(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 November 2010 (04.11.2010)

PCT

(10) International Publication Number
WO 2010/126865 A1

(51) International Patent Classification:
*G01H 1/00* (2006.01)

(21) International Application Number:
PCT/US2010/032508

(22) International Filing Date:
27 April 2010 (27.04.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/214,711 27 April 2009 (27.04.2009) US

(71) Applicant *(for all designated States except US)*: **NEWFREY LLC** [US/US]; 1207 Drummond Plaza, Newark, Delaware 19711 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **DAMIKOLAS, Gerry** [US/US]; 2221 Shadow Way, Upland, California 91784 (US).

(74) Agent: **VELTMAN, Richard**; 701 E. Joppa Road, TW-199, Towson, Maryland 21286 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17**:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

**Published**:

— *with international search report (Art. 21(3))*

# (54) Title: APPARATUS FOR RAPIDLY VERIFYING TOLERANCES OF PRECISION COMPONENTS

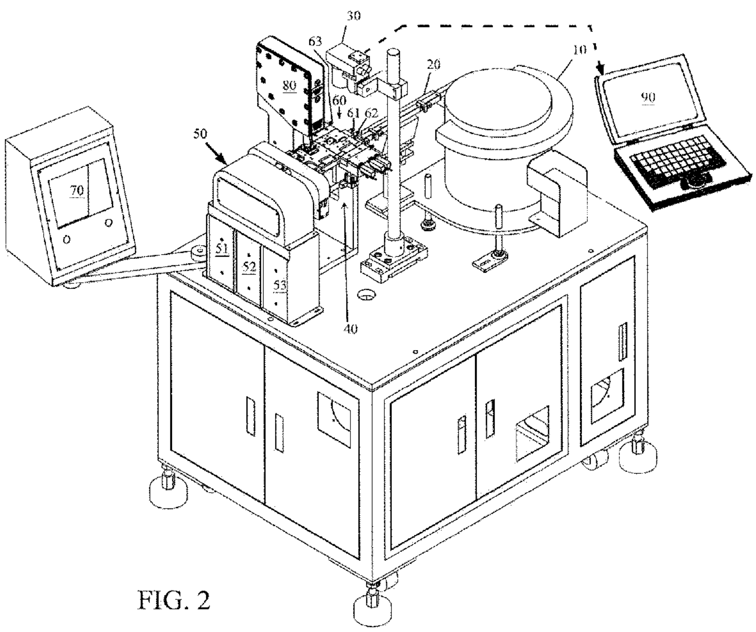


FIG. 2

**(57) Abstract**: An automated inspection system for inspecting, sorting and re-coining each of the locking bar, the rack, and the pin of a rekeyable lock cylinder, as well as other small close-tolerance components in an average cycle time of 1.5 seconds. The inspection system includes a high-speed pneumatic sorting matrix which reorients the components into various camera inspection stations, mechanical gauge stations, and/or coining stations, for combined gauge and visual tolerance checking and sorting. Defects are identified by a combination of visual and machine-gauge inspection, and the sorted components are sorted into three bins: rejects; good parts; and parts for coining. The inspection/sorting system is capable of tolerance-checking down to.00011811", with a repeatability of.00005906.

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# APPARATUS FOR RAPIDLY VERIFYING TOLERANCES OF PRECISION COMPONENTS

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application derives priority from U.S. provisional application serial number 61/214,711 filed 27 April 2009.

## FIELD OF THE INVENTION

The present invention relates to inspection machines for small precision parts, and more particularly, to an optical and mechanical inspection station capable of high speed sorting and high-tolerance checking down to .0001" (controlling thickness to very tight tolerances), and coining to perfect deformed, bent or oversize parts.

## SUMMARY OF THE INVENTION

The present invention is an automated system comprising of a combination of optical inspection stations and precision mechanical gauge stations for small-tolerance inspection, and a coining station to repair bent, deformed or oversize (excessively thick) parts. An additional mechanical gauge station verifies that the parts were repaired according to the specified tolerances. The system architecture is adaptable to inspecting and repairing any precision metal parts with small or polished surface features, and is particularly well-suited for inspecting and repairing the locking bar and rack of a rekeyable lock cylinder, and for inspecting and sorting the welded pins therein. The present inspection stations allow parts tolerance verification of these extremely small parts in a cycle time between .7 to 2.3 seconds, which can potentially raise production with higher yields from 110M parts/year (by 100% manual inspection) to 275M parts/year by automated inspection and part "coining" (repairing).

Coining is a known method of precision stamping in which a workpiece is subjected to a sufficiently high stress to induce plastic flow on the surface of the material. Coining is used to manufacture parts for all industries, and when referred to herein connotes reforming existing parts with high relief or very fine features to correct imperfections. Thus, the present system is a high-volume inspection system for small precision parts capable of both detecting and correcting imperfections.

The present system may incorporating various combinations of visual inspection station(s), mechanical inspection station(s), and a coining station, as appropriate for the production parts. The stations are modular, and there may be different production scenarios for each of the racks, pins and locking bars, depending on demand. The speed of the system is achieved by a novel ultra-high-speed pneumatic sorting/positioning matrix that reorients the components into the various camera-inspection and mechanical-gauge-inspection stations for combined gauge and visual tolerance checking.

By way of background FIG. 1 illustrates a typical rekeyable lock cylinder, which comprises a plug assembly 14, a lock cylinder body 12, and a retainer clip 16. The plug assembly 14 includes a plurality of spring-loaded pins 113. The plug assembly 14 includes a keyway opening 52, a rekeying tool opening 54 and a pair of channels 56 extending radially outwardly for receiving anti-drilling ball bearings 60. The carrier sub-assembly 42 includes a carrier 90, a plurality of racks 92, a spring-loaded locking bar 94 journaled into the carrier 90 and biased by springs 95, and a return spring 98. The carrier sub-assembly 42 and the plug body 14 combine to form a cylinder that fits inside the lock cylinder body 12.

To rekey the lock cylinder 10, a valid key is inserted into the keyway 52 and is rotated approximately 90 degrees counterclockwise or clockwise from the home position. A learning tool or other pointed device is inserted into the rekeying tool opening 54 and is pushed against the carrier 90 to move the carrier 90 parallel to the longitudinal axis of the lock cylinder 10 into a learn mode. The valid key is removed and a second valid key is inserted and rotated clockwise or counterclockwise. The carrier 90 is biased toward the plug assembly 14 face by the return spring 98, causing the racks 92 to re-engage the pins 113. The racks 92 each include a frontal pin-engaging surface having a plurality of gear teeth configured to engage the annular gear teeth of the pins 113, a semi-circular recess at the bottom, and a backside surface with a plurality of anti-pick grooves and a pair of locking bar-engaging grooves. The plurality of spring-loaded pins 113 are generally cylindrical with annular gear teeth and a central longitudinal bore for receiving biasing springs 115. The spring-loaded locking bar 94 is configured to fit into a recess in the carrier 90 and also includes triangular edges configured to fit into grooves.

The racks 92, pins 113 and locking bar 94, are small extreme precision parts that must be manufactured to very tight tolerances. In a production environment this necessarily entails a thorough 100% inspection and, where necessary, coining for compliance before use in the field. It should be apparent from FIG. 1 that a thorough 100% inspection for compliance is a time-consuming task in a production environment. Indeed, conventional inspection methods are predominantly manual. Each discrete part must be placed in an optical inspection station and visually inspected under magnification with reference to a measurement gauge or must be measured by mechanical gauges depending on the geometry and part size. This tedious process limits mass production to approximately 30M parts/year.

What is needed is an automated or semi-automated inspection process that can raise production and quality levels drastically, via a system with automated optical and mechanical inspection stations using a configuration that is adaptable to inspecting the locking bar, the rack, and the pin, and for automated coining (resizing) and sorting of bent or oversize racks and locking bars that exceed drawing specifications to meet tight tolerances.

It is also desirable that the inspection system be modular. A thorough inspection involves a combination of visual inspections and mechanical gauge inspections, optionally followed by coining of components that failed an inspection. The racks 92, pins 113 and locking bar 94 differ, and production requirements may vary. It follows that the particular combination and sequence of inspections and coining may vary. Consequently, for each component part there may be several suitable system configurations available to satisfy the various inspection and/or coining needs.

## SUMMARY OF THE INVENTION

The present system accomplishes the foregoing for the components of rekeyable lock cylinders including racks, pins and locking bars, as well as any other small high-precision parts that must be manufactured to very tight tolerances. The system is modular and easily reconfigurable to accommodate possible variations in system configuration and operation. Despite the desired number or sequence of inspections, it remains necessary to sort, convey and orient the components through and into each of the plurality of inspection/coining stations. This high-speed sorting, conveying and orientation is herein achieved with an ultra-high-speed pneumatic sorting/positioning matrix that reorients the components into the various camera inspection and gauge stations for combined gauge and visual tolerance checking. Defects are identified by a combination of visual and machine-gauge inspection, and the components are sorted into three bins: 1) rejects; 2) good parts; 3) parts for coining. The sorters orient and feed the components to a dispenser that dispenses the sorted components single file from a queue.

Rather than merely sorting components for coining, the system can also be configured with an integral coining station for resizing the parts, followed by a mechanical thickness gauge for checking the coining result. The automated optical and mechanical gauge inspection station(s), component sorters and component dispensers, and coining station are adaptable to the various machine configurations shown above for each of the locking bar, rack, and pin components, and will herein be described in the context of a Locking Bar

System Configuration including a visual inspection station and mechanical gauge for thickness and straightness sorting of the locking bar in the X-Direction, a component sorter for 90° part rotation, and then another visual inspection station and mechanical gauge for thickness and straightness sorting in the Y-Direction.

