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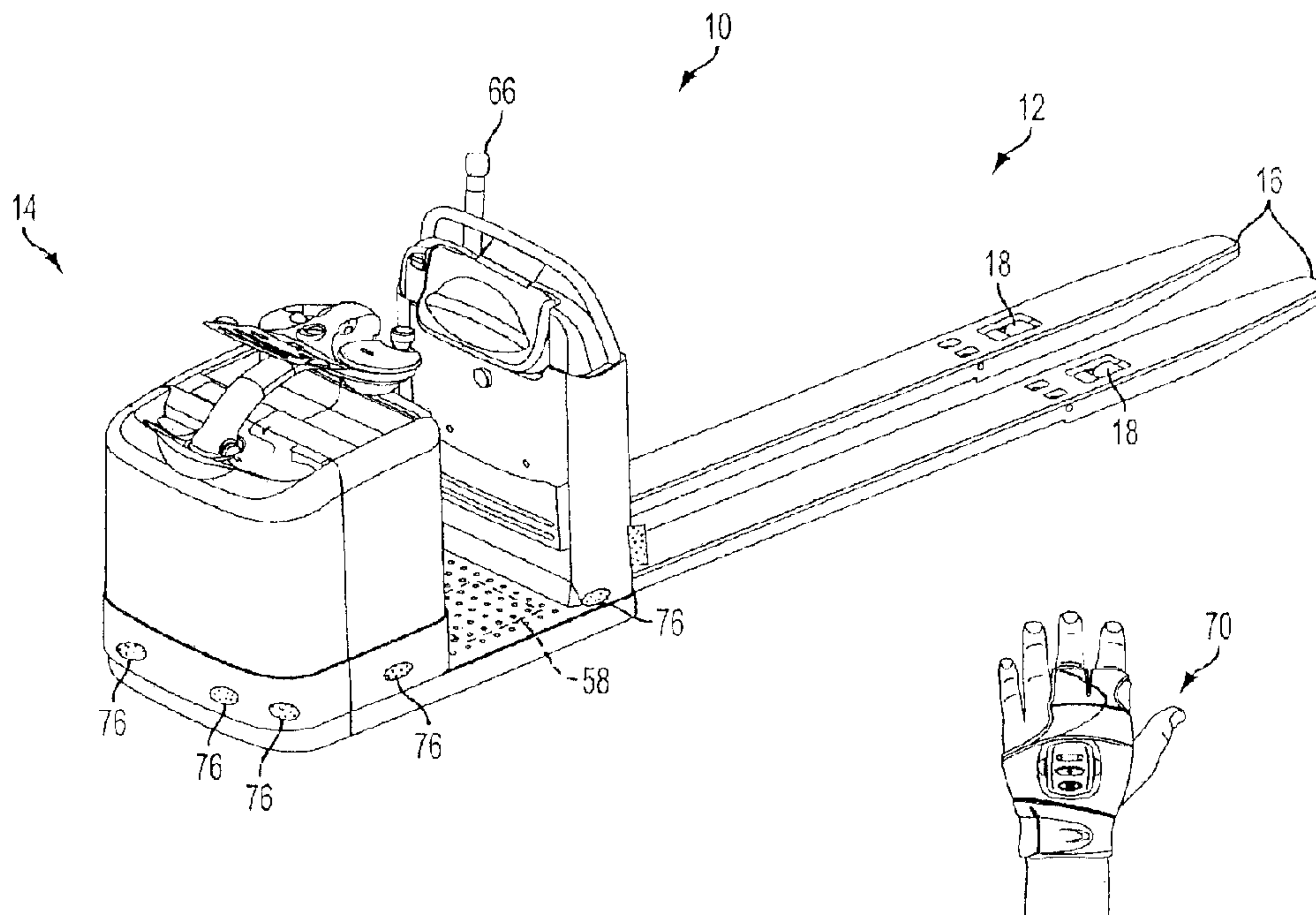
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(57) Abrégé/Abstract:

A finger-mounted remote control device (170) capable of wirelessly transmitting a travel request signal to a materials handling vehicle. The finger-mounted remote control device includes a rigid mounting structure adapted to be mounted over at least one finger of an operator's hand; a mounting strap coupled to said rigid mounting structure for securing said rigid mounting structure to the at least one finger; a wireless transmitter/power pack unit coupled to said rigid mounting structure; and control structure coupled to said mounting structure and comprising a switch (184b) adapted to be actuated by an operator's thumb so as to cause said wireless transmitter/power pack unit to generate a travel request signal to the materials handling vehicle, apparatus for remotely controlling a materials handling vehicle.

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ABSTRACT

A finger-mounted remote control device (170) capable of wirelessly transmitting a travel request signal to a materials handling vehicle. The finger-mounted remote control device includes a rigid mounting structure adapted to be mounted over at least one finger of an operator's hand; a mounting strap coupled to said rigid mounting structure for securing said rigid mounting structure to the at least one finger; a wireless transmitter/power pack unit coupled to said rigid mounting structure; and control structure coupled to said mounting structure and comprising a switch (184b) adapted to be actuated by an operator's thumb so as to cause said wireless transmitter/power pack unit to generate a travel request signal to the materials handling vehicle, apparatus for remotely controlling a materials handling vehicle.

APPARATUS FOR REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE

This Patent Application is a divisional of Canadian Patent Application No. 2,765,565 filed December 30, 2009.

TECHNICAL FIELD

[0001] The present invention relates in general to materials handling vehicles, and more particularly, to apparatus for remotely controlling materials handling vehicles.

BACKGROUND ART

[0002] Low level order picking trucks are commonly used for picking stock in warehouses and distribution centers. Such order picking trucks typically include load carrying forks and a power unit having a platform upon which an operator may step and ride while controlling the truck. The power unit also has a steerable wheel and corresponding traction and steering control mechanisms, e.g., a movable steering arm that is coupled to the steerable wheel. A control handle attached to the steering arm typically includes the operational controls necessary for driving the truck and operating its load handling features.

[0003] In a typical stock picking operation, an operator fills orders from available stock items that are located in storage areas provided along a plurality of aisles of a warehouse or distribution center. In this regard, the operator drives a low level order picking truck to a first location where item(s) are to be picked. In a pick process, the operator typically steps off the truck, walks over to the appropriate location and retrieves the ordered stock item(s) from their associated storage area(s). The operator then places the picked stock on a pallet, collection cage or other support structure carried by the forks of the order picking truck. Upon completing the pick process, the operator advances the order picking truck to the next location where item(s) are to be picked. The above process is repeated until all stock items on the order have been picked.

[0004] It is not uncommon for an operator to repeat the pick process several hundred times per order. Moreover, the operator may be required to pick numerous orders per shift. As such, the operator may be required to spend a considerable amount of time relocating and repositioning the order picking truck, which reduces the time available for the operator to spend picking stock.

DISCLOSURE OF INVENTION

[0005] In accordance with a first aspect of the present invention, a materials handling vehicle is provided comprising: a power unit; a load handling assembly coupled to the power unit; at least one obstacle detector mounted to the power unit to detect an object located along a path of travel of the power unit; a load sensor to generate a weight signal indicative of a weight of a load on the load handling assembly; and a controller. The detector generates a distance signal upon detecting an object corresponding to a distance between the detected object and the power unit. The controller receives the distance signal and the weight signal and generates a corresponding vehicle stop or maximum allowable speed signal based on the distance and weight signals. Conveniently, the load handling assembly is mounted at the rear of the power unit and the at least one obstacle detector is located on the vehicle so as to detect objects or obstacles in front of the vehicle. One or more obstacle detectors may also be arranged to detect objects to the front sides or the sides of the vehicle. The obstacle sensors may be adapted to detect objects within a predetermined detection zone (area or volume) relative to the vehicle or detector. The detection zone may be spaced from the vehicle or detector such that there is a region (or "dead zone") between the vehicle or detector and the near edge of the detection zone, within which objects or obstacles are undetectable. The one or more obstacle detectors may be arranged so as to define more than one detection zone, such as two, three, four or more detection zones. The detection zones may be exclusive or may overlap. In which zone an obstacle is detected may determine the response of the controller and hence the resultant movement of the vehicle.

[0006] For a given first load weight, if a sensed object is located at a distance within a first detection zone, a stop signal may be generated by the controller to effect stopping of the vehicle.

[0007] Wherein for the given first load weight, if a sensed object is located at a distance within a second detection zone spaced further away from the power unit than the first detection zone, then a first allowable maximum vehicle speed is defined corresponding to the first load weight and an object being detecting in the second detection zone.

[0008] Wherein for the given first load weight, if a sensed object is located at a distance within a third detection zone spaced further away from the power unit than the first and second detection zones, then a second allowable maximum vehicle speed greater than the first maximum is defined corresponding to the first load weight and an object being detected in the third detection zone.

[0009] The at least one obstacle sensor may comprise at least one first obstacle detector mounted at a first location on the power unit to detect an object located along a path of travel of said power unit beyond a dead zone of said first detector, and at least one second obstacle detector mounted at a second location on said power unit, spaced from said power unit first location, and capable of detecting an object in said dead zone of said first obstacle detector.

[0010] Thus, in accordance with a second aspect of the present invention, a materials handling vehicle is provided comprising: a power unit; a load handling assembly coupled to the power unit; at least one first obstacle detector mounted at a first location on the power unit to detect an object located along a path of travel of the power unit beyond or outside a dead zone of the first detector; and at least one second obstacle detector mounted at a second location on the power unit, spaced from the power unit first location, and capable of detecting an object in the dead zone of the first obstacle detector.

[0011] The at least one first obstacle detector may be located at a front portion of the power unit, such as at a front edge of the materials handling vehicle or the power unit. The at least one second obstacle detector may be spaced away from the first obstacle detector. Suitably the at least one second obstacle detector is mounted in a direction towards the load handling assembly, i.e. rearwards on the vehicle relative to the at least one first obstacle detector. The axial spacing (rearwards) of the at least one first obstacle sensor and the at least one second obstacle sensor may be approximately a distance corresponding to the length of a dead zone of the at least first obstacle sensor. Suitably, the detection zone of the at least one second obstacle detector overlaps the dead zone of the at least one first obstacle sensor.

[0012] In accordance with a third aspect of the present invention, a finger-mounted remote control device is provided capable of wirelessly transmitting a travel request signal to a materials handling vehicle comprising: a mounting structure adapted to be mounted over at least one finger of an operator's hand; a mounting strap coupled to the mounting structure for securing the mounting structure to the at least one finger; a wireless transmitter/power pack unit coupled to the mounting structure; and control structure coupled to the mounting structure and comprising a switch adapted to be actuated by an operator's thumb so as to cause the wireless transmitter/power pack unit to generate a travel request signal to the materials handling vehicle.

[0013] Preferably, the mounting strap contacts at least one finger of the operator's hand.

[0014] Suitably the mounting structure may be rigid. The rigid mounting structure may be formed from a rigid polymeric material.

In accordance with another aspect of the present invention there is provided a materials handling vehicle comprising: a power unit; a load handling assembly coupled to said power unit; at least one first obstacle detector mounted at a first location on said power unit to detect an object located along a path of travel of said power unit in a detection zone spaced from the vehicle beyond a dead zone (DZ) of said first detector; and at least one second obstacle detector mounted at a second location on said power unit, spaced from said power unit first location, and capable of detecting an object located along the path of travel of said power unit in a detection zone overlapping said dead zone (DZ) of said first obstacle detector.

[0015] Preferably, substantially the entirety of the remote control device is mounted and positioned directly over the at least one finger of the operator's hand. For example, in use, approximately 60% or more of the wireless transmitter/power pack unit may be positioned directly over the at least one finger of the operator's hand.

[0016] In accordance with a fourth aspect of the present invention, there is provided a materials handling vehicle comprising a power unit, a load handling assembly coupled to said power unit, at least one first obstacle detector mounted at a first location on said power unit to detect an object located along a path of travel of said power unit beyond a dead zone of said first detector, and at least one second obstacle detector mounted at a second location on said power unit. The at least one second obstacle detector may be spaced from said power unit first location, such that it is capable of detecting an object in said dead zone of said first obstacle detector. There may be one or more first obstacle detectors, such as 2, 3, 4 or 5; and there may be one or more second obstacle detectors, such as 2, 3, 4 or 5, depending on the desired number and direction of detection zones.

[0017] In a fifth aspect there is provided a materials handling vehicle comprising a power unit, a load handling assembly coupled to said power unit, and at least one obstacle detector mounted to said power unit to detect an object located along a path of travel of said power unit, and a controller. The detector generates a distance signal upon detecting an object corresponding to a distance between the detected object and said power unit, and transmits a distance signal to the controller. On receiving the signal from the detector, the controller generates a corresponding vehicle stop or maximum allowable speed signal based on said distance signal, in order to control the movement of the vehicle.

[0018] In a sixth aspect of the invention, there is provided a method of operating a materials handling vehicle of the invention. Thus, the materials handling vehicle may comprise a power unit and a load handling assembly coupled to said power unit, and a controller for controlling at least a speed parameter of the vehicle. The method comprising: providing at least one obstacle detector mounted to said power unit, the at least one obstacle detector adapted to detect an object located along a path of travel of said power unit and generate a distance signal upon detecting an object corresponding to a distance between the detected object and said power unit; providing a load sensor to generate a weight signal indicative of a weight of a load on said load handling assembly. A controller is adapted to receive a distance signal from said at least one obstacle detector and a weight signal from said load sensor and to execute a corresponding vehicle control function on said vehicle based on said distance and weight signals. Suitably, the corresponding vehicle control function is a

vehicle stop or maximum allowable speed signal. The method may further comprise providing a remote control device of the invention.

[0019] It should be appreciated that any one or more features of the materials handling vehicle described elsewhere herein may be incorporated into any of the aspects and embodiments of the invention. It will be appreciated that any features described in relation to a particular aspect or embodiment of the invention, such as in relation to a vehicle of the invention, may be incorporated into any other aspect or embodiment of the invention, e.g. in relation to a method of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0020] Fig. 1 is an illustration of a materials handling vehicle capable of remote control according to various aspects of the present invention;

[0021] Fig. 2 is a schematic diagram of several components of a materials handling vehicle capable of remote control according to various aspects of the present invention;

[0022] Fig. 3 is a schematic diagram illustrating detection zones of a materials handling vehicle according to various aspects of the present invention;

[0023] Fig. 4 is a schematic diagram illustrating an exemplary approach for detecting an object according to various aspects of the present invention;

[0024] Fig. 5 is a schematic diagram illustrating a plurality of detection zones of a materials handling vehicle according to further aspects of the present invention;

[0025] Figs. 6 and 8 illustrate a materials handling vehicle having first and second spaced-apart obstacle detectors;

[0026] Fig. 7 is a schematic view illustrating a materials handling vehicle having obstacle detectors located only at a front of the vehicle;

[0027] Figs. 9A and 9B are views illustrating a finger-mounted remote control device mounted to fingers of an operator;

[0028] Figs. 9C and 9D are views illustrating a communications device including exemplary components that can be utilized in the finger-mounted remote control device of Figs. 9A and 9B;

[0029] Figs 10A, 10C, 10D, and 10E illustrate various views of the finger-mounted remote control device of Figs. 9A and 9B;

[0030] Fig. 10B is an exploded view of the finger-mounted remote control device of Figs. 9A and 9B;

[0031] Fig. 10F is a cross sectional view of the finger-mounted remote control device of Figs. 9A and 9B;

[0032] Fig. 11 illustrates example lookup table data;

[0033] Fig. 12 is a flow chart of a method of implementing steer correction according to various aspects of the present invention; and

[0034] Fig. 13 is a schematic illustration of a materials handling vehicle traveling down a narrow warehouse aisle under remote wireless operation, which is automatically implementing a steer correction maneuver according to various aspects of the present invention.

MODES FOR CARRYING OUT THE INVENTION

[0035] In the following detailed description of the illustrated embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration, and not by way of limitation, specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and that changes may be made without departing from the spirit and scope of various embodiments of the present invention. In particular, unless otherwise stated, the features described with reference to a particular figure should not be considered as being limited only to that specific embodiment but may be incorporated into or exchanged with features described in relation to other specific embodiments as will be apparent to the skilled person.

[0036] Low Level Order Picking Truck:

[0037] Referring now to the drawings, and particularly to Fig. 1, a materials handling vehicle, which is illustrated as a low level order picking truck 10, includes in general a load handling assembly 12 that extends from a power unit 14. The load handling assembly 12 includes a pair of forks 16, each fork 16 having a load supporting wheel assembly 18. The load handling assembly 12 may include other load handling features in addition to, or in lieu of the illustrated arrangement of the forks 16, such as a load backrest, scissors-type elevating forks, outriggers or separate height adjustable forks. Still further, the load handling assembly 12 may include load handling features such as a mast, a load platform, collection cage or other support structure carried by the forks 16 or otherwise provided for handling a load supported and carried by the truck 10.

[0038] The illustrated power unit 14 comprises a step-through operator's station dividing a first end section of the power unit 14 (opposite the forks 16) from a second end section

(proximate the forks 16). The step-through operator's station provides a platform upon which an operator may stand to drive the truck 10. The platform also provides a position from which the operator may operate the load handling features of the truck 10. Presence sensors 58 may be provided, e.g., on, above, or under the platform floor of the operator's station. Still further, presence sensors 58 may be otherwise provided about the operator's station to detect the presence of an operator on the truck 10. In the exemplary truck of Fig. 1, the presence sensors 58 are shown in dashed lines indicating that they are positioned under the platform floor. Under this arrangement, the presence sensors 58 may comprise load sensors, switches, etc. As an alternative, the presence sensors 58 may be implemented above the platform 56, such as by using ultrasonic, capacitive or other suitable sensing technology.

[0039] An antenna 66 extends vertically from the power unit 14 and is provided for receiving control signals from a corresponding remote control device 70. The remote control device 70 may comprise a transmitter that is worn or otherwise maintained by the operator. As an example, the remote control device 70 may be manually operable by an operator, e.g., by pressing a button or other control, to cause the device 70 to wirelessly transmit at least a first type signal designating a travel request to the vehicle, thus requesting the vehicle to travel by a predetermined amount. The remote control device 70 may comprise a glove-like structure 70, see Fig. 1, such as disclosed in U.S. Provisional Patent Application Serial No. 60/825,688, filed September 14, 2006 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE," U.S. Patent Application Serial No. 11/855,310, entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE," U.S. Patent Application Serial No. 11/855,324, entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE."

[0040] The remote control device may alternatively comprise a finger-mounted remote control device 170, as illustrated in Figs. 9A, 9B and 10A-10F. The finger-mounted remote control device 170 comprises, in the illustrated embodiment, a polymeric rigid base 172, a polymeric rigid upper housing 174 and a pivotable latch 173 coupled to the base 172 via a generally straight spring rod 273 so as to be spring biased to a home/locking position, as shown in Fig. 10F. The latch 173 can be moved generally linearly/laterally against the bias of the spring bar 273 in a direction, designated by arrow A in Fig. 10F, to a release position. The base and upper housing 172 and 174 are coupled together via screws 273A and define a docking area 175 for removably receiving a wireless transmitter/power pack unit 176. The base and upper housing 172 and 174 may alternatively be coupled together using any suitable means, such as via an adhesive or an ultrasonic welding operation.

