses during which the controller **850** is not receiving the light-detection signal from the detector **808**, the controller **850** determines the diameter of each passing coin, which can be used to discriminate the denomination of the coin. For example, in the U.S. coin set, each of the coins—pennies, nickels, dimes, quarters, half-dollar coins, and dollar coins—have a different diameter. Because the encoder has a high resolution according to one embodiment of the present invention, the controller **850** is capable of distinguishing between different denominations of coins that have a difference in diameter of at least about 0.0014 inch.

According to one embodiment of the present invention, the memory **288** of the coin processing system **100** has stored therein a master denominating characteristic information that includes the number of encoder pulses and the corresponding coin denominations that the system **100** is designed to process. The number of encoder pulses for each coin denomination corresponding to the size (e.g., the diameter) of each coin. This information maybe stored in the form of a look-up table (LUT). The master denominating information may also include an acceptable range of encoder counts, depending on the desired sensitivity, within which each coin denomination to be processed falls. During the processing of coins, the controller **850** compares the counted number of encoder pulses during which a light-detection signal from the light detector **808** is not received by the controller **850** and, then, compares that number to the stored numbers in the look up table to determine the denomination of each coin. If the counted number of encoder pulses does not favorably compare to a number, or a range of numbers, in the stored look up table, the coin is considered an invalid coin, and the controller **850** rejects the coin as described above.

Turning to FIG. **15**, a method for discriminating coins with the optical coin discrimination sensor **700** will be described according to one embodiment of the present invention. Initially, bulk coins are loaded into the coin processing system **100** and the coins are aligned within the queuing channel **770** of the sorting head **702** as described in connection with FIGS. **14**a and **2**. The L-shaped queuing channel **170** provides spacing between adjacent coins as described in connection with FIG. **2**. As the disk **114** continues to rotate, each coin to be processed is moved along the queuing channel **770** past the light detection optics (e.g., the first light guide **804**) at step **902**.

At step **904**, the light source **802** illuminates the light detection optics, which includes the first and second light guides **804**, **806** and the light detector **808** according to one embodiment of the present invention. In other embodiments, a light detector may directly receive light emitted by a light source. In yet other alternative embodiments, one or a plurality of light directing members (e.g., light guides, optical fibers, etc.) may direct light to a light detector. The light detector **804** outputs, to the controller **850**, a light-detection signal indicating that it is detecting light emitted by the light source **802** at step **906**. To ensure the light detector is not receiving light from some other source (e.g., ambient light), the light detector may only detect light having a wavelength within a specific range, wherein the light source outputs light within that wavelength range, according to one embodiment of the present invention.

The controller **850** monitors the detector **804** for the light-detection signal at step **906**. If there is no interruption in the light-detection signal (output by the detector **808**) received by the controller **850** at step **910**, the controller **850** continues to monitor the light-detection signal output by the detector **808** for an interruption in that signal at step **908**. If, at step **910**, an interruption in the light-detection signal output by the detector **880** is detected by the controller **850**, the controller **850** determines the number of encoder pulses received from the encoder **284** (FIG. **14**d) by the controller **850** during the period that the light-detection signal is interrupted at step **912**. The determined number of encoder pulses is then compared to the stored master denominating characteristic information at step **915**. If the determined number of encoder counts favorably compares with the stored information, the controller **850** determines the coin's denomination, and the coin is determined to be a valid coin at step **916**. If the determined number of encoder counts does not favorably compare to the stored information, the controller **850** rejects the coins as an invalid coin at **918**. The discrimination process is repeated for each coin.

According to one embodiment of the present invention, the controller **850** maintains a running count of the denominations of the accepted coins that are transported to and discharged by the coin exit channels **761-766** of the sorting head **702**. In other embodiments, the optional coin counting sensors **271-278** (FIG. **14**d) each maintain a count of coins discharged by the associated coin exit channel **761-766**.

In an alternative embodiment of the present invention, the time period in which a light-detection signal is not received by the controller **850** from the detector **808** is used to discriminate the coins (rather than the number of encoder counts counted when the light-detection signal is not received). Put another way, the diameter of each coin is measured in time rather than encoder counts. The determined time period is then compared to master-denomination characteristic information stored in the memory **288**, which include time periods obtained using known authentic coins. In such an embodiment, the rotational speed of the disc **114** at the time the master-denomination characteristic information is obtained should be substantially the same as that during the discriminating of coins.