For each component part there may be several suitable system configurations available to satisfy the various inspection and/or coining needs. For example, the following configurations of the present system are suitable for the various components as follows:

1. Rack System Configurations (3 examples)

a. Visual Inspection Station plus Mechanical Gauge for thickness and straightness inspection and sorting;

b. Mechanical Gauge with Coining Station for resizing parts, and another Mechanical Gauge to sort resized parts;

c. Visual Inspection Station with Mechanical Gauge and Coining Station for resizing parts and another Mechanical Gauge to sort resized parts

2. Pin System Configurations (two examples)

a. Feeder Bowl to separate unwanted welded pins (Caused by metal injection molding ("MIM") Sintering Process) from single pins;

b. Welded Pin Separator and Visual Inspection Station

3. Locking Bar System Configurations (three examples)

a. Visual Inspection Station with Mechanical Gauge for thickness and straightness sorting in the X plane, 90° Part Rotator and Visual Inspection Station with Mechanical Gauge for thickness and straightens sorting in the Y plane;

b. Mechanical Gauge with Coining for Resizing Parts, followed by Mechanical Gauge to sort resized parts;

c. Visual Inspection Station with Mechanical Gauge and Coining for resizing parts, followed by Mechanical Gauge to sort resized parts.

In each of the foregoing system configurations it is possible to electronically enable or disable all or some of the stations. For example, for the Locking Bar System Configuration (a), it is possible to turn OFF the visual inspection station and leave ON the Mechanical Gauge, or vice versa.

The system as a whole is capable of tolerance-checking down to .00011811", with a repeatability of .00005906.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features, and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments and certain modifications thereof when taken together with the accompanying drawings in which:

FIG. 1 illustrates a typical rekeyable lock cylinder, with various close-tolerance components. FIG. 2 is a perspective view of an automated machine with one optical inspection station, a part rotator and two mechanical thickness gauges, adapted for inspecting the locking bar according to an embodiment of the present invention.

FIG. 3 is an overhead view of the sorting assembly 40, which includes an ultra-high-speed pneumatic sorting/positioning matrix 60.

FIGs. 4, 6 and 7 are sequential overhead views illustrating a component traversing the high-speed pneumatic sorting/positioning matrix 60?.

FIG. 5 shows the locking bar images captured by the cameras in the vertical and then after 90° rotation in the horizontal positions.

FIG. 8 illustrates the amplifiers used for fiber-optic sensors that sense the position of the locking bar as it is transported from station-to-station by the pneumatic air jets.

FIG. 9 are photographs of two programmable controller 70 screens showing the set up parameters for the set up and calibration of the locking bar sorter.

FIG. 10 illustrates the two amplifiers for controlling the feed rates of the feeder bowl and the linear track used for orienting and dispensing the locking bars.

FIG. 11 is a perspective close-up view of the coining station 80.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is an automated optical and mechanical inspection, sorting and coining system capable of high speed sorting and small-tolerance checking down to .0001", plus coining and re-inspection to straighten bent or oversized part. The optical/mechanical inspection and coining system employs an adaptable multi-station architecture suitable for both optical and mechanical inspection, as well as coining and re-inspection, specifically adapted for each of the locking bar, rack, and pin of a rekeyable lock cylinder, and other small parts. Rekeyable lock cylinder components are shown, for example, in United States Patent No. 6,862,909 to Armstrong et al. and FIG. 1 which is reproduced herein. Again, FIG. 1 illustrates this rekeyable lock cylinder with racks 92, pins 113 and locking bar 94, all of which require optical and mechanical inspection, sorting and coining as facilitated by the present system.

The present system includes a configurable series of optical and mechanical inspection stations, plus sorting and coining stations, that allow parts tolerance verification of extremely small parts in an average cycle time of 1.5 seconds (2.3 seconds (max)), and is capable of tolerance-checking down to .00011811", with a repeatability of .00005906".

The system cycle time is variable from .7 to 2.3 seconds and depends on the following:

1. the number of sorting stations selected for optical inspection, mechanical gauging and coining;
2. the number of areas of each component that must be optically inspected by the cameras;
3. desired component yields.

FIG. 2 is a perspective view of an automated optical inspection system for inspecting and sorting the locking bar 94 of FIG. 1, according to one exemplary embodiment of the present invention that includes a visual inspection station plus mechanical gauge station for thickness and straightness sorting along an X plane, followed by a 90° part rotator, and then another visual inspection station plus mechanical gauge station for thickness and straightness sorting in the Y plane.

The illustrated inspection system generally includes a vibrating feeder bowl 10 for vibratory feeding of locking bars to an inline single-file conveyor 20. The conveyor 20 transfers the individual locking bars and infeeds them in an indexed manner one-by-one into a sorting assembly 40. The sorting assembly 40 includes an ultra-high-speed pneumatic sorting/positioning matrix 60 that reorients the components into various camera-inspection and mechanical-gauge-inspection stations for combined gauge and visual tolerance checking. Specifically, the single-file conveyor 20 moves each locking bar into the sorting/positioning matrix 60 of sorting assembly 40, which then moves each locking bar into a first visual inspection station beneath camera 30 for optical inspection. Optical camera imaging is provided by mast-mounted overhead optical inspection cameras 30 in communication with a remote display such as a laptop computer 90. There may be one or two mast-mounted overhead optical inspection cameras 30 as needed, depending on the desired number of optical inspections. With two cameras optical inspection may occur in two different planes. Specifically, the camera 30 images the locking bar along an X plane for visual tolerance checking relative to a gradient scale displayed on computer 90. The sorting/positioning matrix 60 then rotates each locking bar onto its side at a 90° part rotator, and moves it to a second visual inspection station (under a second camera 30) for visual tolerance checking along a Y plane, again relative to a gradient scale displayed on computer 90. The sorting/positioning matrix 60 then ushers the components through two pre-calibrated mechanical gauge stations 61, 62 each comprising a digital-output micrometer adjusting a fixed-dimension pass-through gate (described below). The locking bar passes through the first mechanical gauge station 61 for thickness and straightness sorting along an X plane. The sorting/positioning matrix 60 then rotates each locking bar onto its side at a 90° part rotator, and moves it successively to the second mechanical gauge station 62 for thickness and straightness sorting in the Y plane.

Defects identified during the combined visual and machine-gauge inspections are fed to a coining station 80 and then to a supplemental mechanical gauge station 63 for automated coining (remanufacture) and re-inspection of coined parts.

A programmable controller with a touch screen display 70 synchronizes the entire operation. Locking bars passing the combined visual and machine-gauge inspections, successfully coined locking bars, and unsuccessfully coined locking bars are sorted into a collection station 50 in three bins: 1) Mechanical Gauge rejected parts into bin 51; 2) good parts (including failed-coined-and now-good parts) into bin 52; and 3) Optical Inspection rejected parts into bin 53. The system as a whole is capable of tolerance-checking down to .00011811", with a repeatability of .00005906. The automated inspection, sorting and coining system is adaptable with minimal modification for each of the locking bar, rack, and pin components, although the embodiment illustrated and described herein is adapted for inspection of locking bars.

The vibrating feeder bowl 10 accepts bulk components onto a vibrating bowl which aligns them against a circular sidewall. The components line-up against the sidewall where they are fed in a continuous stream onto the inline single-file feed vibratory conveyor 20 (arranged as a linear track). The vibrating feeder bowl 10 is continuous motion with adjustable vibration frequency and feed rate. A variety of vibratory feeders are commercially available and will serve as the vibrating feeder bowl 10 so long as it is capable of sorting, orienting and feeding the locking bars (or others parts) single-file to the conveyor 20.

The components are transported by the vibratory feed conveyor 20 in a single file and continuous stream. The feed conveyor 20 may be any suitable small parts conveyor although in the presently preferred embodiment is a vibratory conveyor (linear track). The vibration frequencies and hence the feed rates of both the vibrating feeder bowl 10 and vibratory conveyor 20 are adjusted by individual linear amplifiers (shown and described below with regard to FIG 10).

FIG. 3 is an overhead view of the sorting assembly 40, which includes an ultra-high-speed pneumatic sorting/positioning matrix 60 that transfers and reorients the components from conveyor 20 into various camera inspection and mechanical gauge stations for combined mechanical gauge and optical tolerance checking (by the one or two mast-mounted overhead optical inspection camera(s) 30 (not shown) and two mechanical gauges 61, 62). Components are admitted in a continuous stream, single file in an upright orientation. A pneumatic slide 101 gates the individual parts into the matrix 60 under the control of a programmable controller as monitored on the controller's touch screen display 70. The slide 101 slides back and forth pneumatically, and parts are gated by slide 101 when it is in the rightmost position. The pneumatic slide 101 moves left to transport a single component received from the feeder 20 component stream to the first station (here a first mechanical gauge station 62 for mechanical inspection along an X-plane). When the slide 101 moves back to the right it serves as a closed gate. Several such slides 101, 102, 103 are provided to facilitate movement and gating of the component parts through the various stations, and each is actuated by a pneumatic cylinder controlled by the programmable controller 70. The slide positions (left or right) are reported to the programmable controller 70 via sensors mounted on the pneumatic cylinders.