[0041] The wireless transmitter/power pack unit 176 of the invention may comprise any of the components or features set out below (see also Figs. 9C and 9D), which are described in more detail with respect to the communications device of U.S. Patent Application Serial No. 11/855,324, entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING

VEHICLE." For example, the wearable wireless remote control device 170 may comprise a wireless transmitter and a travel control, e.g., a button or switch that is communicably coupled to the wireless transmitter. Actuation of the travel control causes the wireless transmitter to transmit a first type signal, which may, for example, request the truck to advance in a first direction. Depending upon the particular implementation, the wireless remote control device 170 may further include a power pack such as a battery for powering the remote control device electronics, a control area where the travel control is located on the operator, e.g., on or about the finger(s) of the operator, and a communications link between the transmitter and the control area where the transmitter is physically spaced from the control area when worn by the operator.

[0042] Referring to Figs. 9C and 9D, a communications device 264 according to an embodiment of the invention includes an exemplary arrangement of components on a first surface (shown in Fig. 9C) and components on a corresponding second surface (shown in Fig. 9D) of a circuit board. The communications device 264 comprises a carrier 270, e.g., a double sided printed circuit board that includes on a first side thereof, regulator circuitry 272 for regulating the power utilized to operate the communications device 264, display indicators 274 such as Light Emitting Diodes (LEDs) that provide a visual feedback as to the operation of the communications device 264, input components 276, such as switches, a processor 278 and a crystal 280 or other suitable processor clocking circuitry (if necessary by the particular processor). The carrier further supports on a second side thereof, a battery 282, a communications circuitry 284 such as a transmitter, receiver, transceiver, etc., and contacts 286 that communicate with the connection pads of the docking area 254 when the communications device 264 is docked in a corresponding remote control device 170.

[0043] The display indicators 274 may be utilized to provide a visual feedback to the operator as to the state of the remote control system. For example, a first one of the indicators may be used as a fault condition indicator. Another indicator 274 may be utilized to indicate a low battery as represented by the icon of a battery. Other uses of the indicators may be

implemented, and more or less than two indicators may be provided. The remote control device 170 may further include additional alert elements such as a display screens sounds or other features that provide a visual and/or audible cue as to the status of the remote and/or the associated truck 10.

[0044] The input components 276 may comprise for example, two buttons. A first one of the buttons may correspond to a horn button. When the horn button is pressed, a corresponding message is transmitted to the receiver 102 on the truck 10 to sound the truck horn. A second one of the buttons may comprise an emergency disconnect button. Pressing this button causes an emergency disconnect command to be transmitted to the receiver 102 on the truck 10. In response to receiving an emergency disconnect command, the truck 10 may stop and power down, thus requiring an operator to reinitiate a startup procedure to restart the truck as described in greater detail herein. Alternatively, the second one of the buttons may comprise a stop button. Pressing this button causes the truck 10 to stop.

[0045] The transmitter in the communications circuitry 284 may transmit information in an analog or digital form using any suitable proprietary or standardized wireless transmission formats. For example, transmission may be realized using existing technologies, such as 802.11, 802.16, Bluetooth, short message service (SMS), amplitude shift keying (ASK), on-off keying (OOK), wireless local area network (WLAN), code division multiple access (CDMA), amplitude modulation (AM), frequency modulation (FM), universal mobile telecommunications system (UMTS), cellular phone technology such as global system for mobile communications (GSM), etc. In practice, the manner in which the transmitter transmits messages should correspond to a format that is recognizable by the corresponding receiver on the truck 10. Moreover, the communications circuitry 284 of the remote control device 170 may also contain its own receiver for bi-directional communication with a corresponding truck 10.

[0046] When the communications device 264 is properly docked on a corresponding remote control device 170, the remote control device 170 provides a convenient platform for enabling a truck operator to remotely control their vehicle. For example, a user can operate a "Go" button, which communicates with the processor 278 of the communications device 264 and which will be described in greater detail below with respect to Figs. 9A, 9B, and 10A-10F. The "Go" button causes the processor 278 to format and transmit a travel request that advances the truck if the travel request is received by the truck and is determined to be a valid command.

[0047] If the travel request is properly received by the receiver 102 and is determined to

be a valid travel request, the truck 10 may be wirelessly remotely controlled to travel for a prescribed time and/or distance, and then enter a controlled brake or coast as described in greater detail herein. The "Go" button may alternatively facilitate travel of the truck 10 for as long as there is maintained actuation of the button (or until an intervening event occurs, such as the truck 10 reaching a maximum travel distance, travel time, detecting an environmental or operational condition that stops the truck, etc. The communications device 264 may also optionally include steer and or directional controls to provide commands to the truck 10 to adjust the truck's steer angle as described in greater detail herein.

[0048] Still further, an optional "Stop" button may be provided, e.g., on the communications device 264 to stop the truck, which may be useful where the coast function is implemented. If the stop command is properly received by the receiver 102, the truck 10 will be controlled to come to a controlled stop. Alternatively, an optional additional button may correspond to a coast command, which, if properly received by the receiver 102 on the truck 10, will cause the truck 10 to coast to a rest.

[0049] When any of the buttons on the remote control device 170 are pressed, the processor 278 formats an appropriate message and transmits the resulting signal via the transmitter 284 to the receiver 102. In this regard, the processor 278 may append to the command, a sequence, control or other identification information, a time stamp, channel indication or other data necessary for the receiver 102 to discriminate that the particular remote control device 170 is a valid communications device, to authenticate operators, to log data for historical or other purposes, etc.

[0050] While the remote control device 170 is illustrated as a garment that is worn by the operator on the fingers, other configurations may alternatively be implemented. For example, the transmitter, power supply and or any of one or more controls such as the "Go" button may be worn separately or together on any part of the body where it is comfortable, practical or desirable, as the specific application dictates.

[0051] Further, the "Go" button may optionally be programmed to support multiple commands. For example, the remote control device 170 may be configured to transmit a "stop" command if a single actuation of the button is detected. Moreover, a "travel" command may be transmitted if a double click or double actuation of the button is detected within a predetermined time period.

[0052] Referring back to Figs. 9A, 9B and 10A-10F, in the illustrated embodiment, a transmitter antenna is also housed in the wireless transmitter/power pack unit 176.

[0053] The wireless transmitter/power pack unit 176 is releasably held within the docking area 175 via the latch 173, see Fig. 10F. A contact plate 178 is mounted to the base 172 via screws or pins molded into the base 172 and swaged over the plate (not shown) and includes one or more contacts (not shown) on an upper surface 178A of the contact plate 178 for engaging corresponding contacts on the wireless transmitter/power pack unit 176. The wireless transmitter/power pack unit 176 can be removed from the docking area 175 for recharging a power pack or battery contained therein. It is also contemplated that the wireless transmitter/power pack unit 176 may be non-removable, i.e., integral with or sealed within the base 172 and upper housing 174. In this latter embodiment, the wireless transmitter/power pack unit 176 includes a receptacle (not shown) for receiving an AC adapter for charging the power or battery pack.

[0054] The rigid base 172 is provided with a first slot 172A for receiving a holding strap 190, which will be discussed below, see Figs. 10D and 10E. The rigid base 172 also has a finger-engaging extension 172B extending downward from a lower surface 172C of the base 172 so as to define a portion of a first finger receiving area 200 and a second finger receiving area 202, see Fig. 10F.

[0055] The finger-mounted remote control device 170 further comprises control structure 180. The control structure 180 comprises a backing plate 182 having a recess 282A and a two-state switch 183 received in the recess 282A. Conductors or wires (not shown) extend from the switch 183 to a lower surface 178B of the contact plate 178 such that signals generated by the switch 183 when activated, as will be discussed below, are delivered via the conductors to the contact plate 178 and from the contact plate 178 to the transmitter/power pack unit 176. The backing plate 182 further comprises four bores 182A and a curved lower surface 182C, which defines a portion of the first finger receiving area 200, see Figs. 10B, 10E and 10F.

[0056] The control structure 180 further comprises a button and support plate assembly 184. The support plate assembly 184 may be formed from a rigid polymeric material and comprises four bores 184A that align with the four bores 182A in the backing plate 182. A "Go" button 184B, defined by a flexible polymeric member, is integral with or coupled to a surrounding portion of the support plate 184. The button 184B covers the switch 183. A lower portion 185 of the support plate assembly 184 is provided with a second slot 185A for receiving the holding strap 190. A curved lower surface 185B of the support plate lower portion 185 defines a portion of the first finger receiving area 200, see Figs. 10E and 10F. An outer cover plate 186 having an opening 186A is fitted over the button and support plate

assembly 184. Four screws 186B extend through the bores 182A in the backing plate 182 and the bores 184A in the support plate 184 and are received in threaded openings (not shown) in the outer cover plate 186. The cover plate 186 further comprises first and second laterally extending ears 286 provided with bores 286A through which two of the bolts 273A, noted above, pass. Hence, the bolts 273 couple the control structure 180 to the base and upper housing 172 and 174.

[0057] As illustrated in Figs. 9A and 9B, the remote control device 170 is adapted to be fitted over index and middle fingers F_I and F_M of an operator, wherein the index finger is received in the first finger receiving area 200 and the middle finger is received in the second finger receiving area 202. Both right and left hand versions of the control device 170 may be created.

[0058] The finger-mounted remote control device 170 is compact. As is apparent from Figs. 9A and 9B, substantially the entirety of the remote control device 170 is mounted and positioned directly over the index and middle fingers F_I and F_M of an operator. Hence, approximately 60% or more of the wireless transmitter/power pack unit 176 is positioned directly over the operator's fingers F while a small remaining portion extends over the hand portion HP extending away from the base F_B of the fingers F , see Fig. 9.

[0059] The control device 170 is releasably held on the operator's index and middle fingers via the holding strap 190. A first end 190A of the holding strap 190 is threaded through the first slot 172A in the rigid base 172 and the second slot 185A in the lower portion 185 of the support plate 184. A second end 190B of the strap 190 is enlarged so as not to pass through the first slot 172A, see Fig. 10E. A first portion 190C of the strap 190, extending generally from the strap second end 190B to the second slot 185A, extends across the operator's index and middle fingers, see Fig. 9. A second portion 190D of the strap 190, extending generally from the second slot 185A to the strap first end 190A, is folded back onto the strap first portion 190C and releasably attached to the strap first portion 190C such as by hook and loop fasteners, i.e., Velcro (trademark) or like fastening structure. It is noted that other types of mounting straps 190 may be used, such as, for example expandable/flexible straps, rigid or flexible rings, etc.

[0060] It is contemplated that the finger-mounted remote control device 170 may be worn by an operator over a glove. In the illustrated embodiment, the finger-mounted remote control device 170 is durable and long lasting since the rigid base 172, the upper housing 174 and the outer cover plate 186 are preferably formed from a durable and rigid polymeric material, such as acrylonitrile butadiene styrene (ABS), polycarbonate or nylon. The rigid

base 172, the upper housing 174 and the outer cover plate 186 define a durable, generally non-flexible and rigid mounting structure 270.

[0061] An operator can easily manually actuate the go button 184B via his thumb, thereby actuating the switch 183, to cause the wireless transmitter/power pack unit 176 to wirelessly transmit at least a first type signal designating a travel request or command to the vehicle. It is contemplated that the travel request may result in the vehicle 10 traveling by a predetermined distance or for a predetermined amount of time. It is also contemplated that a brief actuation of the go button 184B may result in the vehicle 10 traveling for a predetermined distance or for a predetermined amount of time, while a prolonged actuation of the go button 184B may result in continuous movement of the vehicle 10 until the go button 184B is released.

[0062] It is noted that the finger-mounted remote control device 170 described herein is an exemplary configuration and may structurally modified without departing from the spirit and scope of the invention. For example, one or more components of the finger-mounted remote control device 170 may be combined in an integral component, or components may be substituted for alternate components that effect a similar/identical purpose. As a few examples, the support plate assembly 184 and the outer cover plate 186 may be combined into an integral piece, which integral piece may be coupled to the backing plate 182 by structure other than screws 186B.

[0063] The truck 10 also comprises one or more obstacle sensors 76, which are provided about the vehicle, e.g., towards the first end section of the power unit 14 and/or to the sides of the power unit 14. The obstacle sensors 76 include at least one contactless obstacle sensor on the vehicle, and are operable to define at least one detection zone, each detection zone defining an area at least partially in front of a forward traveling direction of the vehicle (i.e. with the load handling assembly 12, such as forks 16 facing backwards), particularly when the vehicle is traveling under remote control in response to a travel request as will be described in greater detail herein. The obstacle sensors 76 may comprise any suitable proximity detection technology, such as an ultrasonic sensors, optical recognition devices, infrared sensors, laser sensors, etc., which are capable of detecting the presence of objects/obstacles within the predefined detection zones of the power unit 14.

[0064] In practice, the truck 10 may be implemented in other formats, styles and features, such as an end control pallet truck that includes a steering tiller arm that is coupled to a tiller handle for steering the truck. In this regard, the truck 10 may have similar or alternative control arrangements to that shown in Fig. 1. Still further, the truck 10, remote control

system and/or components thereof, may comprise any additional and/or alternative features, such as set out in U.S. Provisional Patent Application Serial No. 60/825,688, filed September 14, 2006 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE;" U.S. Patent Application Serial No. 11/855,310, filed September 14, 2007 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE;" U.S. Patent Application Serial No. 11/855,324, filed September 14, 2007 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE;" U.S. Provisional Patent Application Serial No. 61/119,952, filed December 4, 2008 entitled "MULTIPLE ZONE SENSING FOR REMOTELY CONTROLLED MATERIALS HANDLING VEHICLES;" U.S. Provisional Patent Application Serial No. 61/234,866, filed August 18, 2009, entitled "STEER CORRECTION FOR A REMOTELY OPERATED MATERIALS HANDLING VEHICLE;" and/or U.S. Patent No. 7,017,689, issued March 28, 2006, entitled "ELECTRICAL STEERING ASSIST FOR MATERIAL HANDLING VEHICLE."

[0065] Control System for Remote Control of a Low Level Order Picking Truck:

[0066] Referring to Fig. 2, a block diagram 100 illustrates a control arrangement for integrating remote control commands with the truck 10. The antenna 66 is coupled to a receiver 102 for receiving commands issued by the remote control device 70, 170. The receiver 102 passes the received control signals to a controller 103, which implements the appropriate response to the received commands. The response may comprise one or more actions, or inaction, depending upon the logic that is being implemented. Positive actions may comprise controlling, adjusting or otherwise affecting one or more components of the truck 10. The controller 103 may also receive information from other inputs 104, e.g., from sources such as the presence sensors 58, the obstacle sensors 76, switches, load sensors, encoders and other devices/features available to the truck 10 to determine appropriate action in response to the received commands from the remote control device 70, 170. The sensors 58, 76, etc. may be coupled to the controller 103 via the inputs 104 or via a suitable truck network, such as a control area network (CAN) bus 110.

[0067] In an exemplary arrangement, the remote control device 70, 170 is operative to wirelessly transmit a control signal that represents a first type signal such as a travel command to the receiver 102 on the truck 10. The travel command is also referred to herein as a "travel signal", "travel request" or "go signal". The travel request is used to initiate a

request to the truck 10 to travel by a predetermined amount, e.g., to cause the truck 10 to advance or jog in a first direction by a limited travel distance. The first direction may be defined, for example, by movement of the truck 10 in a power unit 14 first, i.e., load handling assembly 12 (e.g. forks 16) to the back, direction. However, other directions of travel may alternatively be defined, and therefore, obstacle detectors may be positioned on the vehicle appropriately. Moreover, the truck 10 may be controlled to travel in a generally straight direction or along a previously determined heading. Correspondingly, the limited travel distance may be specified by an approximate travel distance, travel time or other measure.

[0068] Thus, a first type signal received by the receiver 102 is communicated to the controller 103. If the controller 103 determines that the travel signal is a valid travel signal and that the current vehicle conditions are appropriate (explained in greater detail below), the controller 103 sends a signal to the appropriate control configuration of the particular truck 10 to advance and then stop the truck 10. As will be described in greater detail herein, stopping the truck 10 may be implemented, for example, by either allowing the truck 10 to coast to a stop or by applying a brake to stop the truck.

[0069] As an example, the controller 103 may be communicably coupled to a traction control system, illustrated as a traction motor controller 106 of the truck 10. The traction motor controller 106 is coupled to a traction motor 107 that drives at least one steered wheel 108 of the truck 10. The controller 103 may communicate with the traction motor controller 106 so as to accelerate, decelerate, adjust and/or otherwise limit the speed of the truck 10 in response to receiving a travel request from the remote control device 70, 170. The controller 103 may also be communicably coupled to a steer controller 112, which is coupled to a steer motor 114 that steers at least one steered wheel 108 of the truck 10. In this regard, the truck may be controlled by the controller 103 to travel an intended path or maintain an intended heading in response to receiving a travel request from the remote control device 70, 170.

[0070] As yet another illustrative example, the controller 103 may be communicably coupled to a brake controller 116 that controls truck brakes 117 to decelerate, stop or otherwise control the speed of the truck in response to receiving a travel request from the remote control device 70, 170. Still further, the controller 103 may be communicably coupled to other vehicle features, such as main contactors 118, and/or other outputs 119 associated with the truck 10, where applicable, to implement desired actions in response to implementing remote travel functionality.

[0071] According to various aspects of the present invention, the controller 103 may communicate with the receiver 102 and with the traction controller 106 to operate the vehicle

under remote control in response to receiving travel commands from the associated remote control device 70, 170. Moreover, the controller 103 may be configured to perform a first action if the vehicle is traveling, for example, under remote control in response to a travel request, and an obstacle is detected in a first one of the detection zones. The controller 103 may be further configured to perform a second action different from the first action if the vehicle is traveling (e.g. under remote control in response to a travel request) and an obstacle is detected in a second one of the detection zones. In this regard, when a travel signal is received by the controller 103 from the remote control device 70, 170, any number of factors may be considered by the controller 103 to determine whether the travel signal should be acted upon and what action(s) should be taken, if any. The particular vehicle features, the state/condition of one or more vehicle features, vehicle environment, etc., may influence the manner in which controller 103 responds to travel requests from the remote control device 70, 170.

[0072] The controller 103 may also refuse to acknowledge the travel signal depending upon vehicle condition(s), e.g., that relate to environmental or/ operational factor(s). For example, the controller 103 may disregard an otherwise valid travel request based upon information obtained from one or more of the sensors 58, 76. For example, according to various aspects of the present invention, the controller 103 may optionally consider factors such as whether an operator is on the truck 10 when determining whether to respond to a travel command from the remote control device 70, 170. For example, as noted above, the truck 10 may comprise at least one presence sensor 58 for detecting whether an operator is positioned on the vehicle. In this regard, the controller 103 may be further configured to respond to a travel request to operate the vehicle under remote control when the presence sensor(s) 58 designate that no operator is on the vehicle.