Referring back to FIG. **9**, an alternative embodiment of the optical coin discrimination senor will be described. As discussed in connection with FIG. **9**, the queuing channel **404** is configured to move a portion of each coin beyond the outer periphery **404** of the sorting head **400**. The optical sensor **406** serves as a light detector described above for detecting the presence of a light beam from a light source (not shown in FIG. **9**). The light beam extends perpendicular to the page as viewed in FIG. **4** and is perpendicular to the surface of the coins being processed on the sorting head **400**. When the coin is moved beyond the outer periphery **404** of the sorting head **400**, the coin (shown in dashed lines) breaks the light beam extending between the optical sensor **406** and the light source. The controller **850** (FIG. **14**d) tracks encoder pulses or time, as discussed above, during which the light-detection signal is not received from the optical sensor **406**. The number of encoder pulses or time determined is then compared, by the controller **850**, to the master-denominating information stored in memory for determining the coin's denomination similar to that discussed above. According to one embodiment of the present invention, because only a portion of each coin (e.g., less than half) extends beyond the outer periphery **404** of the sorting head **400**, it is a chord of the coin being evaluated that is measured in terms of encoder counts or time. In other embodiments of the present invention where more than half of each coin extends beyond the outer periphery **404**, the diameter of each coin can be measured in terms of encoder pulses or time.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and described in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A coin processing system, comprising:

a continuously rotatable disc for imparting motion to a plurality of coins of mixed denominations, wherein a rate of rotation is adjustable;

an encoder attached to the rotatable disc for producing an encoder pulse for each incremental movement of the rotatable disc;

a memory adapted to store master denominating characteristic information including a plurality of predetermined numbers of encoder pulses, each predetermined number of encoder pulses corresponding to the size of a particular coin denomination the coin processing system is adapted to process;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a coin path for directing the movement of each of the coins and a coin exit region for sorting and discharging coins of particular denominations;

a light source for outputting a light beam along a first axis that traverses the coin path in substantially the same plane as the coin path;

a light detector for receiving the light beam along a second axis substantially perpendicular to the first axis, the light detector being adapted to generate a light-detection signal indicative of detecting the light beam, each coin moving along the coin path passing through the light beam resulting in the suspension of the generation of the light-detection signal; and

a controller adapted to receive the encoder pulses from the encoder, the controller adapted to receive the light-detection signal from the light detector, the controller being adapted to determine the number of encoder pulses received during a period of non-receipt of the light-detection signal caused by each coin passing through the light beam, the controller being adapted to compare the determined number of encoder counts to the stored master denominating characteristic information upon resuming to receive the light-detection signal from the light detector.

2. The coin processing system of claim **1** wherein the controller is adapted to determine the denomination of the coin passing through the light beam when the determined number of encoder pulses favorably compares to the stored master denominating characteristic information.

3. The coin processing system of claim **1** wherein the light beam comprises a laser beam.

4. The coin processing system of claim **3** wherein the light source is a single laser diode.

5. The coin processing system of claim **1** wherein the light detector is a photodetector.

6. The coin processing system of claim **1** further comprising at least one light guide for guiding light received from the light source to the light detector.

7. The coin processing system of claim **6** wherein the light guide has an inlet disposed along the coin path opposite the light source.

8. The coin processing system of claim **1** further comprising a diverter disposed along the coin path beyond the light source, the diverter being moveable between a first position for permitting coins to proceed to a plurality of exit channels and a second position for diverting coins to a reject region.

9. The coin processing system of claim **8** wherein the controller causes the diverter to move from the first position to the second position when the number of encoder pulses determined when a coin passes through the light beam does not favorably compare to the stored master denominating characteristic information.

10. The coin processing system of claim **1**, wherein the stationary sorting head lower surface forms a common coin path which directs the movement of all coins prior to sorting of coins having different denominations into separate coin paths for discharge from an exit region associated with a particular denomination, and wherein said light source is disposed to output a light beam that traverses the coin path at a point along such common coin path.

11. A method for processing coins with a coin processing system including at least one coin path and a plurality of coin exit regions for sorting and discharging coins of particular denominations, the system including a light source, disposed on one side of the coin path, comprising:

moving a coin along the coin path defined by a stationary sorting head of a high-speed coin processing machine at a rate that can be adjusted;

emitting a light beam along a first axis across the coin path in substantially the same plane as the coin path to a light detector disposed on another side of the coin path configured to receive the light beam along a second axis substantially perpendicular to the first axis;

interrupting, with the coin moving along a portion of the coin path between the light source and the light detector, the light beam traversing the coin path such that the light beam is not incident on the light detector;

counting, with **[**the**]** *a* controller, the number of encoder pulses generated by an encoder during the interruption of the light beam; and

comparing the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

12. The method of claim **11** wherein the light beam comprises a laser beam.

13. The method of claim **11** comprising determining the denomination of the coin when the counted number of encoder pulses favorably compares to one or more of a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

14. The method of claim **11** comprising determining the coin to be an invalid coin when the counted number of encoder pulses does not favorably compare to a number of encoder pulses corresponding to a particular coin denomination.