Once gated in from conveyor 20 at gate 63, the components are then pneumatically blown through the matrix 60, stopping at a first mechanical gauge station 62 for mechanical inspection, then shifted to the left by pneumatic slide 101 and blown into a first camera station 65 for optical inspection, both mechanical and optical inspections being in an X-plane. The components are then re-oriented by 90 degree rotation onto their sides at a parts rotator 67, are shifted to the left by pneumatic slide 102 and are blown into a second mechanical gauge station 61 for mechanical inspection along a Y-plane, and then a second camera station 64 for optical inspection. Depending on the results of the combined inspections, the component is shifted either right or left by pneumatic slide 103 through a singulation station 68 which isolates the component. If it is determined by inspection that the component requires coining, it is transferred left to the coining station 80 which re-manufactures (coins) the parts in real time to resize them. The parts are coined and then sent through a supplemental mechanical gauge 63 to quality-check the coining operation. Coined components that pass the mechanical gauge 63 are gated one-by-one single file through an exit gate 71 at the bottom of the figure, this gating occurring under control of the programmable controller 70. Components that do not require coining are gated one-by-one single file through an exit gate 69 at the bottom of the figure, this gating also occurring under control of the programmable controller 70. The components may be ejected into one of the three bins, mechanical gauge rejects into bin 51; good parts (with or without coining) into bin 52; and optical inspection rejects into bin 53. The programmable controller 70 maintains a synchronous operation by controlling gating and pneumatics. The inspection performed at each station result in a simple go/nogo determination, the end result of which may be earmarking of parts as good, defective or suitable for coining (remanufacturing). The matrix 60 for performing all of this component manipulation comprises a base 80 defined by a plurality of fixed-position raised rows (extending horizontally) separated by a plurality recessed rows there between. A plurality of grooves define pneumatic pathways 72A-C running vertically and traversing the raised horizontal rows from end-to-end along the base 80. A plurality of slide inlays 82A-C are slidably mounted in the base 80, each seated within a recessed row. The slide inlays 82A-C likewise each contain a groove defining a pneumatic pathway, but the slide inlays 82A-C are pneumatically shifted back and forth by the corresponding slides 101-103 to shuttle the components between pneumatic pathways 72A-C. Each of the slide inlays 82A-C comprises a rectangular member formed with a component pathway extending there across. When a slide inlay 82A-C is seated in the base 80, the component pathways formed therein correspond to the pneumatic pathways 72A-C formed in the base 80, thereby providing a straight-across component pathway extending end-to-end across the base 80. However, while a component is seated within a slide inlay 82A-C, that slide inlay can be shifted pneumatically left or right to move the component into a different one of the pneumatic pathways 72A-C. Thus, a component part pneumatically moving through one pathway may be offset to another pathway by pneumatic displacement of a slide inlay 82A-C.

An air supply comprises three pneumatic lines coupled into a manifold 90 (at top) for providing air into the corresponding pathways 72A-C. Similarly, twelve pneumatic lines are coupled to the pneumatic cylinders (at right) feeding the pneumatic slides 101-103, which are controlled by the programmable controller 70 for actuating the slide inlays 82A-C to facilitate and gating of the component parts through the various stations. This way, the components begin their travel along one pneumatic pathway 72C, and are shifted in transit to other component pathways by any of the slide inlays 82A-C.

All pneumatic lines are controlled by corresponding digital on/off pneumatic cylinders connected to the controller. In the illustrated embodiment there are four slides 101-104 and corresponding slide inlays 82A-D, and hence there are eight pneumatic cylinders for moving the four slides left and right on each side. Fiber optic sensors are used to detect the part entering and exiting slide inlays 101-104. This information is communicated to the PLC controller 70 for synchronizing the movements of slides 101-104. This way, parts jams can be detected by the PLC 70 via the fiber optic sensors. The PLC 70 will stop the slide movements and the jam will be reported by an error message. The eight pneumatic cylinders require 16 air lines (each cylinder takes 2 air lines). This allows centralized automatic high speed synchronous on/off operation, and pressure control, by the programmable controller 70. The pneumatic cylinders are commercially-available actuators, available for example from SMC Inc.

As the locking bars travel through the matrix 60 and the system as a whole the individual components positions are tracked by fiber optics. Specifically, FIG. 8 is a front view of amplifiers used for fiber-optic sensors that sense the position of the locking bar as it is transported from station-to-station by the pneumatic air jets. The amplifier gain and triggering thresholds are set during the system set up and calibration. The actual fiber sensors are directed as desired at the various stations to track component progress.

FIG. 9 are photographs of the touch screen display 70 connected to the programmable controller. The touch screen display 70 provides a user-interface of various setup screens, the two provided illustrating setup of the timing sequence of the process, including air pressure settings, delay settings and max reject count.

FIG. 10 shows the amplifiers for controlling the vibration frequencies and hence the feed rates of both the vibrating feeder bowl 10 and vibratory conveyor 20.

FIG. 11 illustrates the coining station 80 and supplemental mechanical gauge 63 for coining and re-inspection to straighten bent or oversized parts. Components that failed an inspection (optical or mechanical) are diverted off the pneumatic sorting/positioning matrix 60 and are pneumatically transferred and reoriented into a coining die 84 beneath the coining ram 82 of a hydraulic press. The coining ram 82 imparts a great deal of force to plastically deform the components so they conform to the die 84. The press itself is a commercially-available hydraulically actuated press, a wide variety of which are readily available. A 50 ton press is acceptable for the present components, and the die 84 may vary depending on the type of component. After each component is coined it is transported to a mechanical gauge station 63 for mechanical inspection. Mechanical gauge station 63 is similar to the above-described pre-calibrated mechanical gauge stations 61, 62, and likewise comprises a digital-output micrometer adjusting a fixed-dimension pass-through gate which confirms that the coining station 80 was successful. If the component fails again it is sorted into rejected parts bin 51, and if it passes it is sorted into good parts into bin 52.

Referring back to FIG. 3, a more detailed explanation of the above-described sorting/positioning matrix 60 is provided. The matrix comprises a cross-hatch pattern of slide inlays 82A-C and pneumatic pathways 72A-C defining fixed-length cells within which the components can be trapped in an exact stationery position. The particular number and placement of the cells and pathways through the pneumatic sorting/positioning matrix 60 may vary as needed, and in the illustrated embodiment two of these cells define two camera optical inspection stations 64, 65, and two cells define two mechanical gauge stations 61, 62. In each of these stations the component is effectively held stationary within exceedingly close confines, where it can be accurately inspected. The components are illuminated from the back with red light. A red sharp cut filter 640nm is attached to the front of the camera to reduce ambient light interference. Note that each of the two camera stations 64, 65 are fronted by plastic windows with measuring indicia for optical inspection by cameras 30A, 30B Each of the two mechanical gauge stations 61, 62 comprises a digital-output micrometer adjusting a fixed-dimension pass-through gate. Once the gate dimension is set by the micrometer to a part-specification, the part either passes through or not, indicating a pass or fail component. If a part is bent or if it is over-thickness, the gate's gauge plates are temporarily opened to let the part through. However, the gauge plate moves precisely back to the original position after the oversized part passes. The position of the moving gauge plate is monitored by a high precision sensor and controlled by the programmable controller to .0001".

A component traverse through the high-speed pneumatic sorting/positioning matrix 60 will now be described with reference to FIGs. 4-7. In summary, the sorting assembly 40 accomplishes the following steps:

1) orients the locking bars vertically;
2) singulates each locking bar;
3) transports to Camera 1 Station 65 for optical inspection;
4) transports to mechanical gauge 1 station 62 for mechanical inspection;
5) rotates locking bar 90°
6) transports to Camera 2 Station 64 for optical inspection;
7) transports to mechanical gauge 2 station 63 for mechanical inspection;
8) transports locking bars for coining to coining station 80;
9) sorts locking bars into one of three bins: 1) Mechanical Gauge rejected parts into bin 51; 2) coined and now-good parts into bin 52; and 3) Optical Inspection rejected parts into bin 53.At step 1, with reference to FIG. 4, a locking bar is gated into position at gate 63 by air pressure from manifold 90, and is initially stopped by the displaced slide inlay 82A. The narrow slot of gate 63 orients the locking bar in a vertical position.

At step 2, the locking bar is singulated (e.g., isolated as a discrete component).

At step 3, under control of programmable controller 70, the slide inlay 82A is urged downward thereby aligning the slots with that of the Camera 1 Station 65. Pressurized air from manifold 90 injects the locking bar into Camera 1 Station 65 for optical inspection. Note that the next successive slide inlay 82B is initially in a blocking position, capturing the locking bar at the Camera 1 Station 65. The first of the two mast-mounted overhead optical inspection cameras 30A zooms in and images the locking bar through the window.

FIG. 5 A illustrates the optical inspection image which may be provided to the user. The Camera 1 Station 65 has a resident controller that works in a “hand shake” communication mode with the programmable controller so that images can be viewed on a flat screen monitor such as computer 90. Specifically, the camera 30 images the locking bar along an X plane for visual tolerance checking relative to a gradient scale displayed on computer 90. In this example a second such mast-mounted camera is provided for imaging at a Camera 2 Station 64. The sorting/positioning matrix 60 rotates each locking bar onto its side at a 90° part rotator, and moves it to the second visual inspection station 64 (under a second camera 30) for visual tolerance checking along a Y plane, again relative to a gradient scale displayed on computer 90. FIG. 5B illustrates the optical inspection image which may be provided to the user at Camera 2 Station 64. In the illustrated configuration both cameras at both camera stations have their own on-board controllers which are capable of operating independently from the main controller once they are set up. The camera controllers communicate with the main PLC controller via any suitable “hand shake” communication protocol (RS-232 or otherwise). Thus, the cameras will send signals to the main PLC controller such as “wait I am checking the image” or “I am done”, “good part or bad part”. The main PLC controller will reply “I got it”, complete the task, and tell the camera(s) to “perform next task”. The controllers of both Camera 1 Station 65 and Camera 2 Station 64 may employ software for differentiating good part or bad parts, and so it is not necessary to provide an optical inspection image to the user at all. Nevertheless, for prototyping purposes a standalone IBM PC was networked to the cameras in order to program the camera parameters, and the optical inspection images of FIG. 5 were displayed on this IBM PC. The images serve to illustrate the optical inspections made by the camera stations.

Specifically, the locking bar is held in a vertical position in Camera 1 Station 65 long enough the Camera 1 Station 65 to take a still image, whereupon the controller completes an accurate software-based inspection making sure that the locking bar fits within a predetermined footprint of programmed grid lines. Preferably, software resident on the controller gives the capability to auto-compare the component against pre-existing gridline-footprint data. A variety of commercial software packages exist for this purpose. The software provides full 2D-geometric inspection capabilities along the side-edges of the locking bar. The software automatically tests go/nogo and, if nogo, slide inlay 82B is displaced and the locking bar is shifted into a reject track where it is transferred to reject bin 51 (or optionally coining bin 53).

As seen in FIG. 6, at step 4 with a successful first optical inspection complete, slide inlay 82B is displaced one row and the locking bar is injected by pressurized air to the first mechanical gauge station 61, for mechanical inspection by micrometer 77. While seated in the first mechanical gauge station 61, the width of the locking bar is checked at a pass-through gate having a dimension fixed by a digital micrometer 77. If the locking bar can pass through the gate it continues on to the next station. If not, slide inlay 82C is displaced and the locking bar is shifted into the reject track where it is transferred to reject bin 51 (or optionally coining bin 53).