[0073] Any other number of reasonable conditions may also/alternatively be implemented by the controller 103 to interpret and take action in response to received signals. Other exemplary factors are set out in greater detail in U.S. Provisional Patent Application Serial No. 60/825,688, filed September 14, 2006 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE," U.S. Patent Application Serial No. 11/855,310, filed September 14, 2007 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE," U.S. Patent Application Serial No. 11/855,324, filed September 14, 2007 entitled "SYSTEMS AND METHODS OF REMOTELY CONTROLLING A MATERIALS HANDLING VEHICLE," U.S. Provisional Patent Application Serial No. 61/119,952, filed December 4,

2008 entitled "MULTIPLE ZONE SENSING FOR REMOTELY CONTROLLED MATERIALS HANDLING VEHICLES," and U.S. Provisional Patent Application Serial No. 61/234,866, filed August 18, 2009, entitled "STEER CORRECTION FOR A REMOTELY OPERATED MATERIALS HANDLING VEHICLE".

[0074] Upon acknowledgement of a travel request, the controller 103 interacts with the traction motor controller 106, e.g., directly, indirectly, via the CAN bus 110, etc., to advance the truck 10. Depending upon the particular implementation, the controller 103 may interact with the traction motor controller 106 to advance the truck 10 by a predetermined distance. Alternatively, the controller 103 may interact with the traction motor controller 106 to advance the truck 10 for a period of time in response to the detection and maintained actuation of a travel control on the remote 70. Further alternatively, the truck 10 may be configured to jog for as long as a travel control signal is received. Still further alternatively, the controller 103 may be configured to "time out" and stop the travel of the truck 10 based upon a predetermined event, such as exceeding a predetermined time period or travel distance regardless of the detection of maintained actuation of a corresponding control on the remote control device 70, 170.

[0075] The remote control device 70, 170 may also be operative to transmit a second type signal, such as a "stop signal", designating that the truck 10 should brake and/or otherwise come to rest. The second type signal may also be implied, e.g., after implementing a "travel" command, e.g., after the truck 10 has traveled a predetermined distance, traveled for a predetermined time, etc., under remote control in response to the travel command. If the controller 103 determines that the signal is a stop signal, the controller 103 sends a signal to the traction controller 106, the brake controller 116 and/or other truck component to bring the truck 10 to a rest. As an alternative to a stop signal, the second type signal may comprise a "coast signal", designating that the truck 10 should coast, eventually slowing to rest or a "controlled deceleration signal."

[0076] The time that it takes to bring the truck 10 to a complete rest may vary, depending for example, upon the intended application, the environmental conditions, the capabilities of the particular truck 10, the load on the truck 10 and other similar factors. For example, after completing an appropriate jog movement, it may be desirable to allow the truck 10 to "coast" some distance before coming to rest so that the truck 10 stops slowly. This may be achieved by utilizing regenerative braking to slow the truck 10 to a stop. Alternatively, a braking operation may be applied after a predetermined delay time to allow a predetermined range of

additional travel to the truck 10 after the initiation of the stop operation. It may also be desirable to bring the truck 10 to a relatively quicker stop, e.g., if an object is detected in the travel path of the truck 10 or if an immediate stop is desired after a successful jog operation. For example, the controller may apply predetermined torque to the braking operation. Under such conditions, the controller 103 may instruct the brake controller 116 to apply the brakes 117 to stop the truck 10.

[0077] Detection Zones of a Materials Handling Vehicle:

[0078] Referring to Fig. 3, according to various aspects of the present invention, one or more obstacle sensors 76 are configured so as to collectively enable detection of objects/obstacles within multiple “detection zones”. In this regard, the controller 103 may be configured to alter one or more operational parameters of the truck 10 in response to detection of an obstacle in one or more of the detection zones as set out in greater detail herein. The control of the vehicle utilizing detection zones may be implemented when an operator is riding/driving the vehicle. The control of the vehicle utilizing detection zones may also be integrated with supplemental remote control as set out and described more fully herein. When an operator is riding the vehicle the operator may have the option of disabling one or more of the detection zones and/or one or more of the responses of the controller when the detectors detect an object, as described below.

[0079] Although six obstacle sensors 76 are shown for purposes of clarity of discussion herein, any number of obstacle sensors 76 may be utilized. The number of obstacle sensors 76 will likely vary, depending upon the technology utilized to implement the sensor, the size and/or range of the detection zones, the number of detection zones, and/or other factors.

[0080] In the illustrative example, a first detection zone 78A is located proximate to the power unit 14 of the truck 10. A second detection zone 78B is defined adjacent to the first detection zone 78A and appears to generally circumscribe the first detection zone 78A. A third area is also conceptually defined as all area outside the first and second detection zones 78A, 78B. Although the second detection zone 78B is illustrated as substantially circumscribing the first detection zone 78A, any other practical arrangement that defines the first and second detection zones 78A, 78B may be realized. For example, all or certain portions of the detection zones 78A, 78B may intersect, overlap or be mutually exclusive. Moreover, the particular shape of the detection zones 78A, 78B can vary. Still further, any number of detection zones may be defined, further examples of which are described in greater detail herein.

[0081] Still further, the detection zones need not surround the entire truck 10. Rather, the shape of the detection zones may be dependent upon the particular implementation as set out in greater detail herein. For example, if the detection zones 78A, 78B are to be used for speed control while the truck 10 is moving without an operator riding thereon, under remote travel control in a power unit first (forks to the rear) orientation, then the detection zones 78A, 78B may be oriented forward of the direction of travel of the truck 10. However, the detection zones can also cover other areas, e.g., adjacent to the sides of the truck 10.

[0082] According to various aspects of the present invention, the first detection zone 78A may further designate a "stop zone". Correspondingly, the second detection zone 78B may further designate a "first speed zone". Under this arrangement, if an object, e.g., some form of obstacle is detected within the first detection zone 78A, and the materials handling vehicle 10 is traveling, for example, under remote control in response to a travel request, then the controller 103 may be configured to implement an action such as a "stop action" to bring the truck 10 to a stop. In this regard, travel of the truck 10 may continue once the obstacle is clear, or a second, subsequent travel request from the remote control device 70, 170 may be required to restart travel of the truck 10.

[0083] If a travel request is received from the remote control device 70, 170 while the truck is at rest and an object is detected within the first detection zone 78A, then the controller 103 may refuse the travel request and keep the truck at rest until the obstacle is cleared out of the stop zone.

[0084] If an object/obstacle is detected within the second detection zone 78B, and the materials handling vehicle 10 is traveling, for example, under remote control in response to a travel request, then the controller 103 may be configured to implement a different action. For example, the controller 103 may implement a first speed reduction action to reduce the speed of the vehicle to a first predetermined speed, such as where the vehicle is traveling at a speed greater than the first predetermined speed.

[0085] Thus, assume the truck 10 is traveling in response to implementing a travel request from the remote control device at a speed V_2 as established by a set of operating conditions where the obstacle sensors 76 do not detect an obstacle in any detection zone. If the truck is initially at rest, the truck may be accelerated up to speed V_2 . The detection of an obstacle within the second detection zone 78B (but not the first detection zone 78A) may cause the truck 10, e.g., via the controller 103 to alter at least one operational parameter, e.g., to slow down the truck 10 to a first predetermined speed V_1 , which is slower than the speed V_2 . That is, $V_1 < V_2$. Once the obstacle is cleared from the second detection zone 78B, the truck 10

may resume its speed V2, or the truck 10 may maintain its speed V1 until the truck stops and the remote control device 70, 170 initiates another travel request. Still further, if the detected object is subsequently detected within the first detection zone 78A, the truck 10 will be stopped as described more fully herein.

[0086] Assume as an illustrative example, that the truck 10 is configured to travel at a speed of approximately 2.5 miles per hour (mph) (4 Kilometers per hour (Km/h)) if the truck 10 is traveling without an operator onboard and is under remote control in response to a travel request from a corresponding remote control 70, so long as no object is detected in a defined detection zone. If an obstacle is detected in the second detection zone 78B, then the controller 103 may adjust the speed of the truck 10 to a speed of approximately 1.5 mph (2.4 Km/h) or some other speed less than 2.5 miles per hour (mph) (4 Kilometers per hour (Km/h)). If an obstacle is detected in the first detection zone 78A, then the controller 103 stops the truck 10.

[0087] The above example assumes that the truck 10 is traveling under remote control. In this regard, the obstacle sensors 76 can be used to adjust the operating conditions of the unoccupied truck 10. However, the obstacle sensors 76 and corresponding controller logic may also be operative when the truck 10 is being driven by an operator, e.g., riding on the platform or other suitable location of the truck 10. Thus, according to various aspects of the present invention, the controller 103 may stop the vehicle or refuse to allow the vehicle to move if an object is detected within the stop zone 78A regardless of whether the truck is being driven by an operator or operating under remote control. Correspondingly, depending upon the specific implementation, its speed control capability of the second detection zone 78B may be implemented regardless of whether the vehicle is operating under remote control, or whether an operator is riding on the vehicle while driving it.

[0088] However, according to various aspects of the present invention, there may be situations where it is desirable to disable one or more of the detection zones when the truck 10 is being driven by an operator. For example, it may be desirable to override/disable the obstacle sensors 76/controller logic while the operator is driving the truck 10 regardless of external conditions. As a further example, it may be desirable to override/disable the obstacle sensors 76/controller logic while the operator is driving the truck 10 to allow the operator to navigate the truck 10 in tight quarters, e.g., to navigate tight spaces, travel around corners, etc., that might otherwise activate one or more of the detection zones. As such, the activation of the controller logic to utilize the detection of objects in the detection zones to help control the vehicle while the vehicle is occupied by an operator, according to various aspects of the

present invention, may be manually controlled, programably controlled or otherwise selectively controlled.

[0089] According to other aspects of the present invention, it may be desirable to disable one or more of the detection zones when an operator is walking alongside the truck 10 and controlling operation of the truck 10 with a supplemental control, such as a jog switch/button, e.g., located on a side portion of the truck 10. Such a jog switch may be used to move or jog the truck 10 in a forward direction at a predetermined and preferably low speed, as will be apparent to those skilled in the art. For example, it may be desirable to override/disable the obstacle sensors 76/controller logic while the operator is actuating the jog switch regardless of external conditions. As a further example, it may be desirable to override/disable the obstacle sensors 76/controller logic while the operator is actuating the jog switch to allow the operator to navigate the truck 10 in tight quarters, e.g., to navigate tight spaces, travel around corners, etc., that might otherwise activate one or more of the detection zones. As yet a further example, upon the operator releasing the jog switch, the truck 10 may coast to a stop. Upon the releasing of the jog switch and the truck 10 coasting, one or more of the disabled detection zones may be enabled, i.e., by enabling one or more of the obstacle sensors 76/controller logic.

[0090] Referring to Fig. 4, according to further aspects of the present invention, one or more of the obstacle sensors 76 may be implemented by ultrasonic technology, laser technology, or other suitable contactless technology capable of a distance measurement and/or position determination. Thus, the distance to an object can be measured, and/or a determination may be made so as to ascertain whether the detected object is within a detection zone 78A, 78B, e.g., by virtue of the distance of the object from the truck 10. As an example, an obstacle sensor 76 may be implemented by an ultrasonic sensor or transducer that provides a “ping” signal, such as a high frequency signal generated by a piezo element. The ultrasonic sensor 76 then rests and listens for a response. In this regard, time of flight information may be determined and utilized to define each zone. Thus, a controller, e.g., the controller 103 or a controller specifically associated with the obstacle sensors 76 may utilize software that looks at time of flight information to determine whether an object is within a detection zone.

[0091] According to further aspects of the present invention, multiple obstacle sensors 76 can work together to obtain object sensing. For example, a first ultrasonic sensor may send out a ping signal. The first ultrasonic sensor and one or more additional ultrasonic sensors may then listen for a response. In this way, the controller may use diversity in identifying the existence of an object within one or more of the detection zones.

[0092] With reference to Fig. 5, an implementation of multiple speed zone control is illustrated according to yet further aspects of the present invention. As illustrated, three detection zones are provided. If an object such as an obstacle is detected in the first detection zone 78A and the truck 10 is moving under remote control, then a first action may be performed, e.g., the truck 10 may be brought to a stop as described more fully herein. If an object such as an obstacle is detected in the second detection zone 78B and the truck 10 is moving under remote control, then a second action may be performed, e.g., the vehicle speed may be limited, reduced, etc. Thus, the second detection zone 78B may further designate a first speed zone. For example, the speed of the truck 10 may be reduced and/or limited to a first relatively slow speed, e.g., approximately 1.5 mph (2.4 Km/h).

[0093] If an object such as an obstacle is detected in the third detection zone 78C and the truck 10 is moving under remote control, then a third action may be performed, e.g., the truck 10 may be reduced in speed or otherwise limited to a second speed, e.g., approximately 2.5 mph (4 Km/h). Thus, the third detection zone may further designate a second speed zone. If no obstacles are detected in the first, second and third detection zones 78A, 78B, 78C, then the vehicle may be remotely controlled to travel, e.g., in response to a remote travel request, at a rate that is greater than the rate of speed when an obstacle is in the third detection zone, e.g., a speed of approximately 4 mph (6.2 Km/h).

[0094] As Fig. 5 further illustrates, the detection zones may be defined by different patterns relative to the truck 10. Also, in Fig. 5, a seventh obstacle sensor 76 is illustrated for purposes of illustration. By way of illustration, the seventh obstacle sensor 76 may be approximately centered, such as on the bumper or other suitable location on the truck 10. On an exemplary truck 10, the third zone 78C may extend approximately 6.5 feet (2 meters) forward of the power unit 14 of the truck 10.

[0095] According to various aspects and embodiments of the present invention, any number of detection zones of any shape may be implemented. For example, depending upon desired truck performance, many small zones may be defined at various coordinates relative to the truck 10. Similarly, a few large detection zones may be defined base upon desired truck performance. As an illustrative example, a database, equation, function or other means of data comparison, such as a look-up table may be set up in the memory of the controller. If travel speed while operating under remote travel control is an operational parameter of interest, then the table may associate travel speed with the detection zones defined by distance, range, position coordinates or some other measure. If the truck 10 is traveling under remote control and an obstacle sensor detects an object, then the distance to that detected

object may be used as a “key” to look up a corresponding travel speed in the table. The travel speed retrieved from the table can be utilized by the controller 103 to adjust the truck 10, e.g., to slow it down, etc.

[0096] Depending upon factors such as the desired speed of the truck when operating under remote control and the required stopping distance, the anticipated load to be transported by the truck 10, whether a certain amount of coast is required for load stability, vehicle reaction time, etc., the areas of each detection zone may be chosen. Moreover, factors such as the range of each desired detection zone etc. may be considered to determine the number of obstacle sensors 76 required. In this regard, such information may be static, or dynamic, e.g., based upon operator experience, vehicle load, nature of the load, environmental conditions, etc.

[0097] It is also contemplated that the controller 103 may generate a warning signal or alarm if an object or a person is detected in a detection zone.

[0098] As an illustrative example, in a configuration with multiple detection zones, e.g., three detection zones, at least three, for example, as many as seven or more object detectors, (e.g., ultrasonic sensors and/or laser sensors) may be used to provide a range of coverage desired by a corresponding application. In this regard, the detector(s) may be able to look ahead of the direction of travel of the vehicle by a sufficient distance to allow the appropriate response, e.g., to slow down. In this regard, at least one sensor may be capable of looking several meters forward in the direction of travel of the truck 10.

[0099] According to various aspects of the present invention, the multiple detection speed zones allows a relatively greater maximum forward travel speed while operating under remote control that prevents unnecessarily early vehicle stops by providing one or more intermediate zones where the vehicle slows down before deciding to come to a complete stop.

[00100] According to further aspects of the present invention, the utilization of multiple detection zones allows a system that rewards the corresponding operator for better alignment of the truck 10 during pick operations. For example, an operator may position the truck 10 so as to not be aligned with a warehouse aisle. As such, as the vehicle is jogged forward, the second detection zone 78B may initially detect an obstacle such as a pick bin or warehouse rack. In response to detecting the rack, the vehicle will slow down. If the rack is sensed in the first detection zone 78A, then the vehicle will come to rest, even if the truck 10 has not jogged its entire programmed jog distance. Similar un-necessary slow downs or stops may also occur in congested and/or messy aisles.

[00101] According to various aspects of the present invention, the truck 10 may shape speed and braking operation parameters based upon the information obtained from the obstacle sensors 76. Moreover, the logic implemented by the truck 10 in response to the detection zones may be changed or varied depending upon a desired application. As a few illustrative examples, the boundaries of each zone in a multiple zone configuration may be programably (and/or reprogramably) entered in the controller, e.g., flash programmed. In view of the defined zones, one or more operational parameters may be associated with each zone. The established operational parameters may define a condition, e.g., maximum allowable travel speed, an action, e.g., brake, coast or otherwise come to a controlled stop, etc. The action may also be an avoidance action. For example, an action may comprise adjusting a steer angle or heading of the truck 10.

[00102] In accordance with a further embodiment of the present invention, one or more obstacle sensors, such as the obstacle sensors 76A, 76B shown in Figs. 6 and 8, may be employed to sense or detect objects within first, second and third detection zones in front of the materials handling vehicle 10 when the vehicle 10 is traveling under remote control in response to a travel request command or signal and generate an object-detected and distance signal to the controller 103 in response to sensing/detecting an object in front of the vehicle 10. A further input 104 into the controller 103 may be a weight signal generated by a load sensor LS, see Fig. 8, which senses the combined weight of the load handling assembly 12 (e.g. forks 16) and any load on the assembly 12 or forks 16. The load sensor LS is shown schematically in Figs. 7 and 8 near the forks 16, but may alternatively be incorporated into a hydraulic system for effecting lift of the forks 16. By subtracting the weight of the forks 16 (a known constant value) from the combined weight defined by the weight signal, the controller 103 determines the weight of the load on the forks. Using sensed load weight and whether an object has been detected in one of the first, second and third detection zones as inputs into a lookup table or appropriate equations, the controller 103 generates an appropriate vehicle stop or maximum allowable speed signal.

[00103] Values defining the vehicle stop and maximum allowable speed signals may be experimentally determined and stored in a look-up table, such as the one illustrated in Fig. 11. In the illustrated embodiment, the controller 103 determines the weight of a load on the forks 16 and whether an obstacle has been detected in one of the first, second and third detection zones and, using the lookup table in Fig. 11, effects a stop command or defines a maximum allowable speed for the vehicle 10 and generates a corresponding maximum allowable speed signal for the vehicle 10.

[00104] With reference to the example lookup table in Fig. 11, if no load is on the forks 16 and no object is being detected by the obstacle sensors 76A, 76B in any one of the first, second and third detection zones, the controller 103 allows the vehicle to be operated at any speed up to and including a maximum speed of e.g. 4.5 MPH. As is apparent from Fig. 11, if no object is being detected in any one of the first, second and third detection zones, the maximum permitted speed decreases as the load on the vehicle increases. For example, for a load weight of 8000 pounds (approx. 3630 kg), the maximum allowable speed of the vehicle is 2.5 MPH. It is noted that, in some locations the maximum allowable speed of the vehicle 10, if unoccupied by a rider, may be set at a predetermined upper limit, e.g., 3.5 MPH. Hence, the maximum speed of the vehicle, if unoccupied by a rider, may be set, e.g., by the controller 103, at this maximum allowable speed.