15. The method of claim **14** comprising diverting the coin from the coin path when the coin is determined to be an invalid coin.

16. The method of claim **11** further comprising receiving the light beam with at least one light guide and directing the received light to the light detector.

17. The method of claim **11**, further comprising:

generating at least a first signal event corresponding to an interruption of the light beam by a leading edge of the coin moving along the coin path;

generating at least a second signal event when the light beam is incident to the light detector following the act of the generating at least a first signal event;

counting a number of encoder pulses occurring between the acts of generating at least the first signal event and generating at least the second signal event; and

comparing at least the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

18. The method of claim **17** comprising determining the denomination of the coin when the counted number of encoder pulses favorably compares to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

19. The method of claim **17** comprising determining the coin to be an invalid coin when the counted number of encoder pulses does not favorably compare to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

20. The method of claim **19** comprising diverting the coin from the coin path when the coin is determined to be an invalid coin.

21. The method of claim **17** further comprising receiving the light beam with at least one light guide and directing the received light to the light detector.

22. The method of claim **11**, further comprising:

generating a first light-detection output when the light beam traversing the coin path is incident upon the light detector; and

generating a second light-detection output when the light beam traversing the coin path is not incident upon the light detector.

23. A method for determining the denomination of a coin with a disk-type coin processing system, comprising:

moving a plurality of coins along a coin path with a continuously rotatable disk, wherein a rate of rotation is adjustable;

generating an encoder pulse for each incremental movement of the continuously rotatable disk;

directing a light beam along a first axis to traverse the coin path in substantially the same plane as the coin path and toward a light detector configured to receive the light beam along a second axis substantially perpendicular to the first axis;

interrupting the light beam traversing the coin path for a period in which a coin of the plurality of coins is moving through the light beam traversing the coin path;

counting a number of encoder pulses occurring during the period; and

comparing the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

24. A method for determining the denomination of a coin with a disk-type coin processing system, comprising:

moving a plurality of coins along a coin path with a continuously rotatable disk, wherein a rate of rotation is adjustable;

generating an encoder pulse for each incremental movement of the continuously rotatable disk;

directing a light beam along a first axis to traverse the coin path in substantially the same plane as the coin path;

detecting the light beam with a light detector configured to receive the light beam along a second axis substantially perpendicular to the first axis;

developing a signal at the light detector indicating the presence of a coin of the plurality of coins in the coin path;

counting a number of encoder pulses occurring while developing the signal at the light detector; and

comparing the counted number of encoder pulses to a plurality of stored numbers of encoder pulses corresponding to the particular coin denominations.

25. The method of claim **24** wherein developing further comprises:

generating a signal at the light detector that is proportional to the amount of detected light;

comparing the generated signal to a threshold value stored in memory; and

determining the signal to be a signal indicating the presence of a coin in the coin path when the generated signal is below the threshold value.

26. The method of claim **25** wherein the generated signal is a voltage signal.

27. The method of claim **25**, further comprising:

interrupting the light beam traversing the coin path for a period in which the coin is moving through the light beam traversing the coin path.

28. The coin processing system of claim 1, wherein the light source is configured to output light within a predetermined range of wavelengths, and wherein the light detector is configured to only detect light having a wavelength within the predetermined range of wavelengths output by the light source.

29. The coin processing system of claim 1, further comprising an analog-to-digital converter configured to receive, as an input, an analog signal output by the light detector and configured to output, to the controller, a digitized light-detection signal.

30. The coin processing system of claim 1, wherein the encoder has a resolution of about 20,000 pulses per revolution of the rotatable disc.

31. The coin processing system of claim 1, wherein the stationary sorting head has a diameter of about 11 inches.

32. The coin processing system of claim 1, wherein the memory storing the master denominating characteristic information further comprises an acceptable range of encoder pulses for each coin denomination.

33. The coin processing system of claim 4, wherein the laser diode outputs light having a wavelength of about 623 nm.

34. The coin processing system of claim 6, further comprising:

an aperture in the sorting head adjacent the light guide;

a nozzle disposed in the aperture and directed toward the light guide; and

a pressurized air source connected to the nozzle,

wherein the nozzle is configured to discharge air onto the light guide.

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