At step 5, after a successful mechanical measurement, the locking bar is transferred to a rotation station where it is rotated 90° onto its side. The rotation may be accomplished by pneumatically blowing the locking bar up onto its side against a wall using air nozzle 87, and then progressing it into a narrower channel in slide inlay 82C which maintains it erect.

At step 6, the locking bar is transported by slide 87C to Camera 2 Station 64 for a second optical inspection along its Y-axis. Pressurized air from manifold 90 injects the locking bar into Camera 2 Station 64, and the next successive slide inlay 82D is initially in a blocking position, capturing the locking bar at the Camera 2 Station 64. The second of the two mast-mounted overhead optical inspection cameras 30B zooms in and images the rotated locking bar through the window.

FIG. 5 B illustrates the optical inspection image which may be provided to the user in the same manner described above in regard to FIG. 5A. The locking bar is now held in a sidelong position in Camera 2 Station 64 long enough to take a still-image, whereupon software resident on the controller 70 gives the capability to auto-compare the component against pre-existing gridline-footprint data. The camera software automatically tests go/nogo and, if nogo, slide inlay 82D is displaced and the locking bar is shifted into a reject track where it is transferred to reject bin 51 (or optionally coining bin 53). If go, slide inlay 82D is partially displaced and the locking bar is shifted to a second mechanical gauge station 62.

As seen in FIG. 7, at step 7 with the second optical inspection successfully completed, slide inlay 82C is displaced and the locking bar is injected by pressurized air to the second mechanical gauge station 62, for a sideways (rotated) mechanical inspection. While seated in the second mechanical gauge station 62, the height of the locking bar is manually checked by passing it through another digital micrometer 65 set pass-through gate. If the locking bar can pass through the gate it continues on. If not, it is shifted into the reject track where it is transferred to reject bin 51 (or optionally coining bin 53).

Finally, at step 8, the inspected components accumulate at collection station 50 in the three bins: 1) rejects in bin 51; 2) good parts in bin 52; and 3) optical inspection rejects into bin 53.

FIG. 9 shows two photographs of programmable controller 70 setup screens, illustrating how all timing parameters for the above-described sequence may be centrally programmed at controller 70 using a setup user interface.

It should now be apparent that the above-described visual inspection station(s), mechanical inspection station(s), coining station(s), and component sorters and component dispensers provide ultra-high-speed pneumatic sorting and reorientation of the components into the various camera inspection and gauge stations for combined gauge and visual tolerance checking. The system can be equipped with an integral coining station for resizing defective parts (preferably followed by another mechanical thickness gauge for checking the coining result). The system is capable of tolerance-checking down to .00011811", with a repeatability of .00005906. Although the Locking Bar System Configuration described above includes a visual inspection station and mechanical gauge for thickness and straightness sorting in the X plane, followed by a rotation station, and then another visual inspection station and mechanical gauge for thickness and straightness sorting in the Y plane, one skilled in the art should readily understand that various related configurations are possible depending on the particular component part to be inspected and the inspection goals of the operator. Specifically, it is envisioned that the following combinations will serve the corresponding component parts:

1. Rack-testing Configurations

a. Visual Inspection Station plus Mechanical Gauge for thickness and straightness sorting;

b. Mechanical Gauge with Coining for resizing parts, and another Mechanical Gauge to sort resized parts;

c. Visual Inspection Station with Mechanical Gauge and Coining for Resizing Parts and another Mechanical Gauge to sort resized parts;

2. Pin-testing Configurations

a. Feeder Bowl to separate unwanted welded pins (Caused by MIM Sintering Process) from single pins;

b. Welded Pin Separator and Visual Inspection Station

3. Locking Bar-testing Configurations

a. Visual Inspection Station with Mechanical Gauge for thickness and straightness sorting in the X plane, 90° Part Rotator and Visual Inspection Station with Mechanical Gauge for thickness and straightens sorting in the Y plane;

b. Mechanical Gauge with Coining for Resizing Parts, followed by Mechanical Gauge to sort resized parts;

c. Visual Inspection Station with Mechanical Gauge and Coining for resizing parts, followed by Mechanical Gauge to sort resized parts.

In all the foregoing exemplary configurations it is possible to electronically enable or disable all or some of the stations. For example, for the Locking Bar System, Configuration (a), it is possible to turn OFF the visual inspection station and leave ON the Mechanical Gauge, or vice versa.

Having now fully set forth the preferred embodiment and certain modifications of the concept underlying the present invention, various other embodiments as well as certain variations and modifications of the embodiments herein shown and described will obviously occur to those skilled in the art upon becoming familiar with said underlying concept. It is to be understood, therefore, that the invention may be practiced otherwise than as specifically set forth in the appended claims.

I claim:

1. A pneumatic sorting matrix for transporting and positioning small component parts for inspection, comprising:

a base having a surface defined by a plurality of raised rows and at least one recessed row between said raised rows, and at least two parallel grooves traversing each of said raised rows and partially defining a first pneumatic part pathway and a second pneumatic part pathway;

a first slide inlay slidably mounted in said at least one recessed row, said first slide inlay being defined by a parallel groove traversing said first slide inlay and fully defining said first pneumatic part pathway when said first slide inlay is in a first position, and fully defining said second pneumatic part pathway when said first slide inlay is in a second position;

a first air supply in communication with said first pneumatic part pathway for blowing a component part therealong;

a second air supply in communication with said second pneumatic part pathway for blowing a component part therealong;

a first pneumatic actuator for selectively shifting said slide inlay between said first and second positions to shuttle a component part between said first and second pneumatic part pathways; and

a programmable logic controller in communication with said pneumatic actuator and said first and second air supplies for controlling traverse of said blown component part down said first pneumatic part pathway, said second pneumatic part pathway, or a combination of said first and second pneumatic part pathways.

2. The pneumatic sorting matrix according to claim 1, further comprising a control gate positioned in one of the grooves in a raised row of said base and in communication with said programmable logic controller for interrupting traverse of said component part and positioning said part for inspection.

3. The pneumatic sorting matrix according to claim 1, wherein said base further comprises at least three raised rows with at least two recessed rows there between, said first slide inlay being slidably mounted in one of said recessed rows and a second slide inlay is slidably mounted in another of said recessed rows.

4. The pneumatic sorting matrix according to claim 3, further comprising a second pneumatic actuator for selectively shifting said second slide inlay between a first and second position to shuttle a component part.

5. An automated system for inspection of precision components, comprising:

a pneumatic sorting matrix for transporting and positioning small component parts for inspection, pneumatic sorting matrix further comprising,

a base having a surface defined by a plurality of raised rows and at least one recessed row between said raised rows, and at least two parallel grooves traversing each of said raised rows and partially defining a first pneumatic part pathway and a second pneumatic part pathway,

a first slide inlay slidably mounted in said at least one recessed row, said first slide inlay being defined by a parallel groove traversing said first slide inlay and fully defining said first pneumatic part pathway when said first slide inlay is in a first position, and fully defining said second pneumatic part pathway when said first slide inlay is in a second position, and

at least one inspection station positioned along said first component part pathway for maintaining said part stationery for inspection;

a first air supply in communication with said first pneumatic part pathway for blowing a component part therealong;

a second air supply in communication with said second pneumatic part pathway for blowing a component part therealong;

a first pneumatic actuator for selectively shifting said slide inlay between said first and second positions to shuttle a component part between said first and second pneumatic part pathways;

a programmable logic controller in communication with said pneumatic actuator and said first and second air supplies for controlling traverse of said blown component part down said first pneumatic part pathway, said second pneumatic part pathway, or a combination of said first and second pneumatic part pathways.

6. The automated system for inspection of precision components according to claim 5, further comprising a first camera for imaging said component part when stationery at a first inspection station.

7. The automated system for inspection of precision components according to claim 6, wherein said first camera is mounted on a boom overhead said first inspection station.

8. The automated system for inspection of precision components according to claim 6, further comprising a second camera for imaging said component part when stationery at a second inspection station.

9. The automated system for inspection of precision components according to claim 8, wherein said second camera is mounted on a boom overhead said second inspection station.

10. The automated system for inspection of precision components according to claim 5, further comprising a part rotator between said first inspection station and second inspection station for rotates each component part 90°.

11. The automated system for inspection of precision components according to claim 5, further comprising a micrometer for measuring said component part at said at least one inspection station.

12. The automated system for inspection of precision components according to claim 7, wherein said micrometer calibrates a pass-through gate in said first pneumatic pathway.

13. The automated system for inspection of precision components according to claim 5, further comprising a coining press and die for coining components that fails inspection.

14. The automated system for inspection of precision components according to claim 5, wherein said component part may be any one of a rack, pin and locking bar of a rekeyable lock cylinder.

15. An inspection, sorting and coining system for component parts, comprising:

a high-speed pneumatic sorting matrix for moving individual component parts to a plurality of optical inspection stations, and for reorienting each individual component at said optical inspection stations, said sorting matrix comprising a base having a plurality of pneumatic slides mounted therein, and a plurality of pneumatic channels defined through said base and slides for carrying said component parts, whereby a component part pneumatically moved through one channel may be offset to another channel by pneumatic displacement of a slide.