[00105] For any load weight on the forks 16, if an object is detected in the first detection zone, the controller 103 generates a "stop signal," designating that the vehicle 10 brake. For any given load weight, the maximum allowable speed of the vehicle is less if an object is detected in the second or the third detection zone as compared to a state where no object is being detected. Also for any given load weight, the maximum allowable speed of the vehicle is less if an object is detected in the second detection zone as compared to when an object is detected in the third detection zone. The maximum allowable vehicle speeds for the second and third detection zones are defined for each load weight so that the vehicle's speed can be reduced in a controlled manner as the vehicle continues to move towards the object so that the vehicle can eventually be safely brought to a stop prior to the truck reaching the point where the object is located. These speeds are experimentally determined and can vary based on vehicle type, size and its braking capabilities.

[00106] For example, if the load weight on the vehicle equals 1500 pounds (680 kg), and an object is sensed in the first detection zone, which first zone is nearest to the vehicle power unit 14, then a stop signal is generated by the controller 103 to effect stopping of the vehicle 10, see Fig. 11. If the load weight on the vehicle remains equal to 1500 pounds, and if a sensed object is located at a distance from the vehicle 10 within the second detection zone, spaced further away from the power unit 14 than the first detection zone, then the maximum allowable vehicle speed is equal to 2.0 MPH, see Fig. 11. Hence, if the vehicle 10 traveling at a speed greater than 2.0 MPH when the object is detected, the controller 103 effects a speed reduction so that the vehicle speed is reduced to 2.0 MPH. If the load weight on the vehicle remains equal to 1500 pounds (680 kg), and if a sensed object is located at a distance within the third detection zone, spaced further away from the power unit 14 than the first and second

detection zones, then the maximum allowable vehicle speed is equal to 3.0 MPH. Hence, if the vehicle 10 traveling at a speed greater than 3.0 MPH when the object is detected, the controller 103 effects a speed reduction so that the vehicle speed is reduced to 3.0 MPH.

[00107] The obstacle sensors may comprise ultrasonic transducers. Ultrasonic transducers are known to experience a phenomena known as transducer "ring down." Essentially "ring down" is the tendency of a transducer to continue to vibrate and transmit ultrasonic signals after the control signal that is used for initiating a transmitted signal has ceased. This "ring down" signal decreases in magnitude rather rapidly, but during the time that it is decreasing to a level below a threshold detection level, detection structure forming part of each obstacle sensor will respond to such "ring down" signals if the signals are above a reference level and thus can indicate that a "ring down" signal is a reflected or return signal when in fact it is not. A common technique to avoid this problem is to blank out all return signals generated by the obstacle sensors for a preselected period of time after initiation of a transmission. The preselected time is determined based on various factors including the type of transducer that is used, but during this preselected time no valid returns can be sensed. If the obstacle sensors are positioned near a front 10A of the vehicle 10, see obstacle sensors 76A in Fig. 7, and if the blanking technique is used, this may result in a "dead" or "non-detect" zone DZ existing immediately in front of the vehicle 10, particularly in embodiments where the obstacle sensor is positioned at or proximate to a front edge of the vehicle. Hence, if an object O is very near the front of the vehicle, e.g., 10 mm or less, and the obstacle sensors 76A are positioned at the front of the vehicle, see Fig. 7, then the object O may not be detected.

[00108] In the embodiment illustrated in Figs. 6 and 8, first and second obstacle sensors 76A and 76B, respectively, are spaced apart from one another along a longitudinal axis L_A of the vehicle 10, see Fig. 8. The first obstacle sensors 76A are positioned at the front 10A of the vehicle 10 and are capable of sensing objects in the second and third detection zones as well as a first portion of the first detection zone, which first detection zone first portion is a predefined distance ahead of the front 10A of the vehicle 10, e.g., a distance 10 mm or greater in front of the vehicle front 10A. So as to ensure that objects O located in the non-detect zone DZ, i.e., an area not sensed by the first obstacle sensors 76A, the second obstacle sensors 76B are positioned on the vehicle 10 a spaced distance behind the first sensors 76A, i.e., in a direction away from the vehicle front 10A, see Fig. 8. Hence, the second sensors 76B function to sense objects in a first detection zone remaining second portion Z_{II} just in front of the vehicle front 10A and corresponding to the dead zone DZ in Fig. 7.

[00109] Algorithm

[00110] According to various aspects of the present invention, a steer correction algorithm is implemented, e.g., by the controller 103. Referring to Fig. 12, a steer correction algorithm comprises determining whether a steer bumper zone warning is detected at 152. A steer bumper signal warning at 152 may comprise, for example, detecting the presence of an object within first and/or second steer bumper zones 132A, 132B with a laser sensor 2000, such as a model number LMS 100 or LMS 111 laser sensor manufactured by Sick AG located in Waldkirch, Germany. The laser sensor 2000 may be mounted to the power unit 14, see Fig. 13. The first steer bumper zone 132A may also be designated as a left steer bumper zone and the second steer bumper zone 132B may also be designated as a right steer bumper zone, see Fig. 13. If a steer bumper zone warning is received, a determination is made at 154 whether the steer bumper zone warning indicates that an object is detected to the left or to the right of the truck 10, e.g., whether the detected object is in the first steer bumper zone 132A or the second steer bumper zone 132B. For example, the laser sensor 2000 may generate two outputs, a first output signal designating whether an object is detected in the first (left) steer bumper zone 132A, and a second signal designating whether an object is detected in the second (right) steer bumper zone 132B. Alternatively, the controller 103 may receive raw laser sensor data and process/distinguish the first and second steer bumper zones 132A, 132B using a predetermined mapping.

[00111] For example, referring additionally to Fig. 13, the laser sensor 2000 may sweep a laser beam in an area in front of truck 10. In this regard, multiple laser sensors may be utilized, or one or more laser beams may be swept, e.g., to raster scan one or more areas forward of the truck 10. If an object is present in an area where the laser beams are swept, the object reflects the beam back to the laser sensor 2000, which is capable of generating object location data from which the location of the sensed object can be determined either by the sensor 2000 or the controller 103, as is known in the laser sensor art. In this regard, the laser sensor 2000 may independently define and scan the left and right steer bumper zones, or the controller 103 may derive the left and/or right steer bumper zones based upon the raster scan of the laser(s). Still further, alternate scanning patterns may be utilized, so long as the controller 103 can determine whether a detected obstacle is to the left or to the right of the truck 10.

[00112] As a few additional examples, although a laser sensor 2000 is illustrated for purposes of discussion herein, other sensing technologies may be utilized, examples of which may include ultrasonic sensors, infrared sensors, etc. For example, ultrasonic sensors, e.g.,

located to the sides of the truck 10, may define the left and right steer bumper zones 132A, 132B. Selection of the type(s) of sensors used on the truck 10 may depend upon the particular operating conditions of the truck 10.

[00113] Additionally, the laser sensor 2000 or one or more additional sensors may be used to define other detection zones, e.g., for stopping, speed limiting, etc. The laser sensor 2000 (or one or more additional sensors) may define a “stop zone”, and/or a “slow down zone” as described in detail herein. For example, if a single stop zone is defined and an object is detected in the stop zone, which may extend, for example, about 1.2 meters in front of a forward traveling direction of the truck 10, the controller 103 may cause the truck 10 to stop, as set out in detail herein. Additionally or alternatively, if an object is detected in a slow down zone, the controller 103 may cause the truck 10 to slow down. It is noted that, according to this embodiment, it may be preferable to define a stop zone while not defining a slow down zone.

[00114] Further, the truck 10 may comprise one or more load presence sensors 53, see Fig. 13. The load presence sensor(s) 53 may comprise proximity or contact technology, e.g., a contact switch, a pressure sensor, an ultrasonic sensor, optical recognition device, infrared sensor or other suitable technology that detects the presence of a suitable load carrying structure 55, e.g., a pallet or other platform, collection cage, etc. The controller 103 may refuse to implement a travel command if one or more of the load presence sensors 53 indicate that the load platform 55 is not in a valid designated position. Still further, the controller 103 may communicate with the brake controller 108 to stop the truck 10 if the load presence sensors 53 detect a change of the load platform 55 from a valid designated position.

[00115] It should be understood that any number of detection zones may be implemented, and the implemented detection zones may overlap or define discrete, mutually exclusive zones. Depending upon the sensor and sensor processing technologies utilized, the input(s) to the controller 103 designating an object in the steer bumper zones 132A, 132B may be in other formats. As yet a further illustration, the first and second laser steer bumper zones 132A, 132B may be defined by both ultrasonic sensors and one or more laser sensors. For example, the laser sensor 2000 may be utilized as a redundant check to verify that the ultrasonic sensors properly detect an object in either the left or right steer bumper zones 132A, 132B, or vice versa. As yet a further example, ultrasonic sensors may be utilized to detect an object in the left or right steer bumper zones 132A, 132B and the laser sensor 2000 may be utilized to distinguish or otherwise locate the object to determine whether the object

was detected in the left steer bumper zone 132A or the right steer bumper zone 132B. Other arrangements and configurations may alternatively be implemented.

[00116] If a steer bumper zone warning designates that an object is detected in the left steer bumper zone 132A, then a steer correction routine is implemented at 156 that includes computing a steer angle correction to steer the truck 10 to the right according to a first set of parameters. By way of illustration and not by way of limitation, a steer right correction implemented at 156 may include steering the truck 10 to the right at a right direction steer angle. In this regard, the right direction steer angle may be fixed or variable. For example, the controller 103 may command the steer controller 112 to ramp up to some desired steer angle, e.g., 8-10 degrees to the right. By ramping up to a fixed steer angle, sudden changes in the angle of the steer wheel(s) will not occur, resulting in a smoother performance. The algorithm accumulates the distance traveled at the steer correction angle, which may be a function of how long the appropriate steer bumper input is engaged.

[00117] According to various aspects of the present invention, the steered wheel angular change may be controlled to achieve, for example, a substantially fixed truck angle correction as a function of accumulated travel distance. The travel distance accumulated while performing a steer correction maneuver may be determined based upon any number of parameters. For example, the distance traveled during the steer correction may comprise the distance traveled by the truck 10 until the detected object is no longer within the associated left bumper detection zone 132A. The accumulated travel distance may also/alternatively comprise, for example, traveling until a time out is encountered, another object is detected in any one of the bumper or detection zones, and/or predetermined maximum steer angle is exceeded, etc.

[00118] Upon exiting a right steer correction at 156, e.g., by maneuvering the truck 10 so that no object is detected within the left steer bumper detection zone 132A, a left steer compensation maneuver is implemented at 158. The left steer compensation maneuver at 158 may comprise, for example, implementing a counter steer to adjust the travel direction of the truck 10 to an appropriate heading. For example, the left steer compensation maneuver may comprise steering the truck 10 at a selected or otherwise determined angle for a distance that is a percentage of the previously accumulated travel distance. The left steer angle utilized for the left steer compensation maneuver may be fixed or variable, and may be the same as, or different from the steer angle utilized to implement the right steer correction at 156.

[00119] By way of illustration and not by way of limitation, the distance utilized for the left steer compensation maneuver at 158 may be approximately one quarter to one half of the

accumulated travel distance while implementing the right steer correction at 156. Similarly, the left steer angle to implement the left steer compensation maneuver may be approximately one half of the angle utilized to implement the right steer correction at 156. Thus, assume that the right steer angle is 8 degrees and the accumulated steer correction travel distance is 1 meter. In this example, the left steer compensation may be approximately one half of right steer correction, or -4 degrees, and the left steer compensation will occur for a travel distance of approximately $\frac{1}{4}$ meters to $\frac{1}{2}$ meters.

[00120] The particular distance and/or angle associated with the left steer compensation maneuver at 158 may be selected, for example, so as to dampen the “bounce” of the truck 10 as the truck 10 moves along its course to steer correct away from detected obstacles. As an illustration, if the truck 10 steer corrects at a fixed degrees per distance traveled, the controller 103 may be able to determine how much the corresponding truck angle has changed, and therefore, adjust the left steer compensation maneuver at 158 to correct back towards the original or other suitable heading. Thus, the truck 10 will avoid “ping ponging” down an aisle and instead, converge to a substantially straight heading down the center of the aisle without tedious manual repositioning required by the truck operator. Moreover, the left steer compensation maneuver at 158 may vary depending upon the particular parameters utilized to implement the right steer correction at 156.

[00121] Correspondingly, if a steer bumper zone warning designates that an object is detected in the right steer bumper zone 132B, then a steer correction routine is implemented at 160 that includes computing a steer angle correction to steer the truck 10 to the left according to a second set of parameters. By way of illustration and not by way of limitation, a steer left correction implemented at 160 may include steering the truck 10 to the left at a left steer angle. In this regard, the left steer correction maneuver at 160 may be implemented in a manner analogous to that described above at 156, except that the correction is to the right at 156 and to the left at 160.

[00122] Similarly, upon exiting a left steer correction at 160, e.g., by maneuvering the truck 10 so that no object is detected within the right bumper detection zone 132B, a right steer compensation maneuver is implemented at 162. The right steer compensation maneuver at 162 may comprise, for example, implementing a counter steer to adjust the travel direction of the truck 10 to an appropriate heading in a manner analogous to that described at 158, except that the steer compensation maneuver at 158 is to the left and the steer compensation maneuver at 162 is to the right.

[00123] After implementing the steer compensation maneuver at 158 or 162, the truck may return to a substantially straight heading, e.g., 0 degrees at 164 and the process loops back to the beginning to wait for the detection of another object in either of the steer bumper zones 132A, 132B.

[00124] The algorithm can further be modified to follow various control logic implementations and/or state machines to facilitate various anticipated circumstances. For example, it is possible that a second object will move into either steer bumper zone 132A or 132B while in the process of implementing a steer compensation maneuver. In this regard, the truck 10 may iteratively attempt to steer correct around the second object. As another illustrative example, if object(s) are simultaneously detected in both the left and right steer bumper zones 132A, 132B, the controller 103 may be programmed to maintain the truck 10 at its current heading (e.g., zero degree steer angle), until either one or more steer bumper zones 132A, 132B are cleared or the associated detection zones cause the truck 10 to come to a stop.

[00125] According to further aspects of the present invention, a user and/or service representative may be able to customize the response of the steer angle correction algorithm parameters. For example, a service representative may have access to programming tools to load customized variables, e.g., in the controller 103, for implementing steer correction. As an alternative, a truck operator may have controls that allow the operator to input customized parameters into the controller, e.g., via potentiometers, encoders, a software user interface, etc.

[00126] The output of the algorithm illustrated in Fig. 12 may comprise, for example, an output that defines a steer correction value that may be coupled from the controller 103 to an appropriate control mechanism of the truck 10. For example, the steer correction value may comprise a +/- steer correction value, e.g., corresponding to steer left or steer right, that is coupled to a vehicle control module, steer controller 112, e.g., as illustrated in Fig. 2, or other suitable controller. Still further, additional parameters that may be editable, e.g., to adjust operational feel may comprise the steer correction angle, a steer correction angle ramp rate, a bumper detection zone size/range for each steer bumper zone, truck speed while steer correcting, etc.

[00127] Referring to Fig. 13, assume in the illustrative example, that the truck 10 is traveling in response to receiving a remote wireless travel request and that before the truck 10 can travel a predetermined jog distance, the truck 10 travels into a position where a rack leg 1720 and a corresponding pallet 1740 are in the path of the left steer bumper zone 132A. Keeping with the exemplary algorithm of Fig. 12, the truck 10, e.g., via the controller 103,

may implement an obstacle avoidance maneuver by entering a steer correction algorithm, to steer the truck to the right. For example, the controller 103 may compute or otherwise lookup or retrieve a steer correction angle that is communicated to a steer controller 112 to turn the drive wheel(s) of the truck 10.

[00128] The truck 10 maintains steer correction until an event occurs, such as the disengagement of the object, e.g., when the scanning laser or other implemented sensor technology no longer detects an object in the left steer bumper zone 132. Assume that the truck 10 accumulated a travel distance of one half of a meter during the steer correction maneuver, which was fixed at 8 degrees. Upon detecting that the left steer bumper zone signal has disengaged, a counter steer compensation is implemented to compensate for the change in heading caused by the steer correction. By way of example the steer compensation may steer the truck 10 to the left for approximately one quarter meter accumulated travel distance, at 4 degrees. For very narrow aisles, the Left / Right steer bumper zone sensors may provide very frequent inputs /little time between senses compared to relatively wider aisles.

[00129] The various steer angle corrections and corresponding counter steer compensations may be determined empirically, or the angles, ramp rates, accumulated distances, etc., may be computed, modeled or otherwise derived.

[00130] In the illustrative arrangement, the system will try to maintain the truck 10 centered in the aisle as the truck 10 advances in response to receiving a corresponding wirelessly transmitted travel request by the transmitter 70. Moreover, bounce, e.g., as measured by the distance from the centerline of a warehouse aisle, is damped. Still further, there may be certain conditions where the truck 10 may still require some operator intervention in order to maneuver around certain objects in the line of travel.

[00131] The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention.

[00132] Having thus described the invention of the present application in detail and by reference to embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims.

What is claimed is:

What is claimed is:

1. A materials handling vehicle comprising:
 - a power unit;
 - a load handling assembly coupled to said power unit;
 - at least one first obstacle detector mounted at a first location on said power unit to detect an object located along a path of travel of said power unit in a first detection zone spaced from the vehicle beyond a dead zone (DZ) of said first detector; and
 - at least one second obstacle detector mounted at a second location on said power unit, spaced from said power unit first location, and capable of detecting an object located along the path of travel of said power unit in a second detection zone overlapping said dead zone (DZ) of said first obstacle detector.
2. The materials handling vehicle as set out in claim 1, wherein said at least one obstacle detector generates a distance signal upon detecting the object, the distance signal corresponding to a distance between the detected object and said power unit and further comprising a controller for receiving said distance signal and generating a corresponding vehicle stop or maximum allowable speed signal based on said distance signal.
3. The materials handling vehicle as set out in claim 2, further comprising a load sensor (LS) to generate a weight signal indicative of a weight of a load on said load handling assembly.
4. The materials handling vehicle as set out in claim 3, wherein said controller receives said distance signal and said weight signal and generates a corresponding vehicle stop signal or maximum allowable speed signal based on said distance and weight signals.
5. The materials handling vehicle as set out in claim 4, wherein for a given first load weight, if a sensed object is located at a first distance away from said power unit, a stop signal is generated by said controller to effect stopping of said vehicle.
6. The materials handling vehicle as set out in claim 5, wherein for said given first load weight, if a sensed object is located at a second distance further away from said power unit than said first distance, then a first maximum allowable vehicle speed is defined.

7. The materials handling vehicle as set out in claim 6, wherein for said given first load weight, if a sensed object is located at a third distance further away from said power unit than said first and second distances, then a second maximum allowable vehicle speed greater than said first maximum is defined.
8. The materials handling vehicle as set out in any one of claims 1 to 7 wherein said dead zone is located between said power unit and a near edge of the first detection zone of said first obstacle detector, within which dead zone objects or obstacles are undetectable by said first obstacle detector.
9. The materials handling vehicle as set out in claim 1, further comprising
a controller that is responsive to travel requests; and
at least one presence sensor capable of detecting the presence of a person on the materials handling vehicle, wherein said controller is configured to decide to not implement said travel request if said status from said presence sensor(s) is indicative of the presence of a person on the materials handling vehicle.
10. The materials handling vehicle as set out in claim 1, further comprising a load sensor (LS) to generate a weight signal indicative of a weight of a load on said load handling assembly.