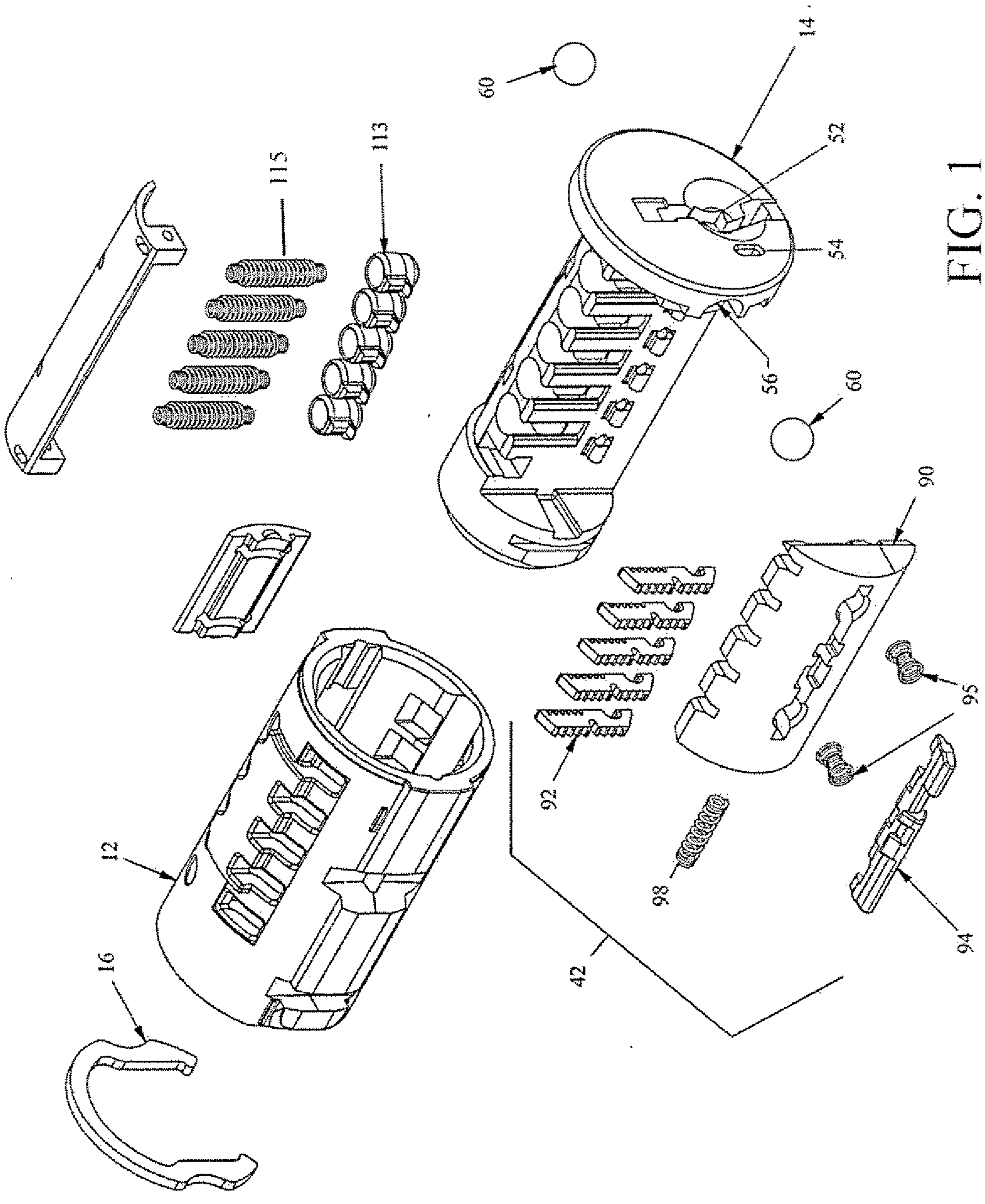



FIG. 1

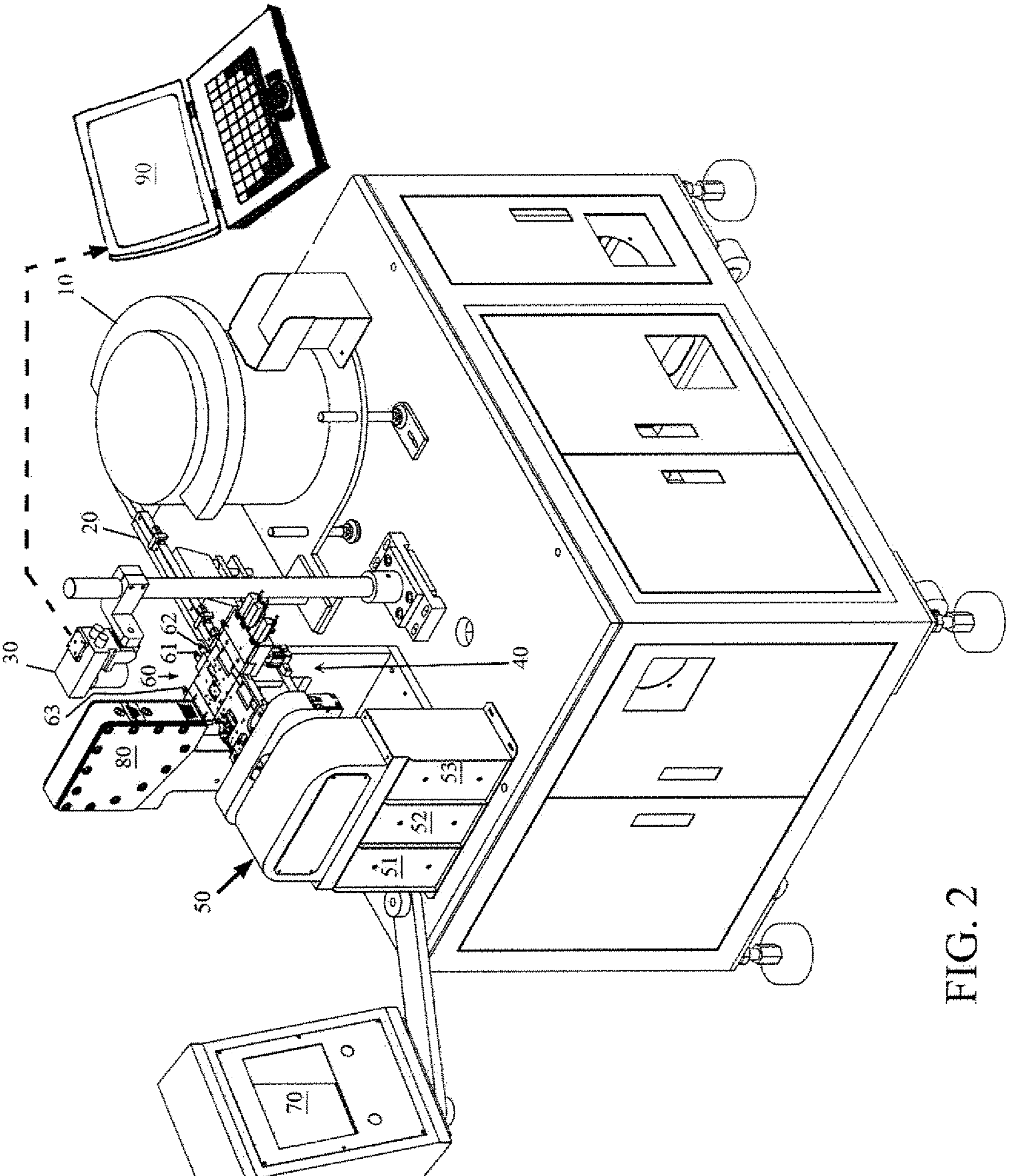
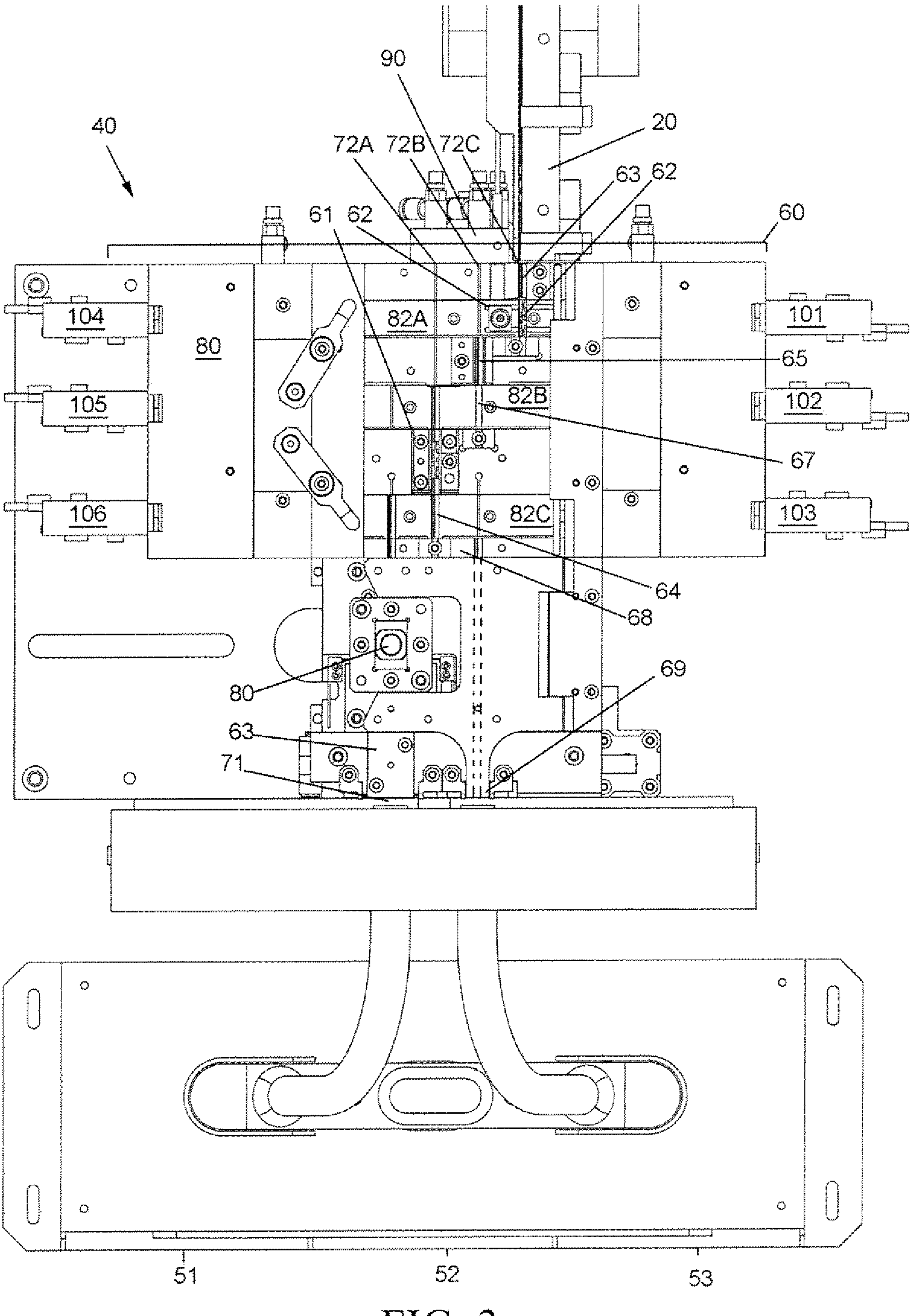