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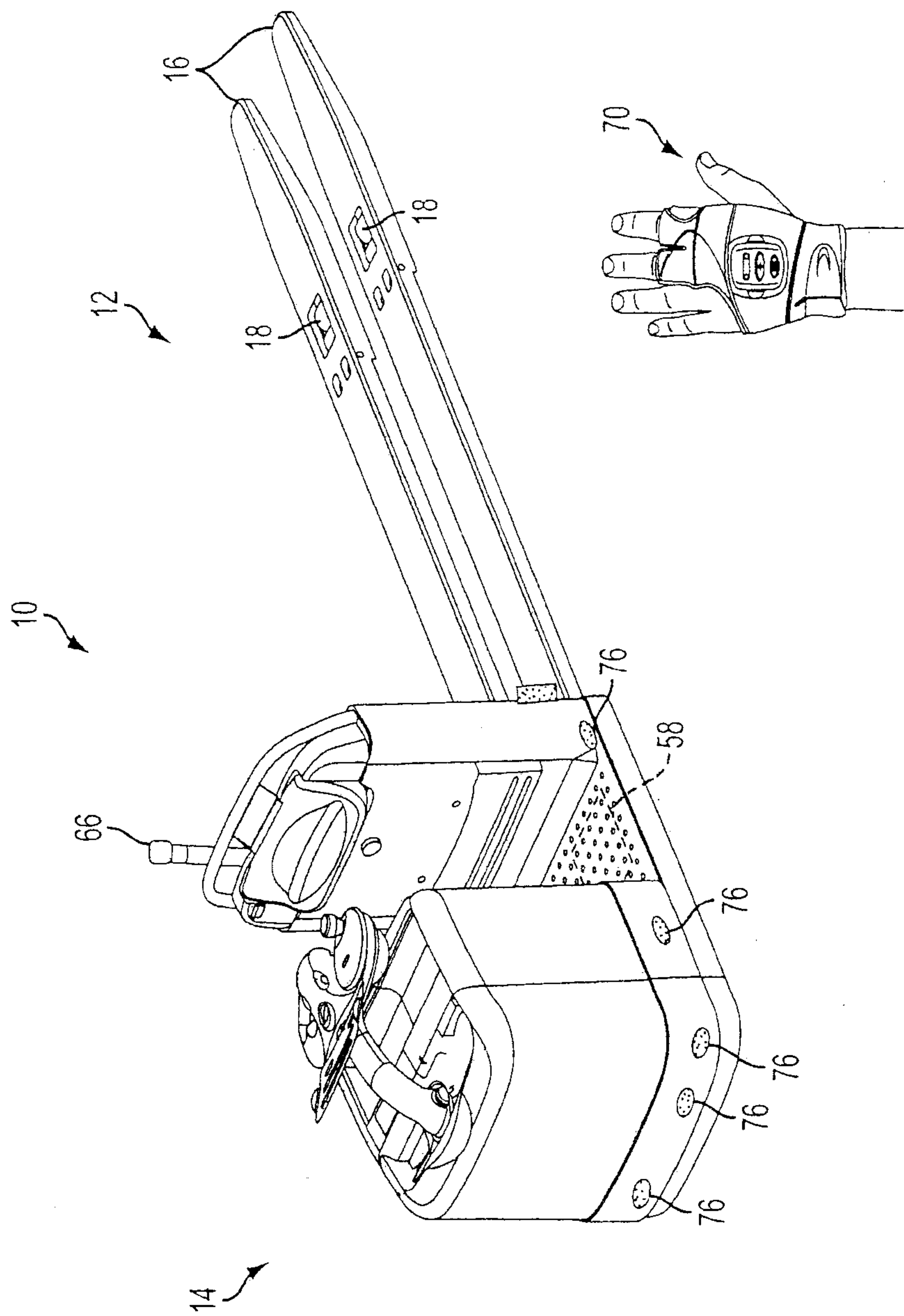


FIG. 1

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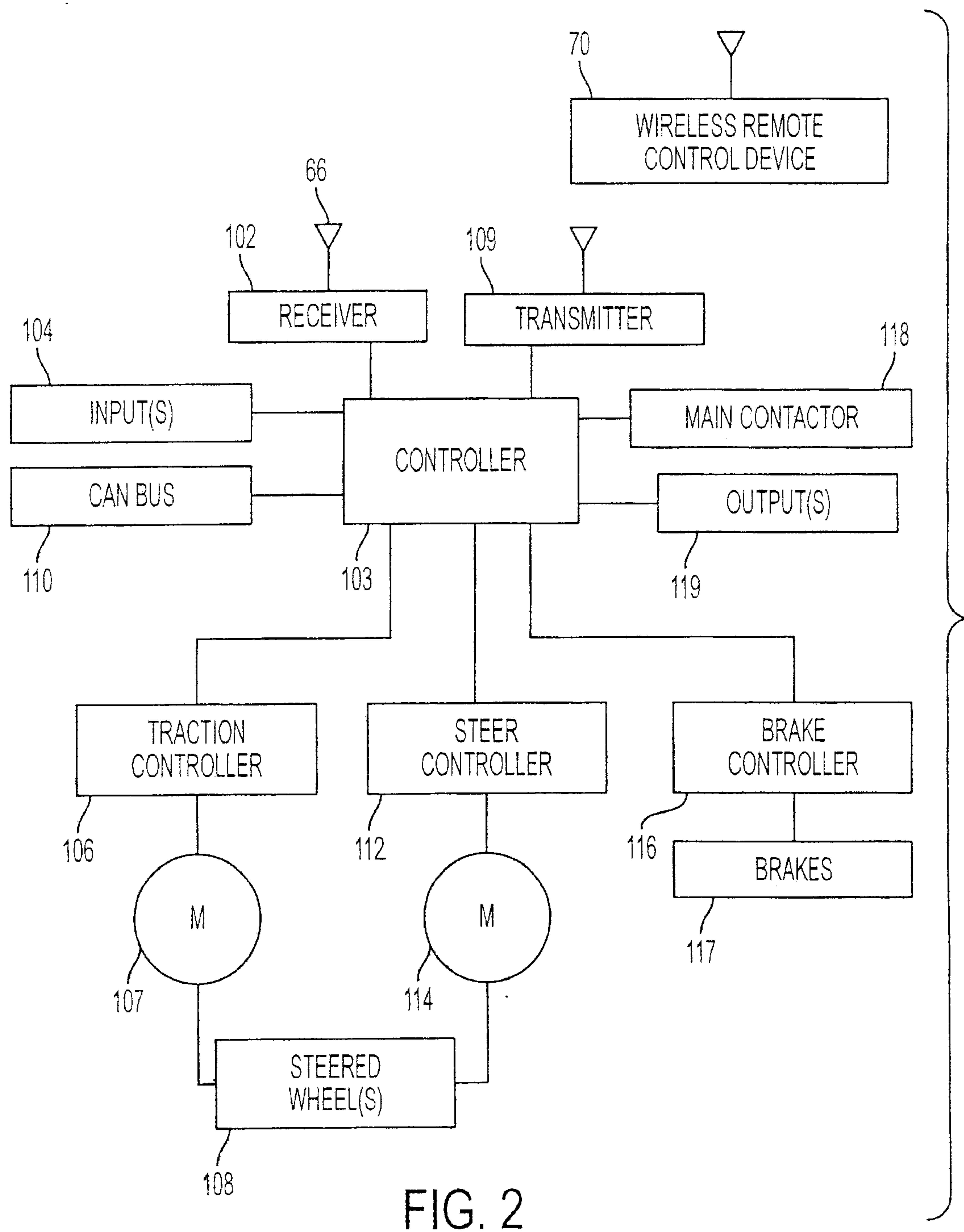


FIG. 2

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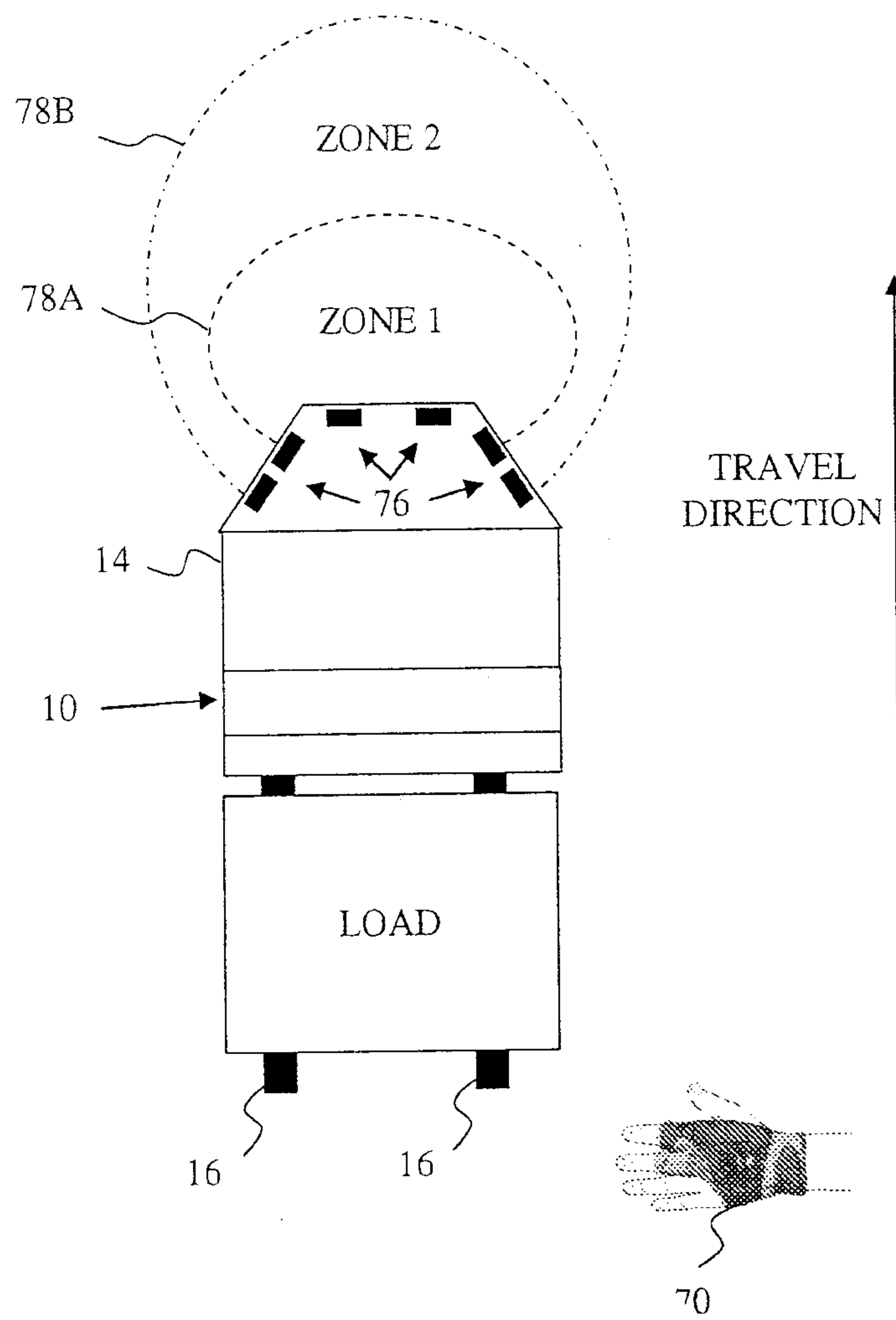


Fig. 3

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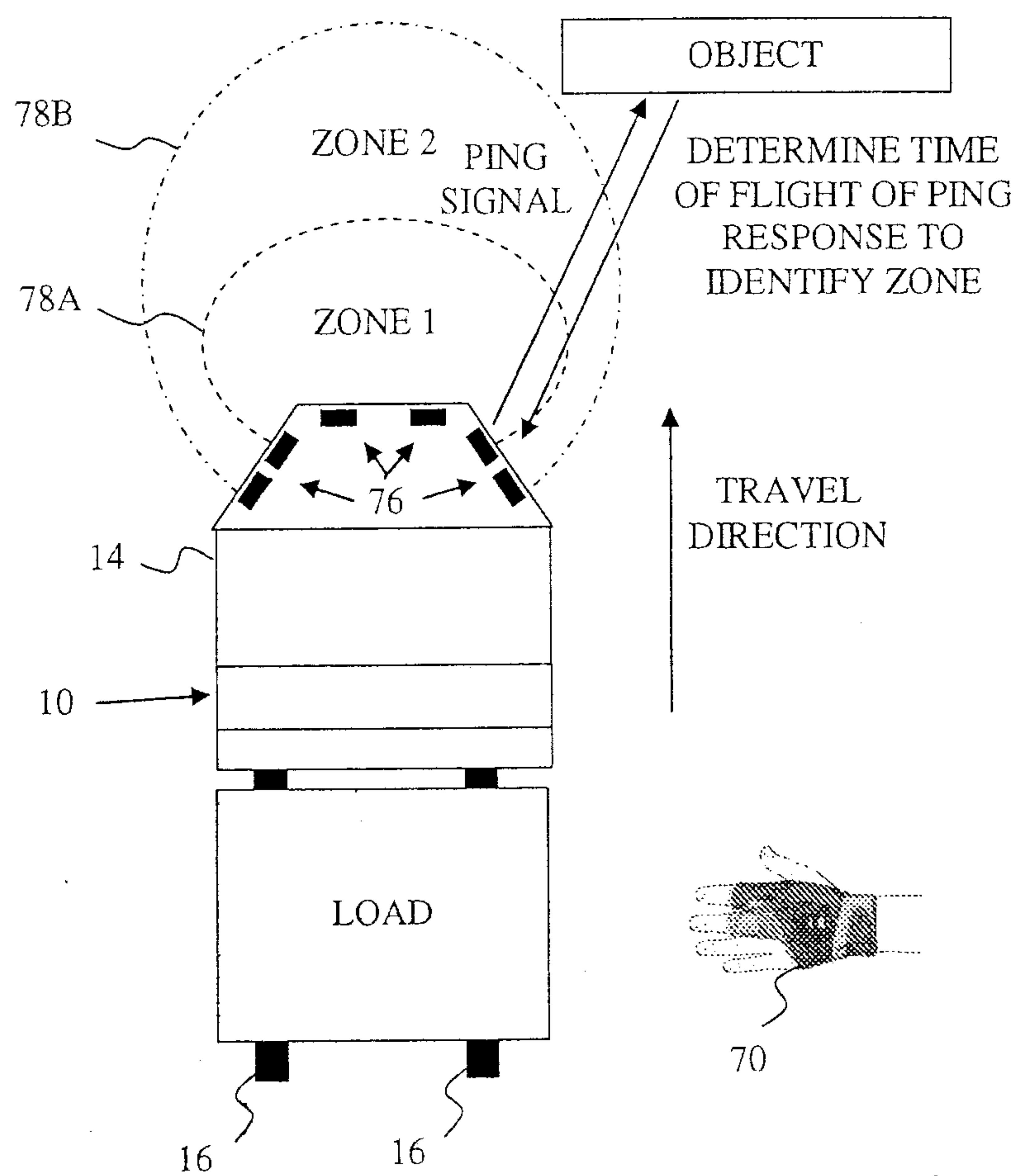


Fig. 4

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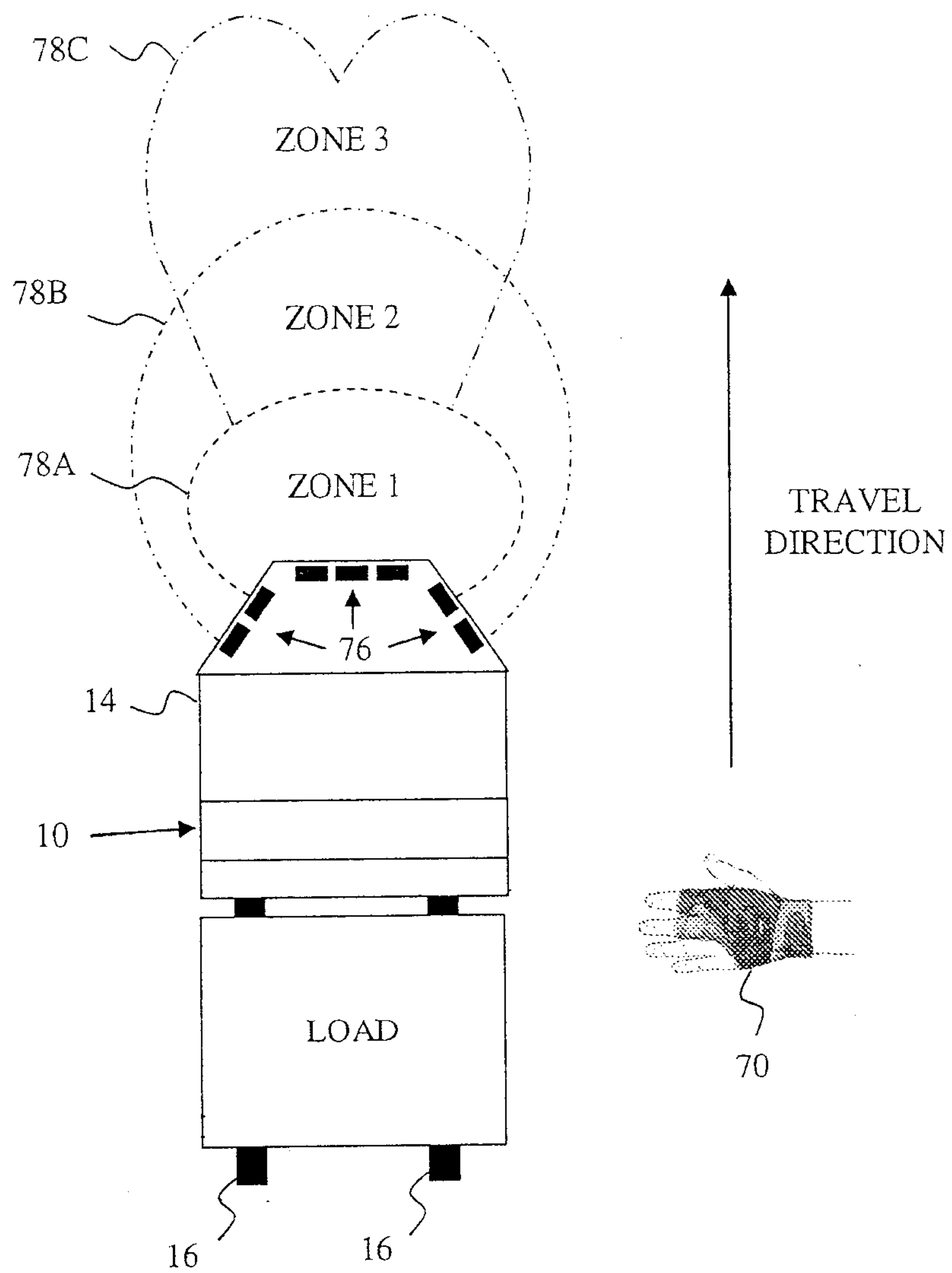
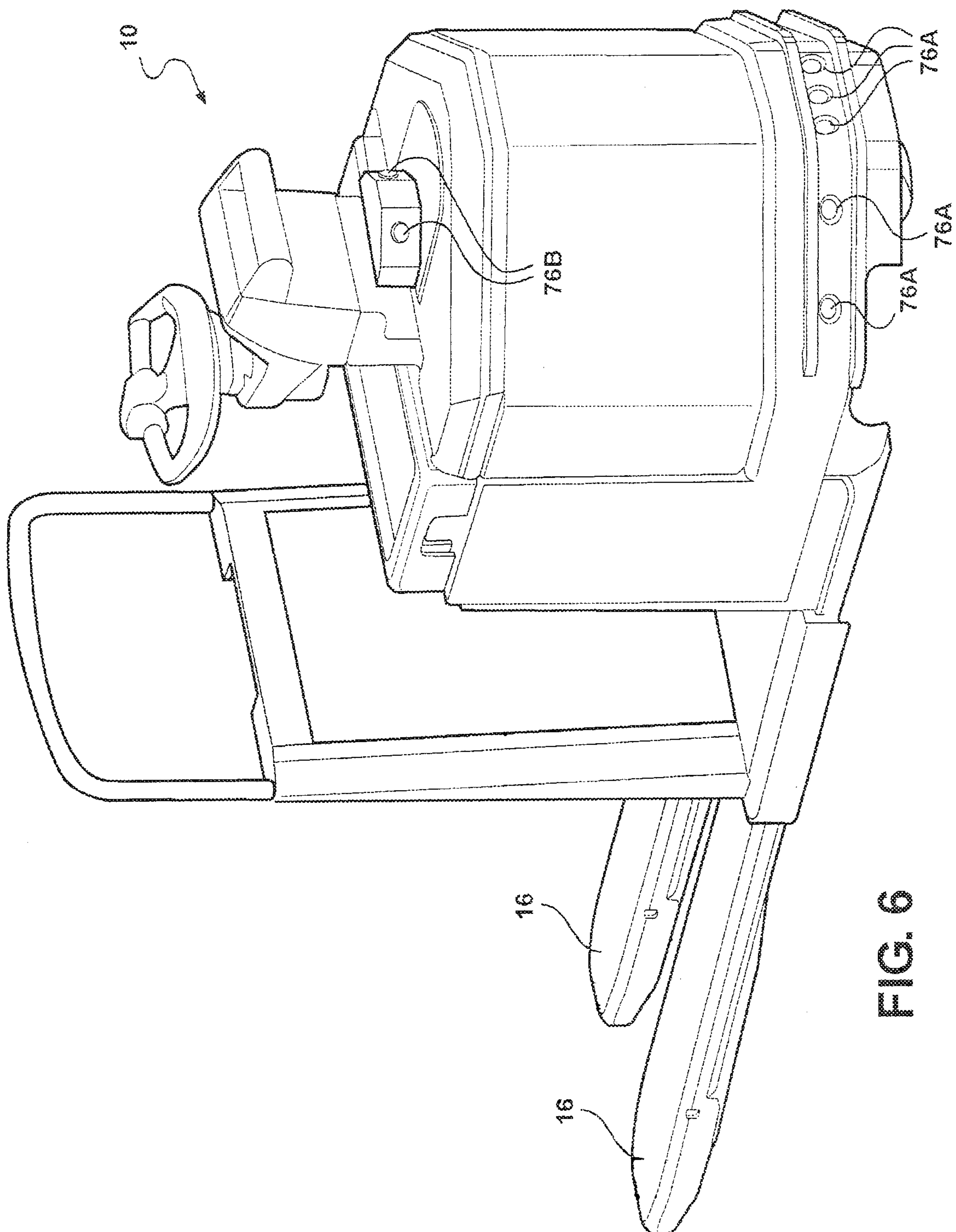


Fig. 5

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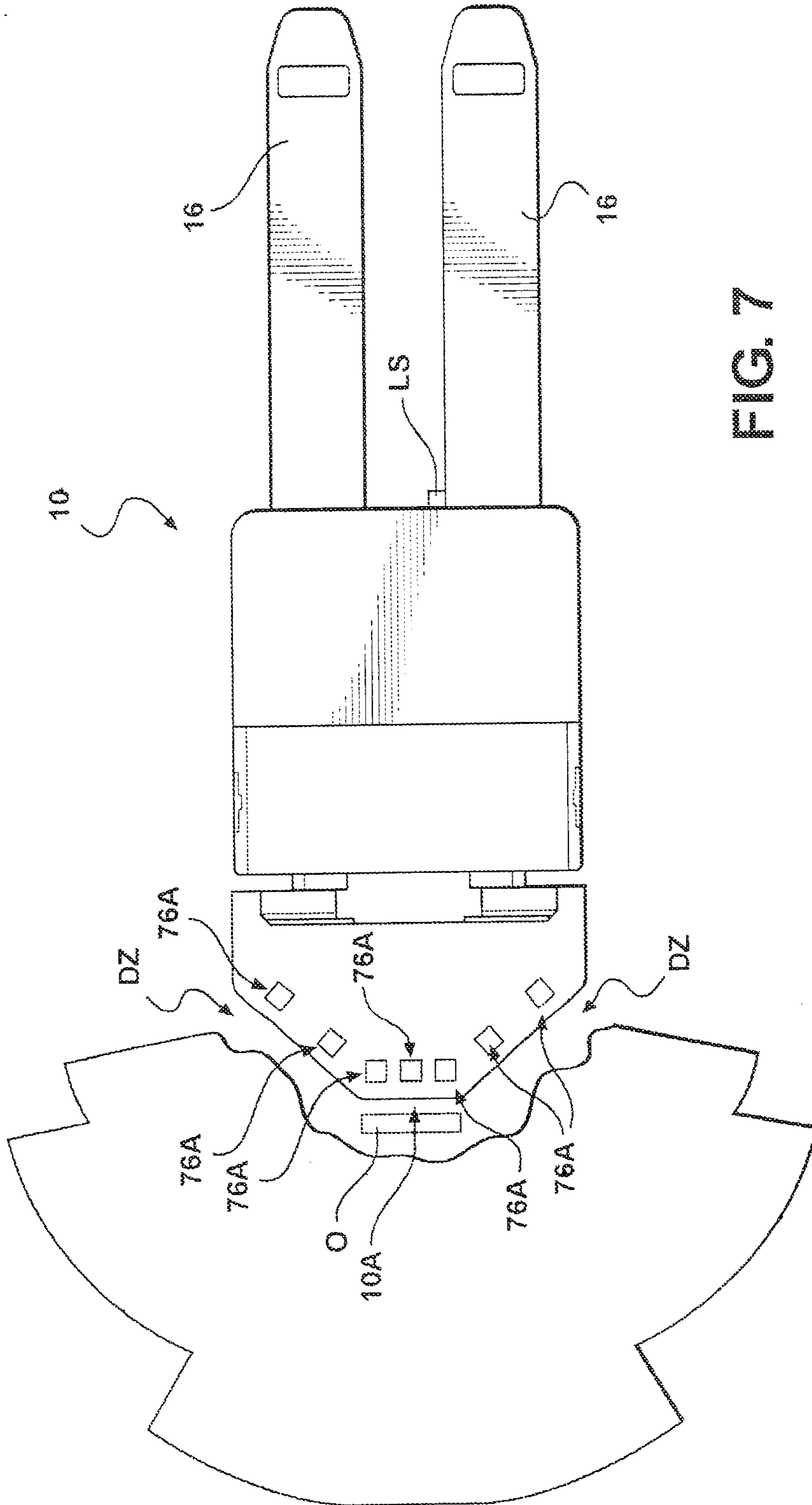


FIG. 7

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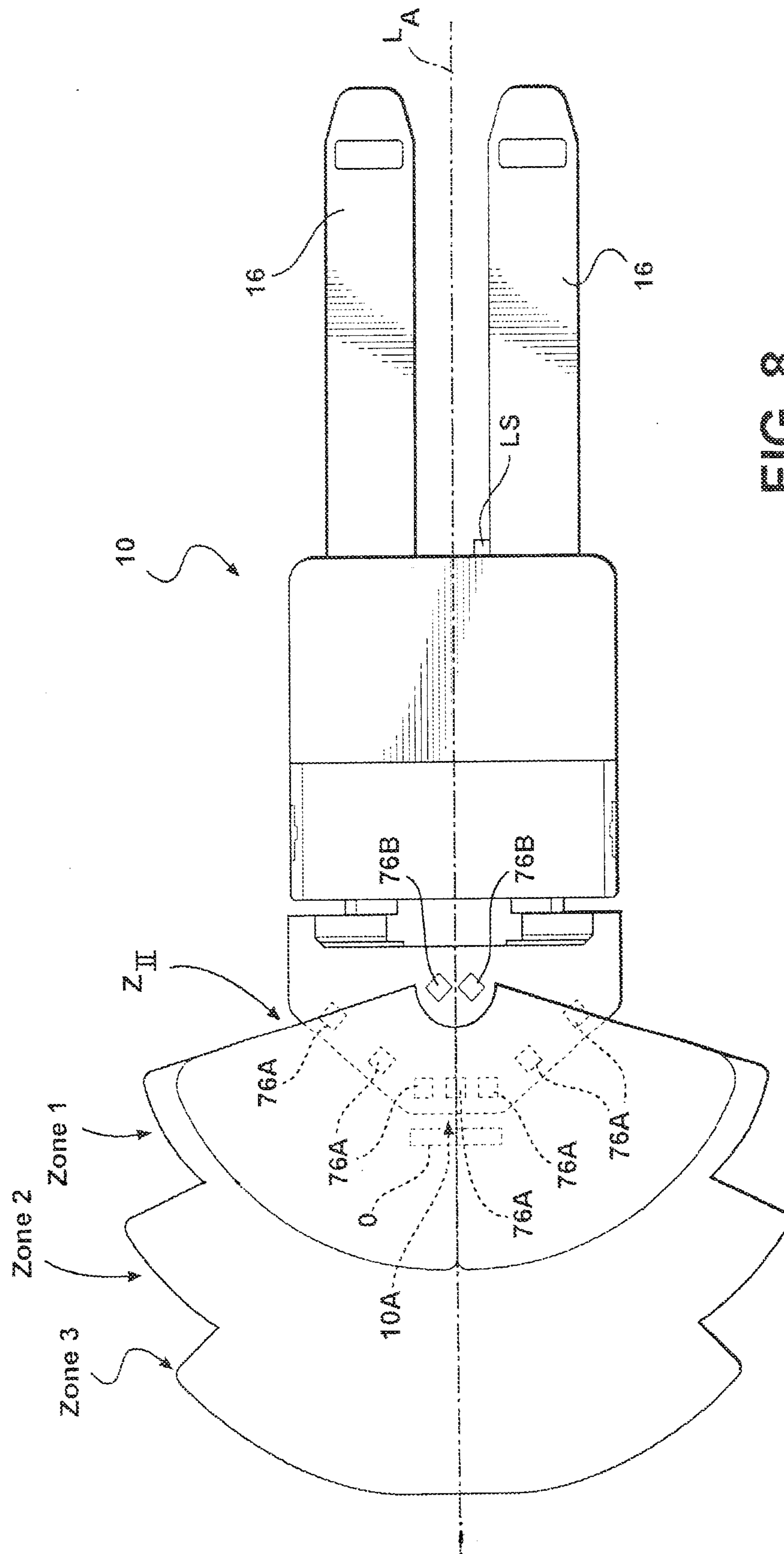
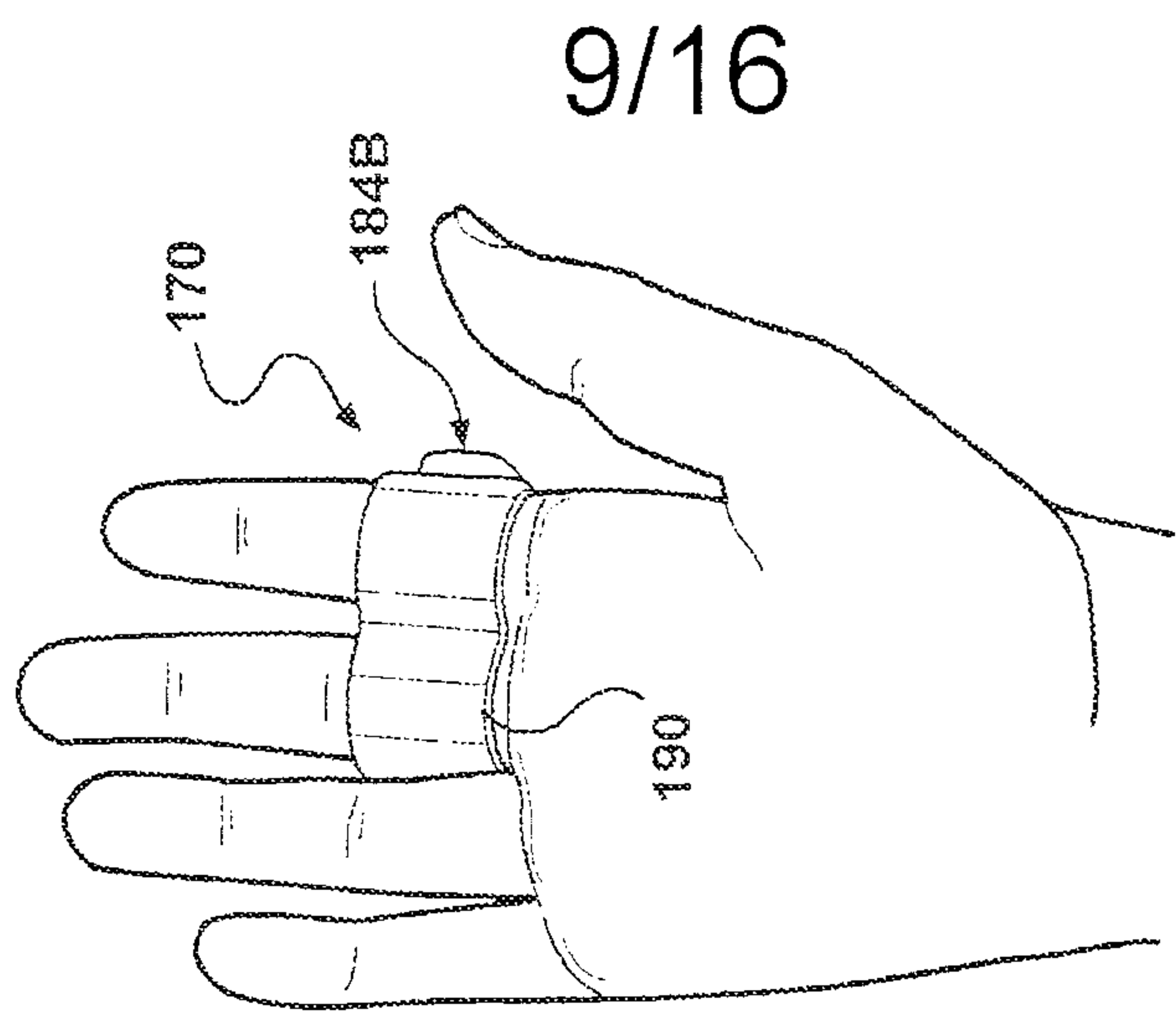
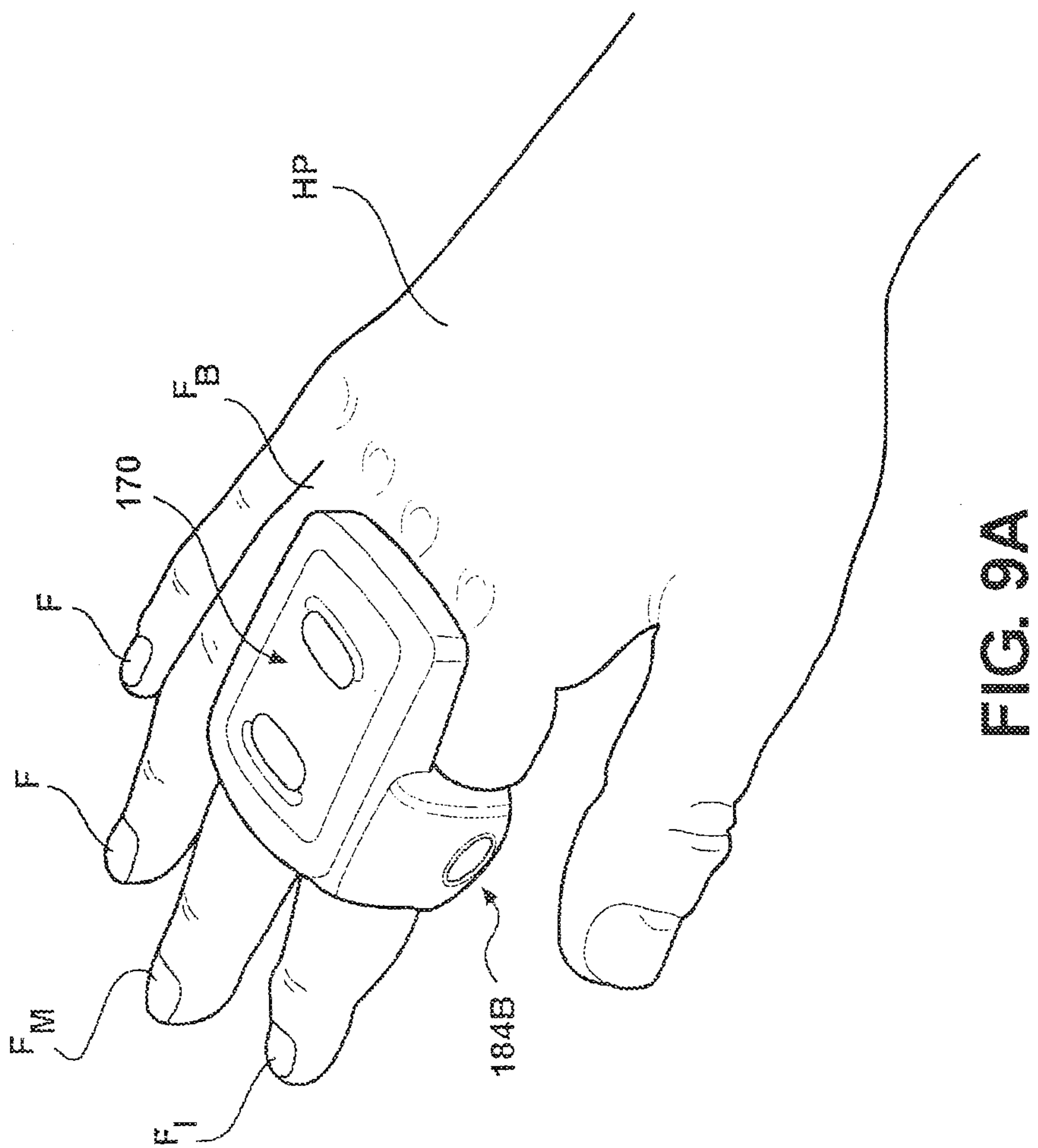