FIG. 2


90
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72A 72B 72C
63 62
61 62
60
104
82A
101
80
65
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67
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69
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71
51
52
53

FIG. 3

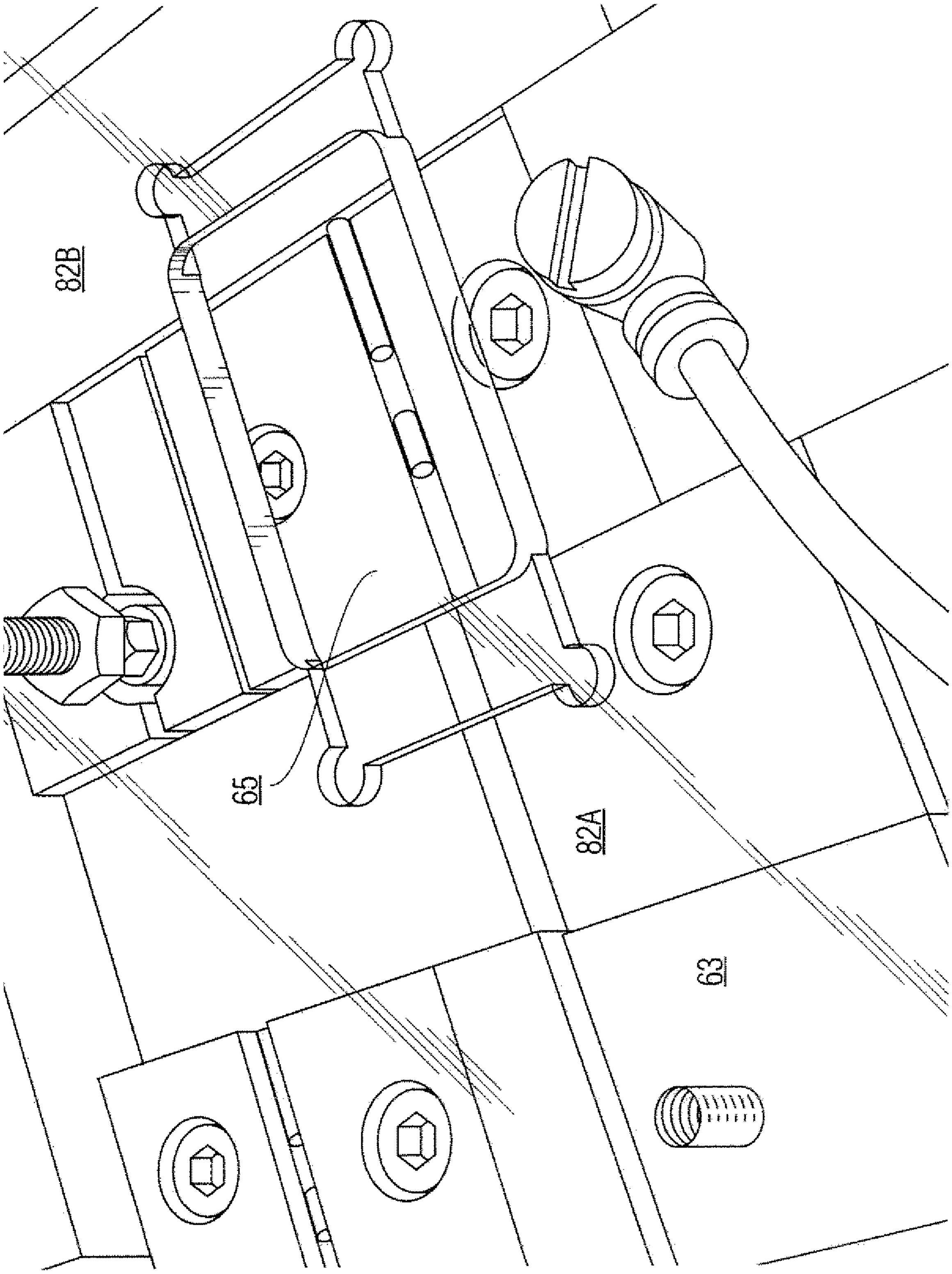
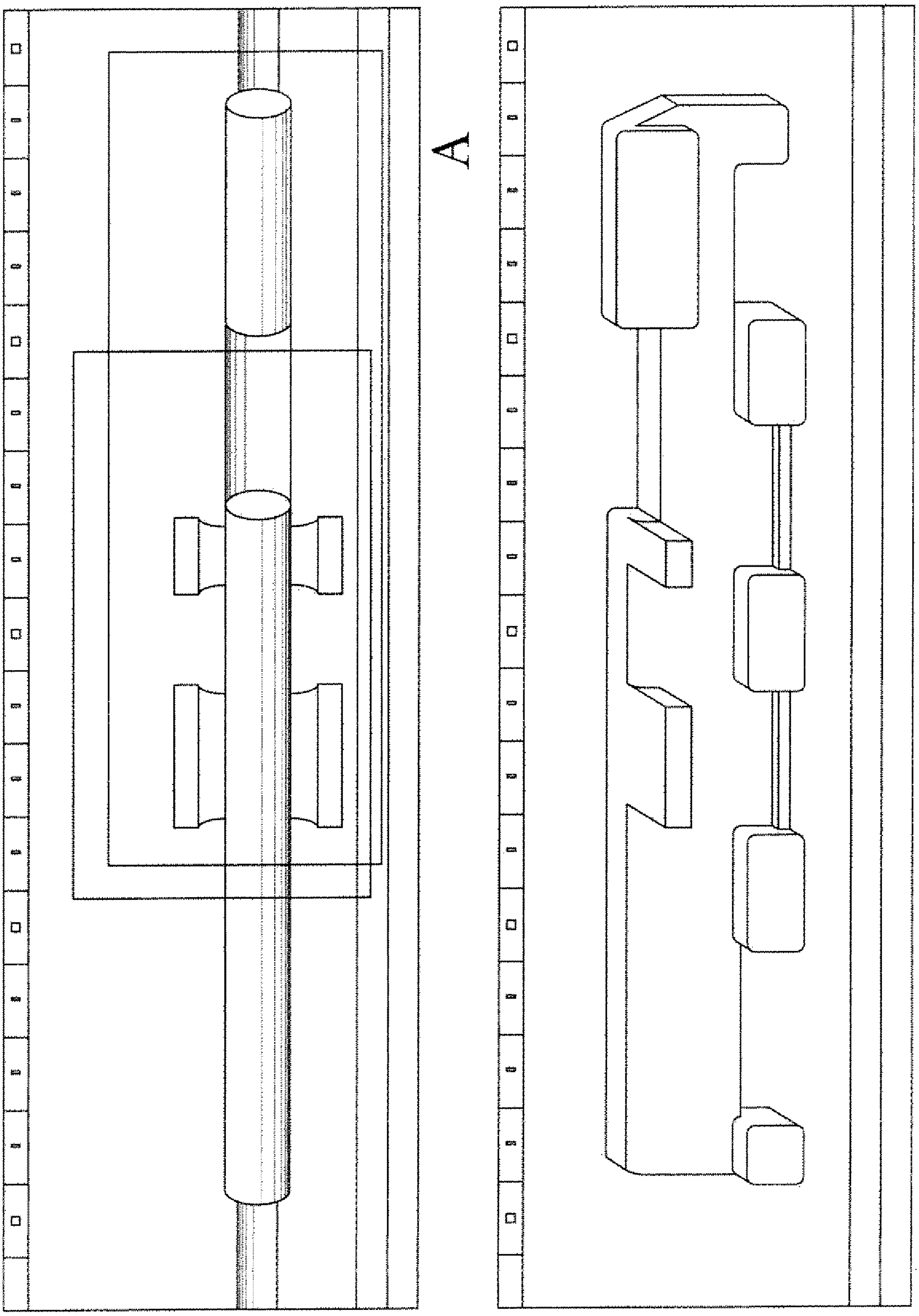