FIG. 8



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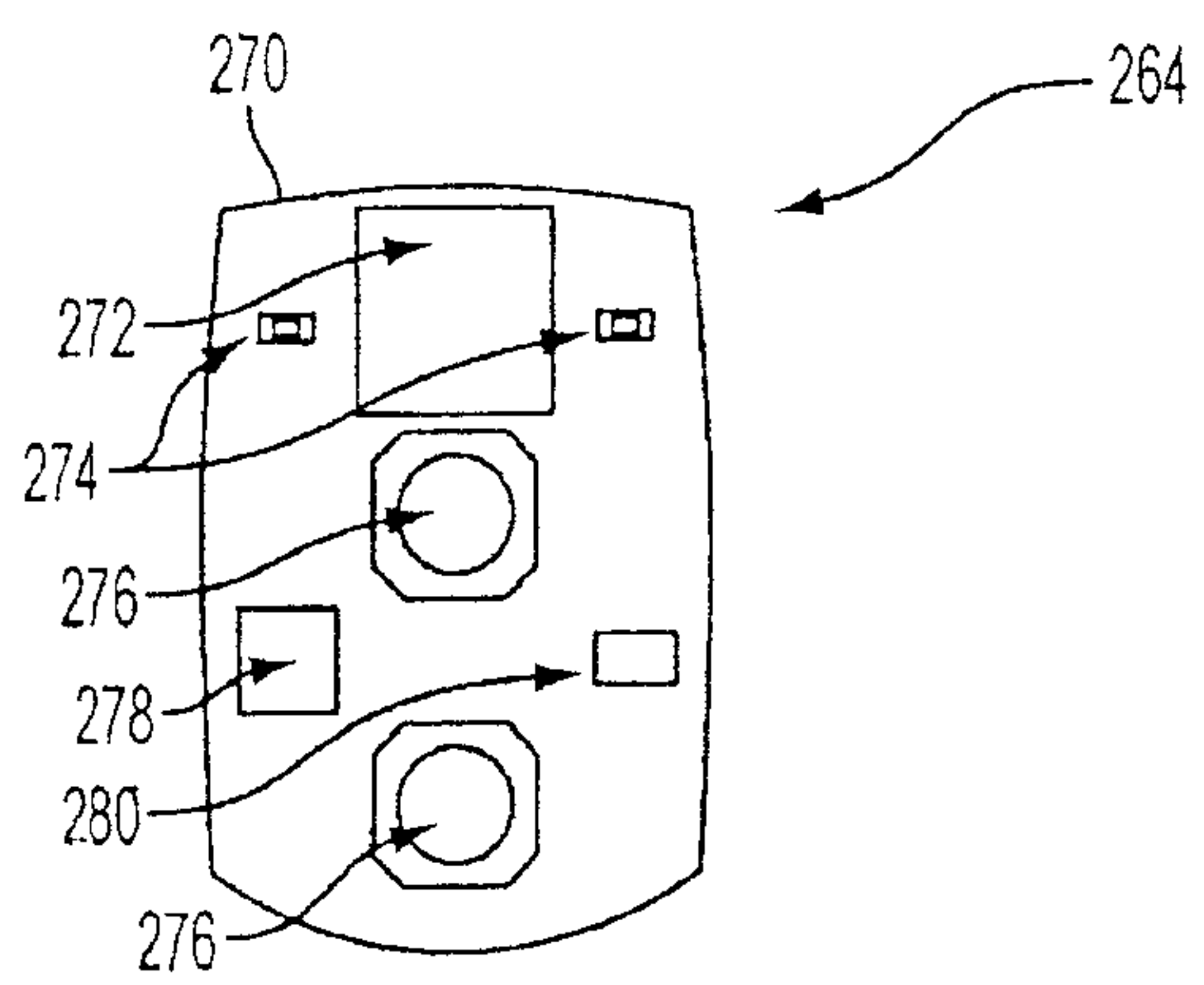


FIG. 9C

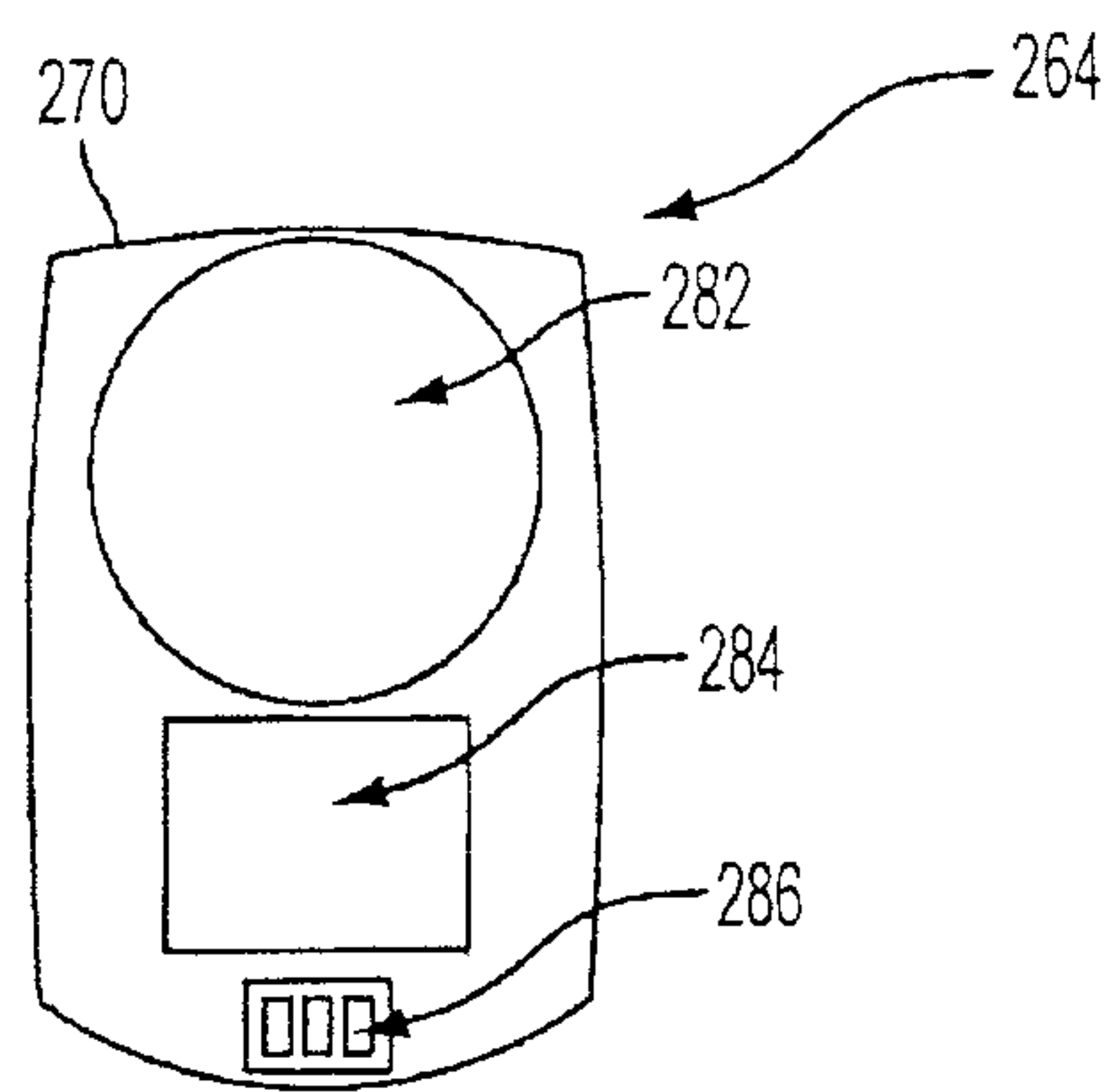
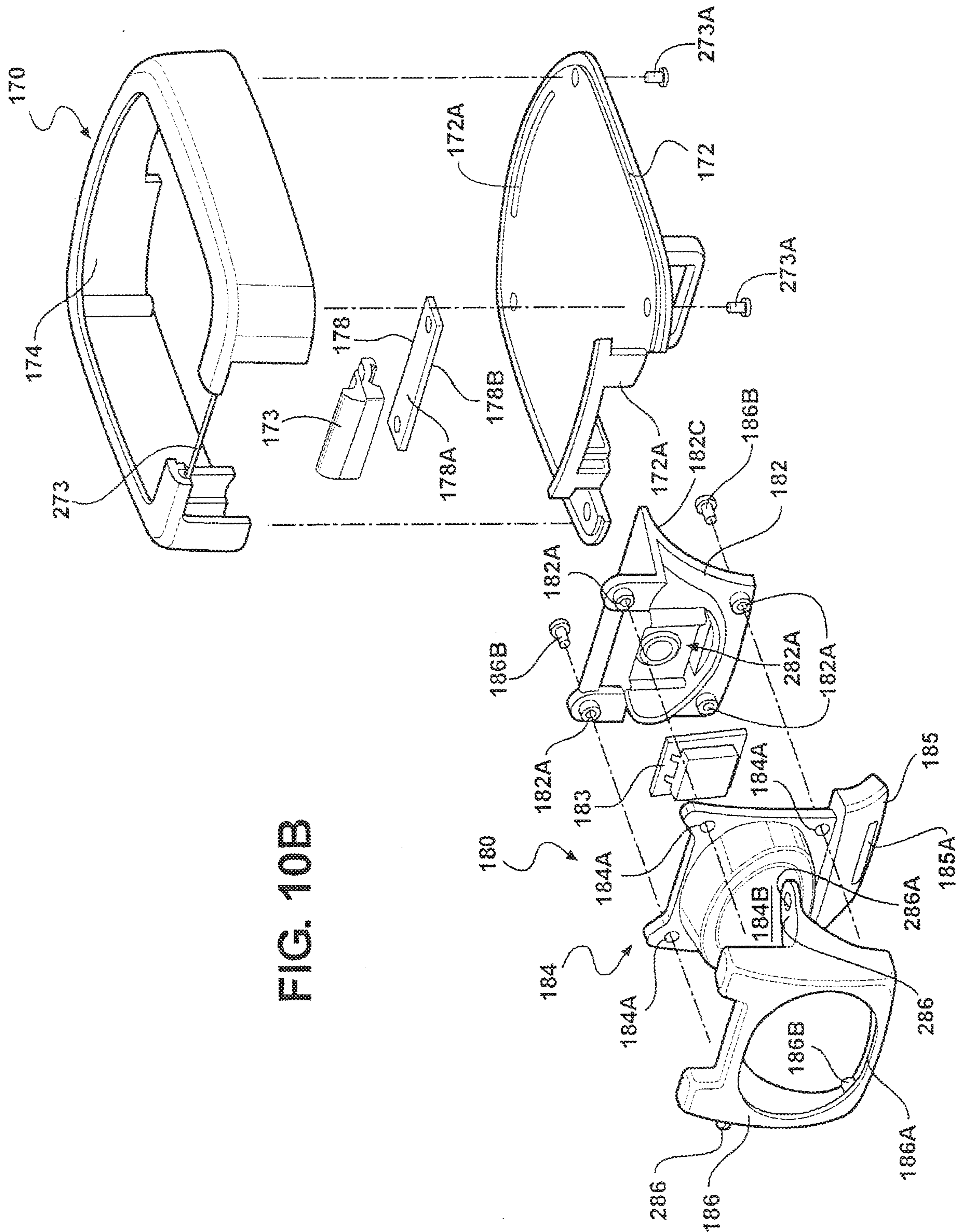