Fig. 4



A

B

Fig. 5

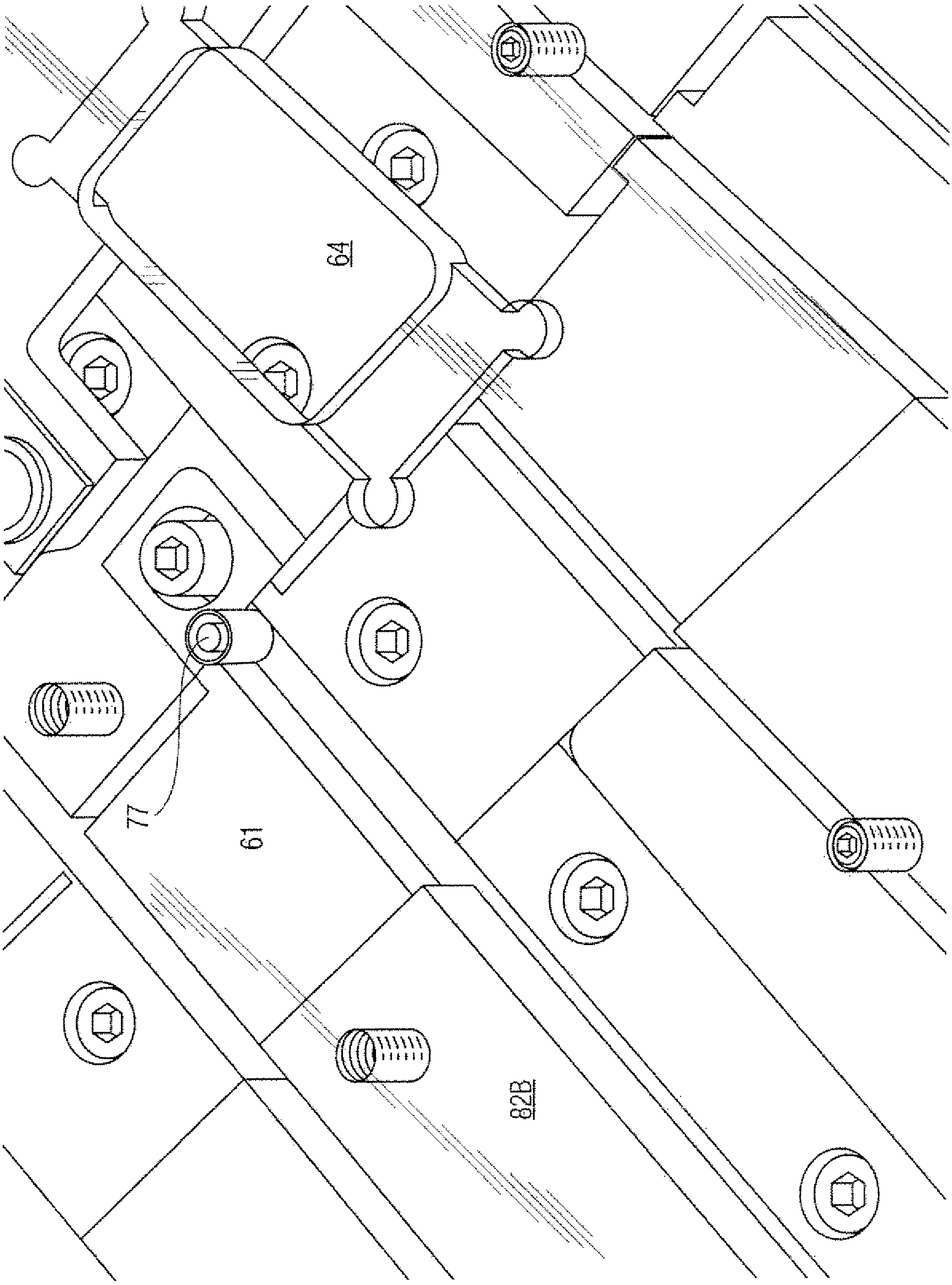



Fig. 6

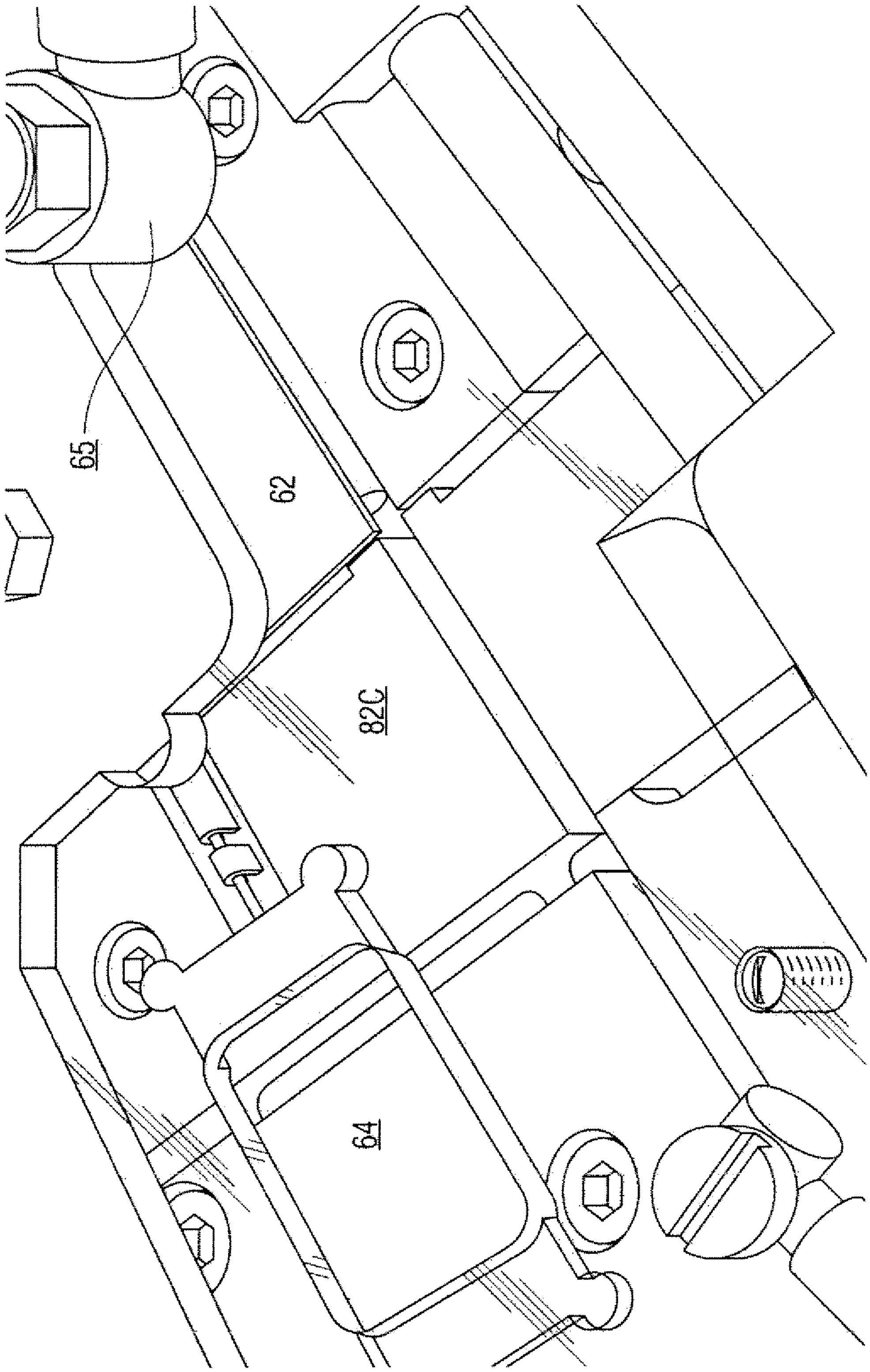
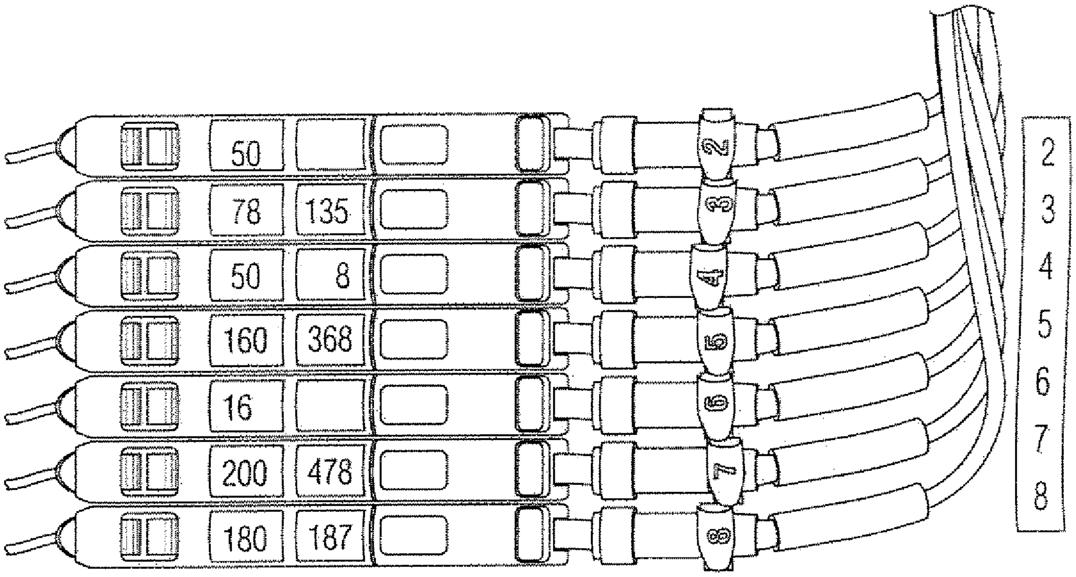



Fig. 7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368
16
200
478
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Fig. 8