FIG. 9D

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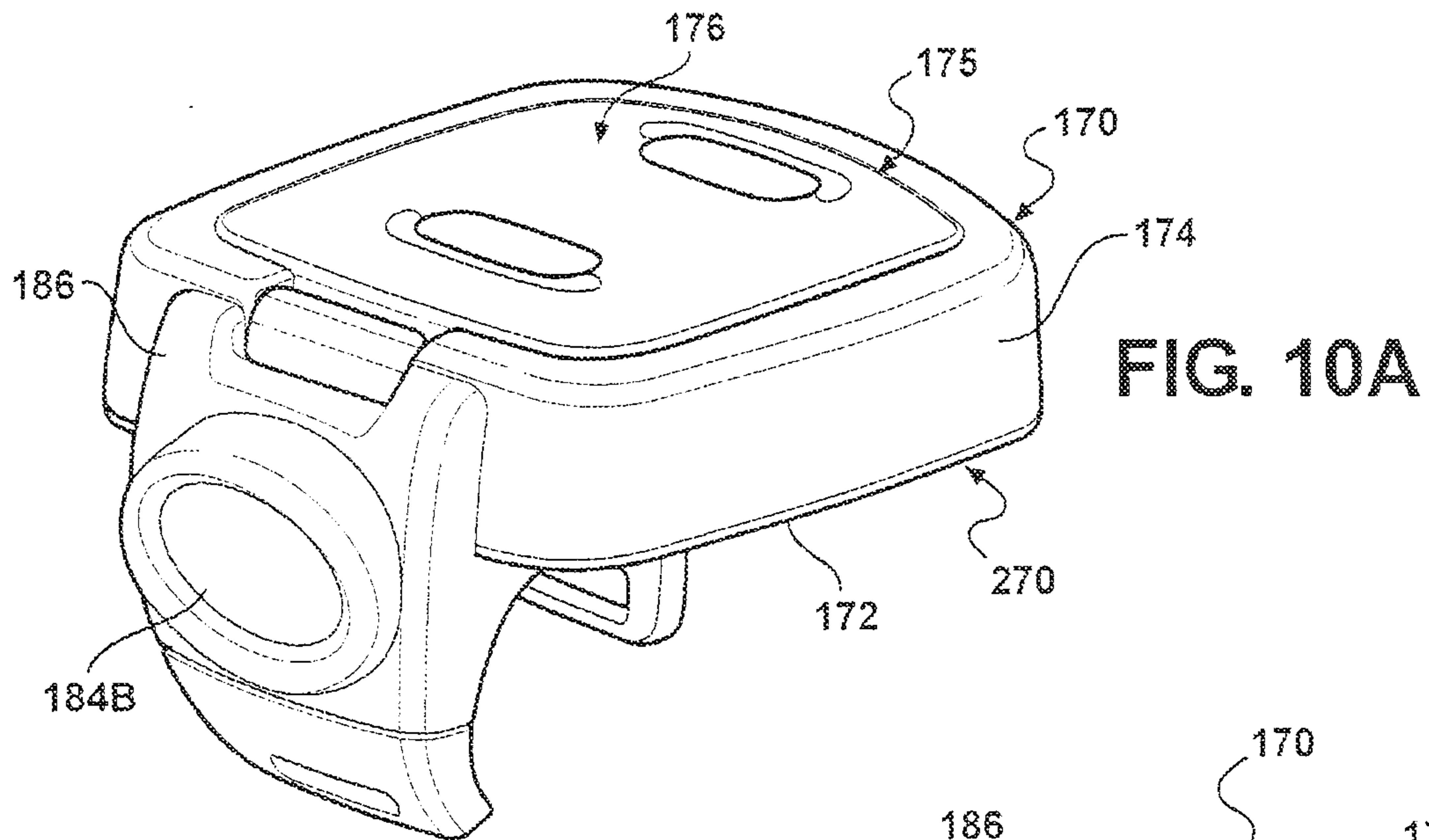
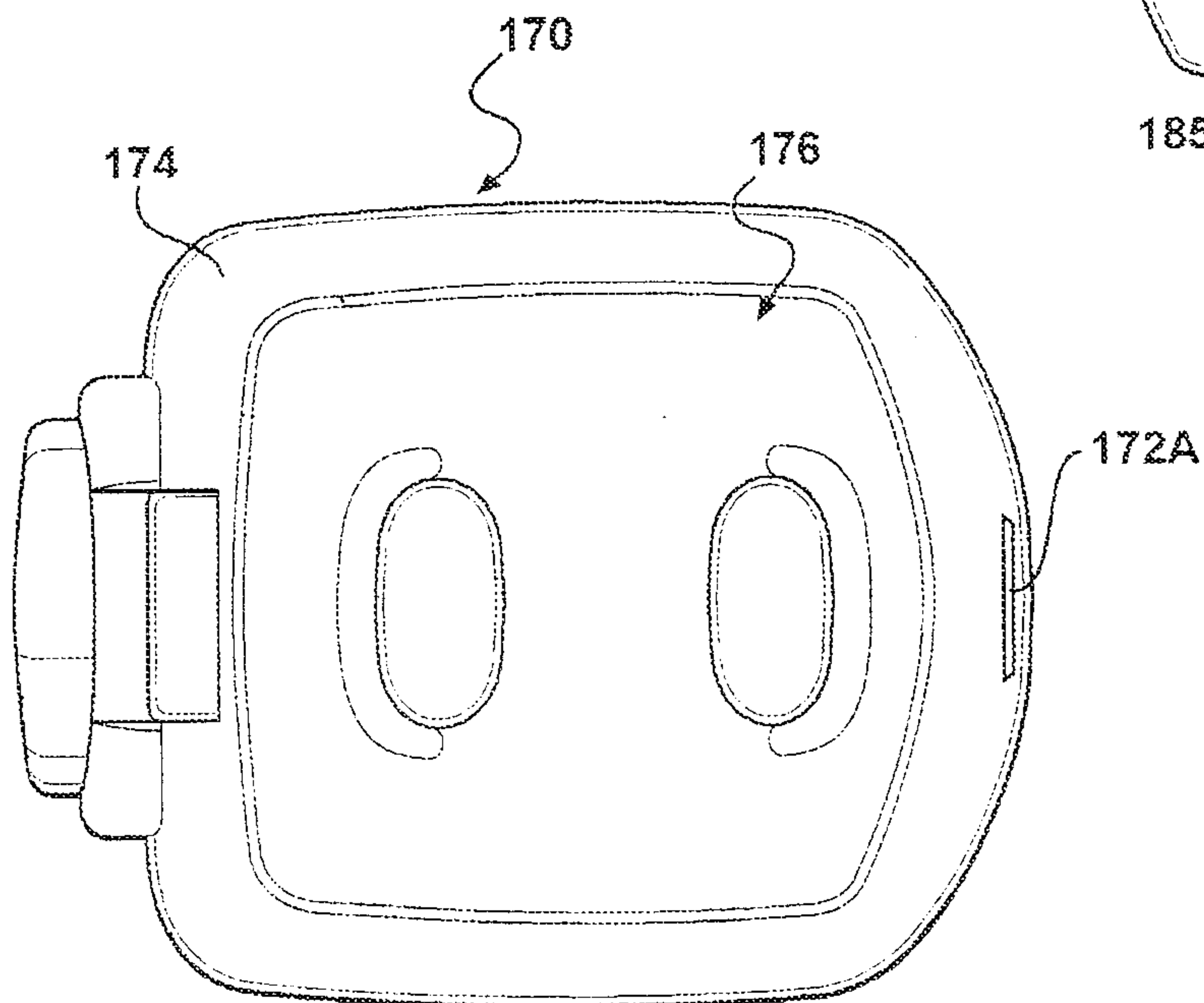
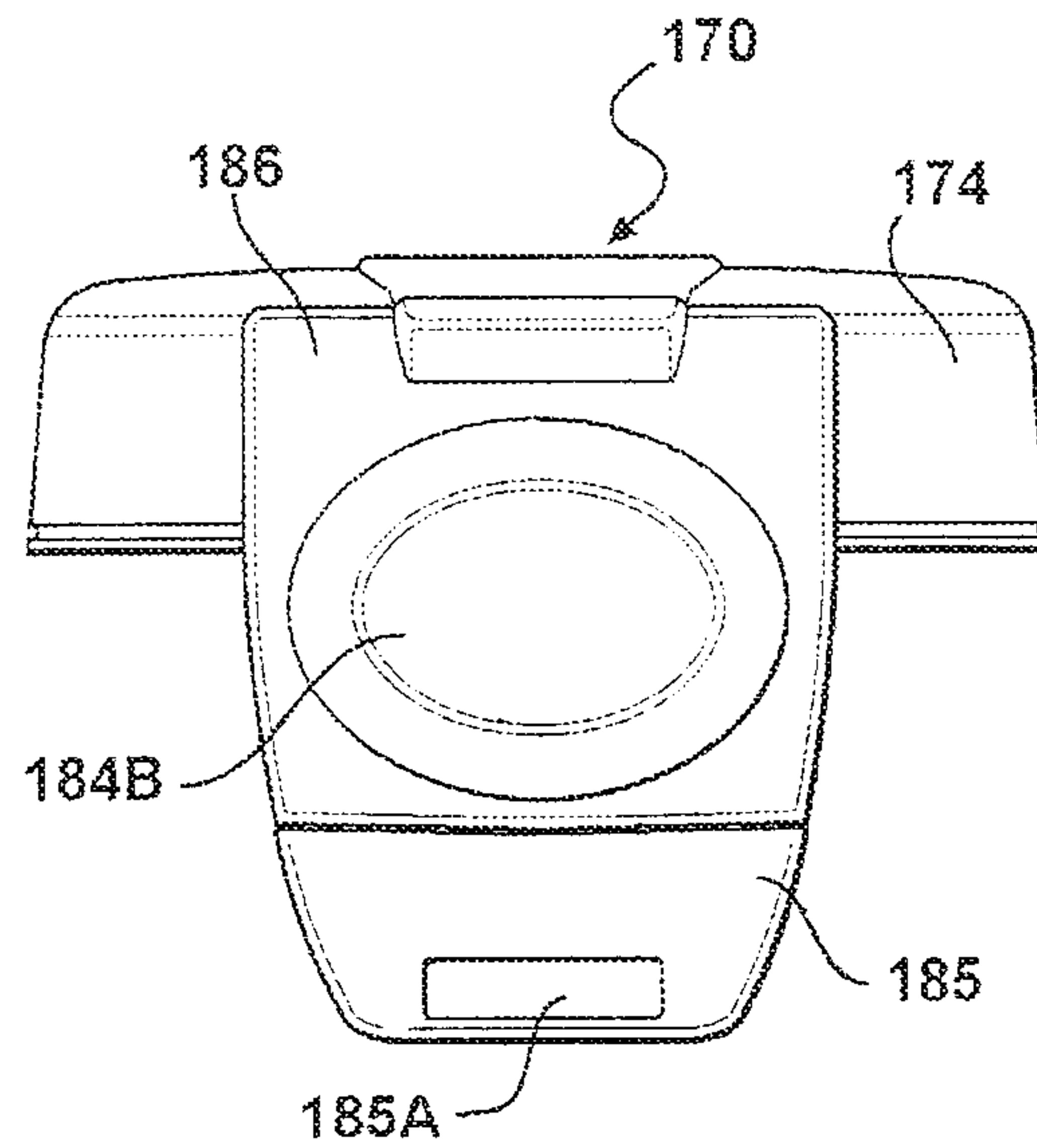
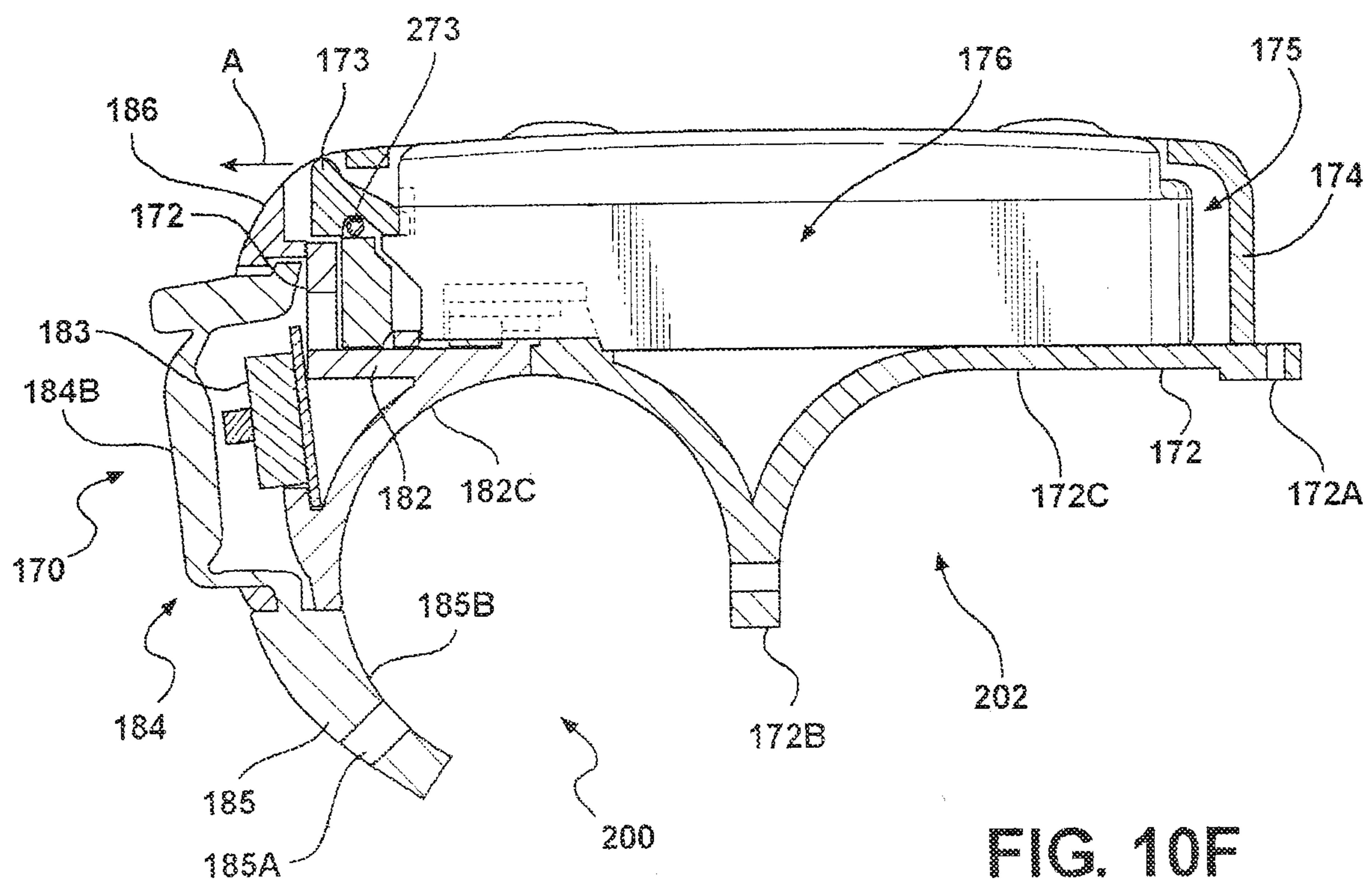
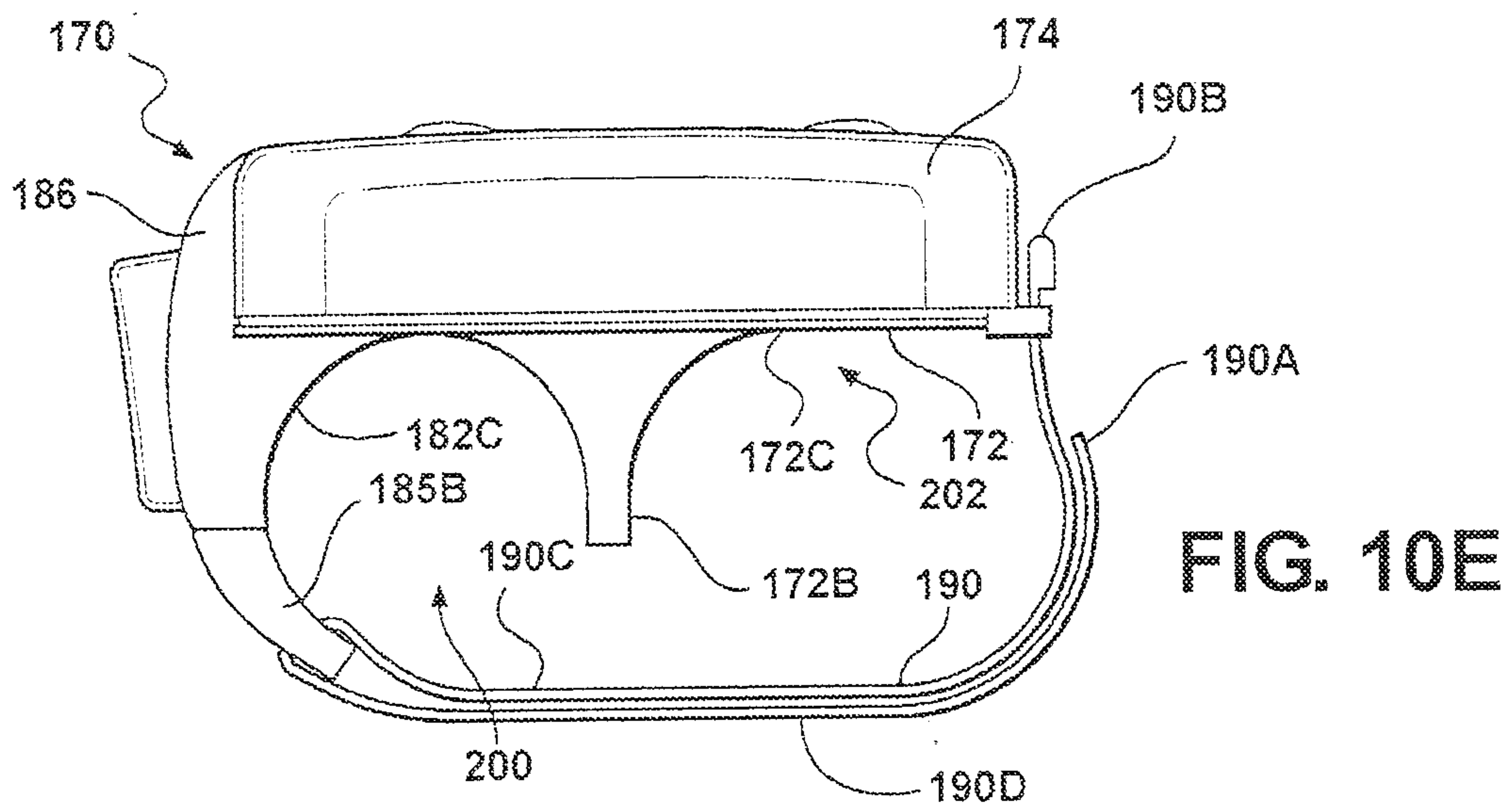


FIG. 10C



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	No Obstacle	Obstacle Detected	Obstacle Detected	Obstacle Detected
		Zone 3	Zone 2	Zone 1
0-999 lb Load	4.5 mph	3.5 mph	2.5 mph	Stop
1000-2999 lb Load	4.0 mph	3.0 mph	2.0 mph	Stop
3000-4999 lb Load	3.5 mph	2.5 mph	1.5 mph	Stop
5000-6999 lb Load	3.0 mph	2.0 mph	1.0 mph	Stop
7000-8000 lb Load	2.5 mph	1.5 mph	Stop	Stop

FIG. 11

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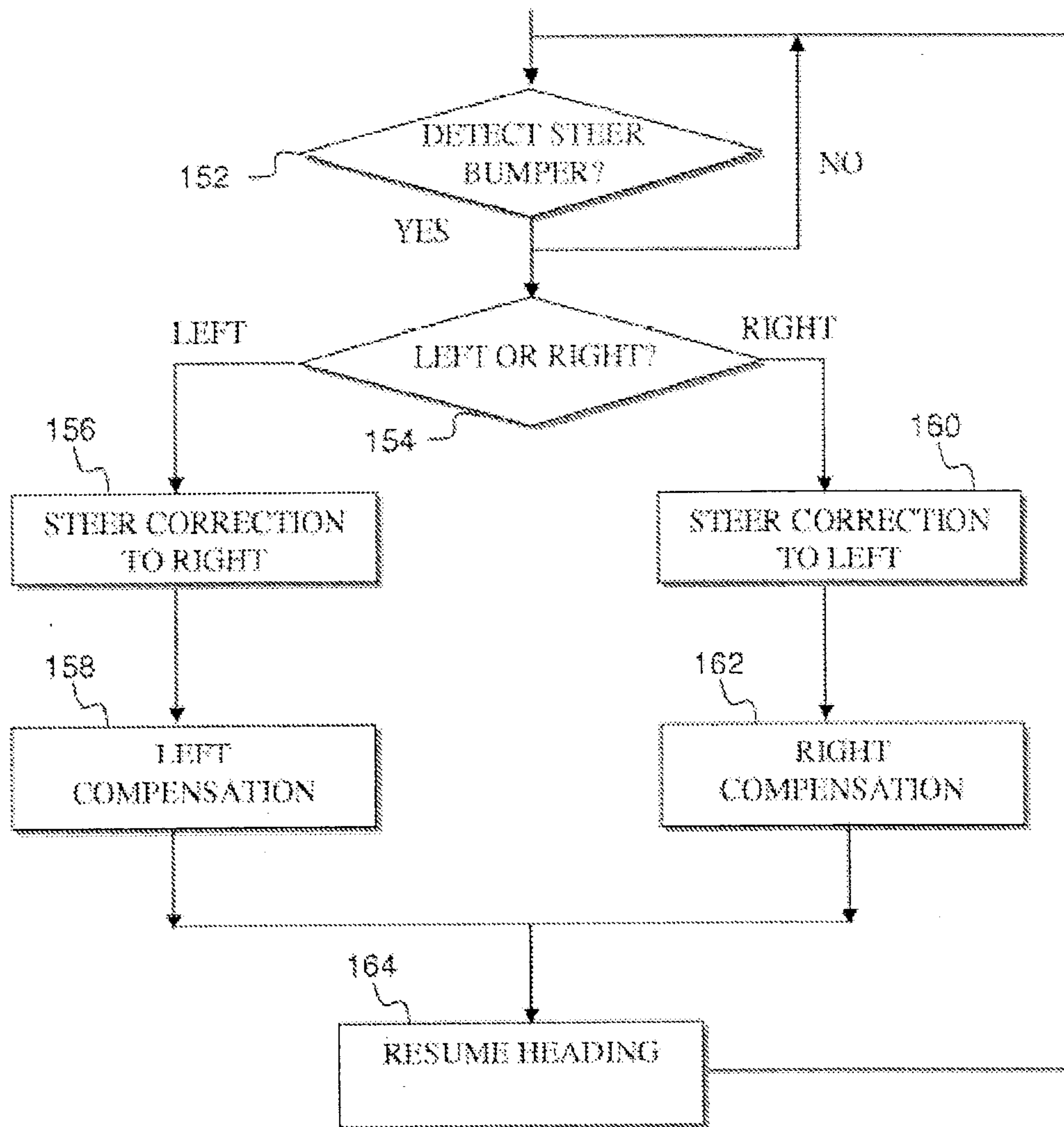


FIG. 12

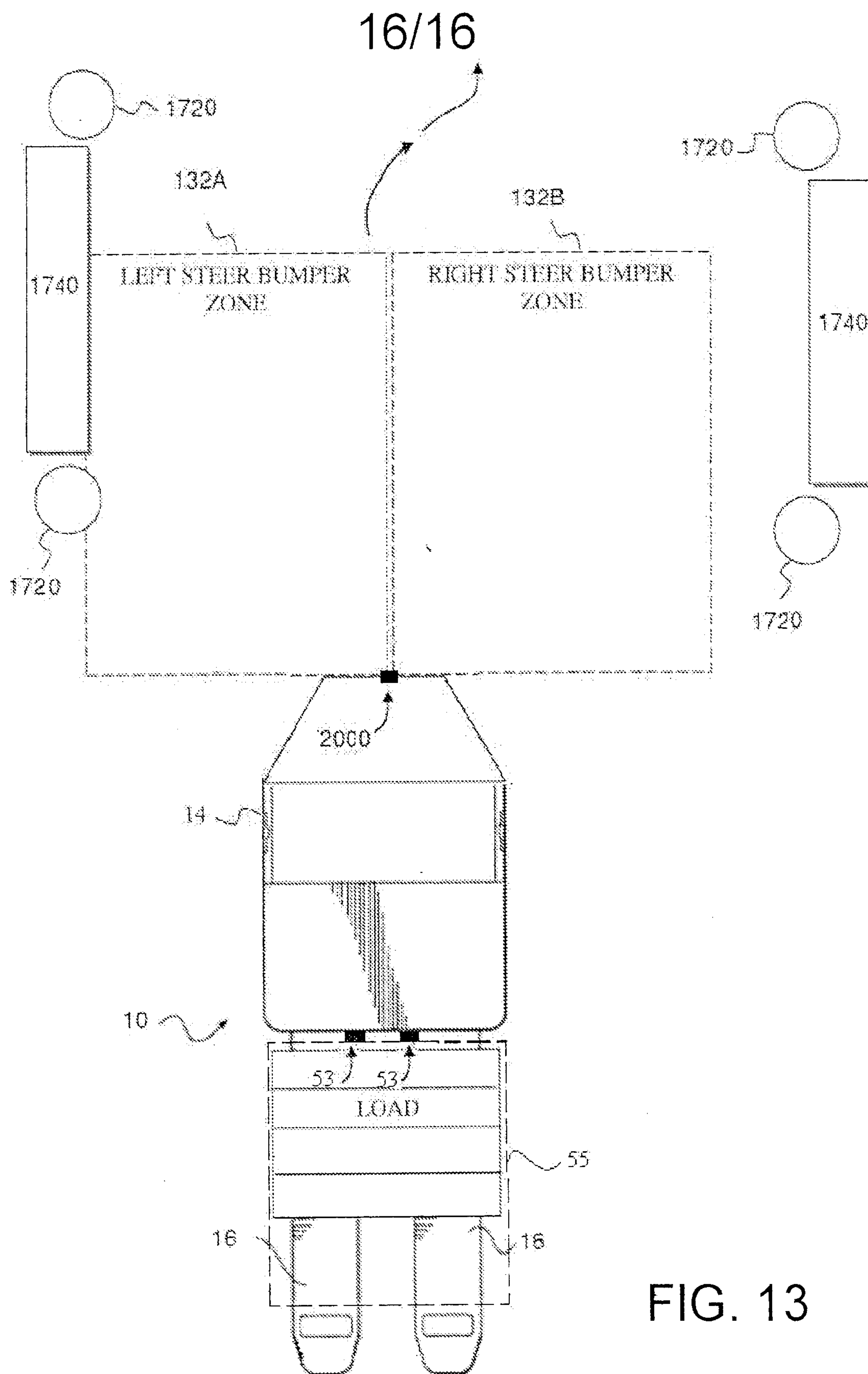


FIG. 13