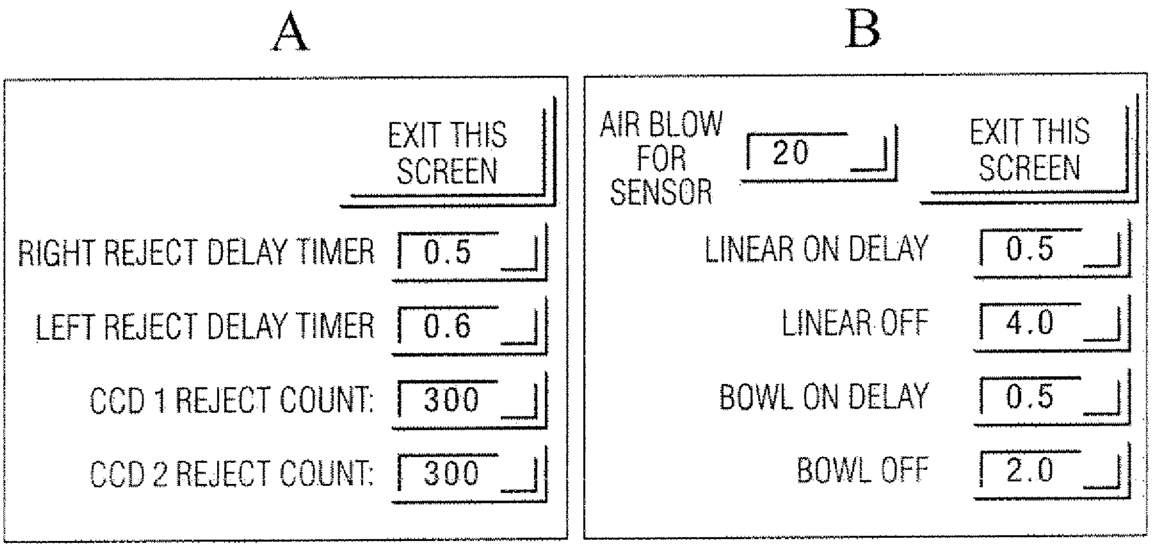
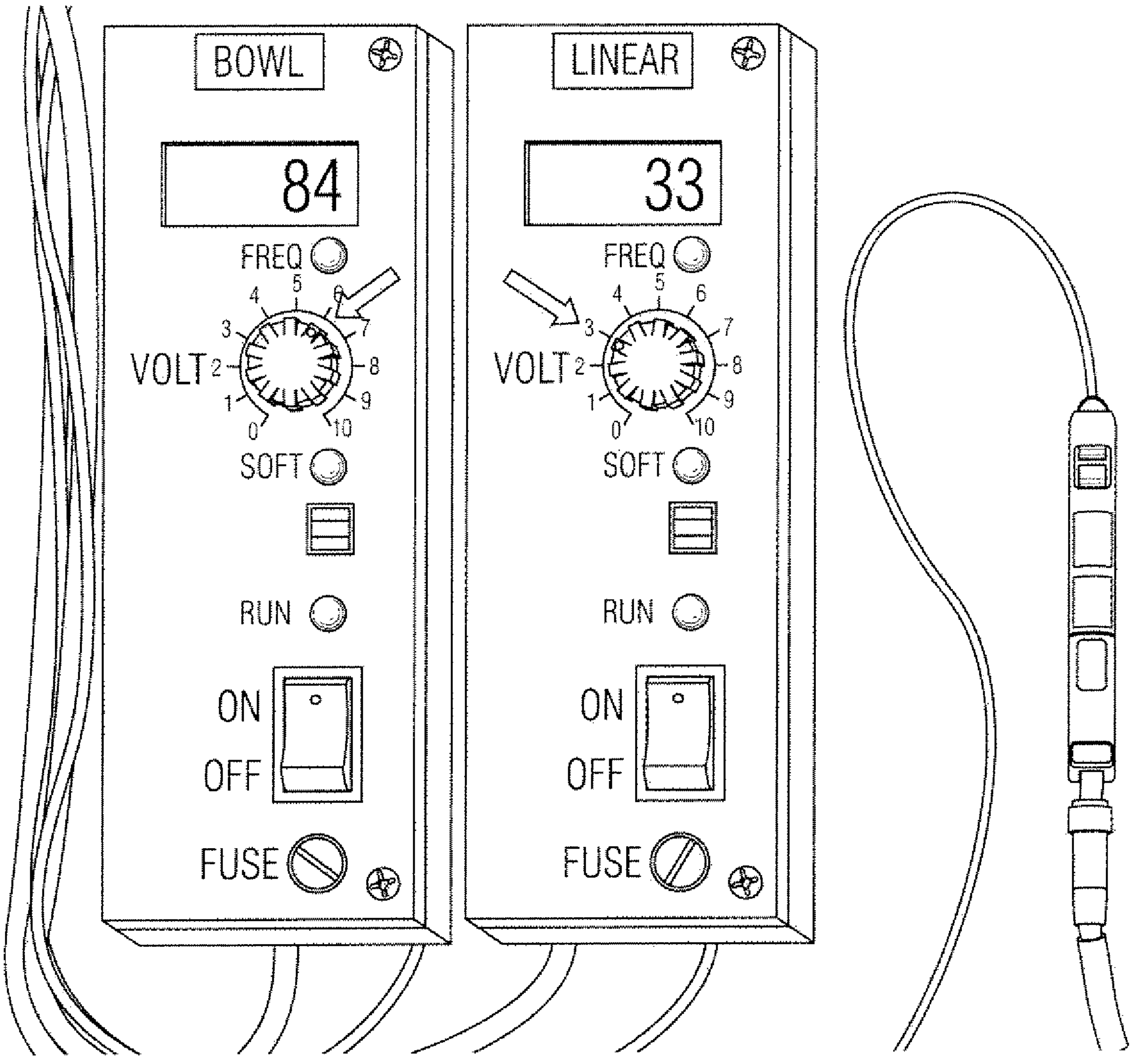

A
B
EXIT THIS SCREEN
RIGHT REJECT DELAY TIMER
0.5
LEFT REJECT DELAY TIMER
0.6
CCD 1 REJECT COUNT:
300
CCD 2 REJECT COUNT:
300
AIR BLOW FOR SENSOR
20
EXIT THIS SCREEN
LINEAR ON DELAY
0.5
LINEAR OFF
4.0
BOWL ON DELAY
0.5
BOWL OFF
2.0

Fig. 9


BOWL
84
FREQ
VOLT
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1
2
3
4
5
6
7
8
9
10
SOFT
RUN
ON
OFF
FUSE
LINEAR
33
FREQ
VOLT
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3
4
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6
7
8
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10
SOFT
RUN
ON
OFF
FUSE

Fig. 10

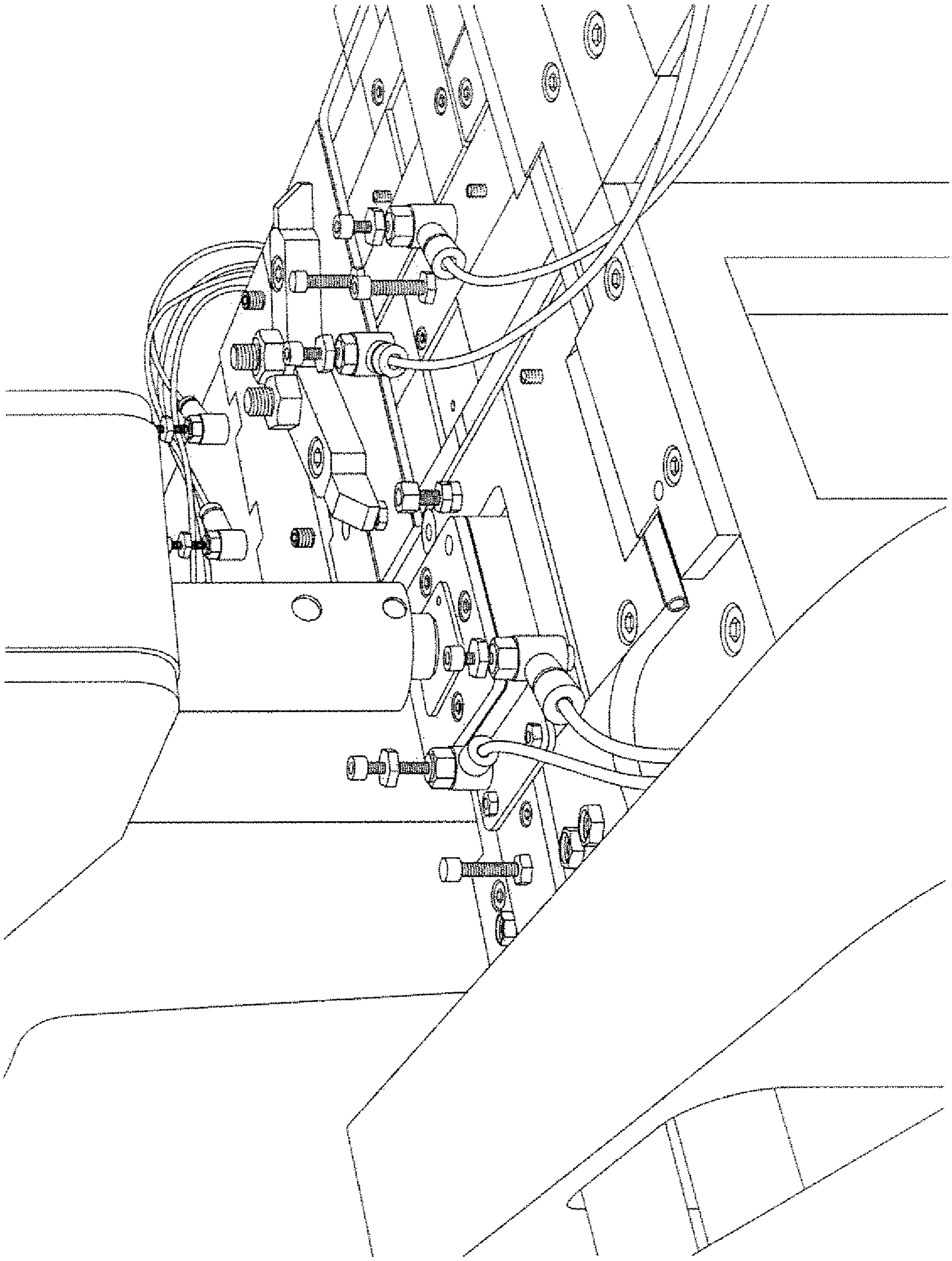

Fig. 11

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/32508

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G01H 1/00 (2010.01)
USPC - 73/572
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 73/572

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 73/570,571,572,649,663,863,864.91

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (PGPB, USPT, EPAB, JPAB); Google
Search terms: pneumatic, air, convey, transfer, slide, shift, propel, move, plural, multiple, select, choose, et al.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2004/0120776 A1 (Dragon et al.) 24 June 2004 (24.06.2004), para [0017]-[0025], Fig 1-5 | 1-15 |
| Y | US 5,738,467 A (Aidlin et al.) 14 April 1998 (14.04.1998), col 7, ln 29-45 | 1-14 |
| Y | US 5,156,278 A (Aaron et al.) 20 October 1992 (20.10.1992), col 4, ln 16-26, col 10, ln 64 to col 11, ln 9, Fig 16 | 6-13, 15 |
| Y | US 2004/0219803 A1 (Staecker et al.) 4 November 2004 (04.11.2004), abstract, claim 25 | 13, 15 |

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 June 2010 (18.06.2010) | 02 JUL 2010 |

| Name and mailing address of the ISA/US | Authorized officer: |
|---|---|
| Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-3201 | Lee W. Young<br>PCT Helpdesk: 571-272-4300<br>PCT OSP: 571-272-7774 |