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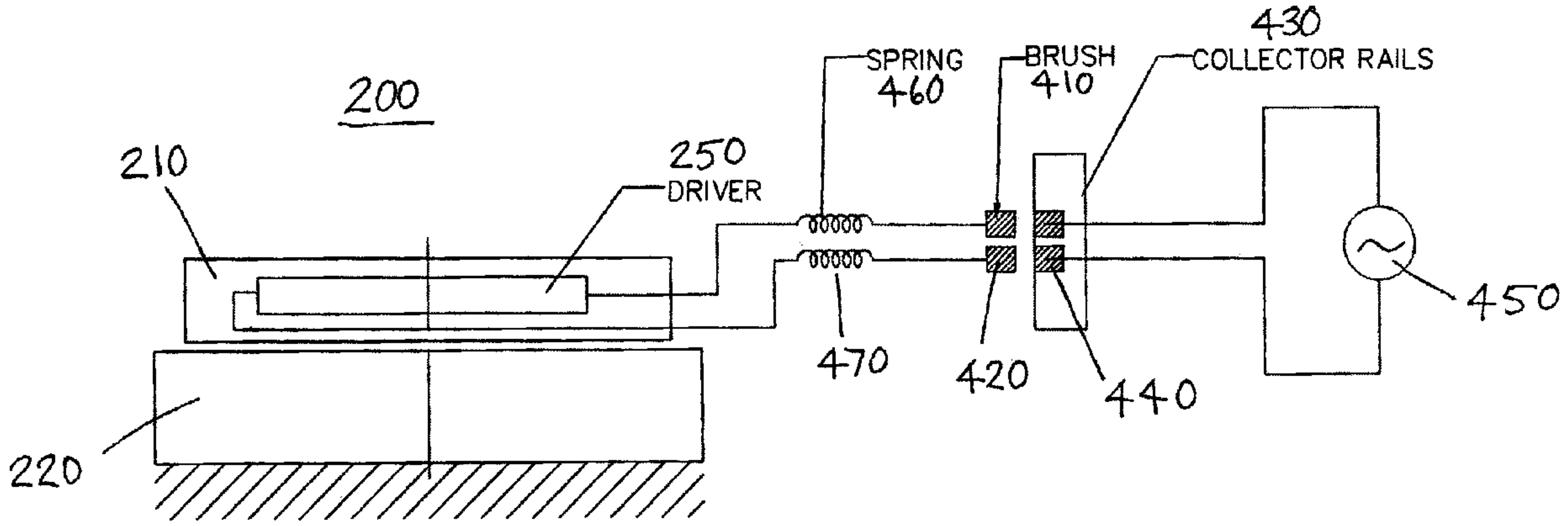
(54) **Titre** : MOTEUR LINEAIRE INTEGRE SANS FIL
(54) **Title:** INTEGRATED WIRELESS LINEAR MOTOR



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INTEGRATED WIRELESS LINEAR MOTOR

The invention relates to the field of linear motors, and more specifically to linear motors without power or control wiring between stator and movable stage.

BACKGROUND OF THE INVENTION

Linear motors having stationary armatures containing coils and movable stages containing magnets are well known in the art. Also known are linear motors having stationary magnets and moving coils. One type of such linear motors is disclosed in U.S. Patent. No. 4,749,921. The linear motor disclosed in this patent has a series of armature windings mounted to a base plate and a stage having a series of magnets that is free to move on the base plate. The stage is urged in the desired direction by applying AC or DC excitation to the coils. When such a linear motor is used in a positioning system, the relationship between the location of the stage and locations of the coils must be accounted for. In another linear motor, commutator contacts are pendant from the stage. The contacts contact one or more power rails, and one or more coil contacts. As the stage moves along the armature, the location of the stage, relative to the armature is automatically accounted for by applying power to the stationary armature windings through the commutator contacts. In yet other linear motors, it is conventional to employ a service loop of wires between the moving stage and the stationary elements.

Typically, the location of the stage is updated using a magnetic or optical position encoder on the stage which senses markings on an encoder tape stationary alongside the path of the stage. The location is transferred by the service loop to a stationary motor controller. Generally, the important location information is the phase of the stage relative to the phase of the armature. For example, in a three-phase armature, the windings are disposed in repeating sets of three for phases U, V and W. If the center of the U phase winding is arbitrarily defined as 0 degrees, then the centers of the V and W windings are defined as 120 and 240 degrees. There may be two, three or more sets of windings as required for the travel distance of the stage. Normally, all U phase windings are connected in parallel. The same is true of all V and W phase windings. Thus, when the location of the stage requires a certain voltage configuration on the particular windings within the influence of the magnets on the stage, besides powering these windings, all of the other windings in the armature are also powered. The maximum force obtainable from a linear motor is limited by the allowable temperature rise in the armature windings. When all windings are powered, whether they contribute to motor force or not, more armature heating occurs than is strictly necessary for performing the motor functions. Some linear motors in the prior art have responded to this heating problem using switches that are closed only to the armature windings actually within the influence of the magnets.

The need for a cable loop connecting moving and stationary elements is inconvenient, and limits the flexibility with which a system can be designed. The wiring harness requires additional clearance from the linear motor to prevent entanglement between the motor and any equipment or items that may be adjacent to the linear motor path. In addition, the wiring harness adds additional weight to the moving element of the linear motor. Furthermore, manufacturing of a linear motor employing a wiring harness incurs additional cost of material and assembly labour. Therefore, it would be desirable to eliminate the use of a wiring harness in a linear motor to decrease the cost of assembly, decrease the overall weight of the moving element, and to eliminate the clearance restrictions on the linear motor's utility.

Linear motors are increasingly being employed in manufacturing equipment. In such equipment, nominal increases in the speed of operation translate into significant savings in the cost of production. Therefore, it is particularly desirable to produce as much force and acceleration as possible in a given linear motor. An increase in force generated requires either an increase in magnetic field intensity or an increase in current applied to coils of the armature. In a permanent magnet linear motor, the available magnetic field intensity is limited by the field strength of available motor magnets. Power dissipated in the coils increases at a rate equal the square of the current. Attendant heat generation limits the force that may be achieved without exceeding the maximum armature temperature. Therefore, improvements in the power dissipation capacity of linear motors provide for increases in their utility.

In typical manufacturing equipment, a linear motor may be employed for driving a positioning table along an axis. For example, positioning tables are commonly used for moving a work object such as an electronic device in a precise path for performing an operation or inspection on the work object. Desirable characteristics of such positioning tables include precision, compactness, the maximum speed at which the table can be driven and the accuracy with which the table may be positioned. U.S. Patent No. 4,151,447 discloses a linear DC motor having rows of pairs of vertically standing permanent magnets between which flat coils are arranged to travel. The polarity of DC power to the flat coils is switched by a magnetic field or electro-optical sensor at predetermined points in the travel of the flat coils. The apparatus in this patent employs trailing cables for feeding power to the coils.

U.S. Patent No. 4,761,573 discloses a linear DC motor suitable for driving a positioning table. This linear DC motor includes a linear toothed structure including coils wound around the individual teeth to form a repeating line pattern of electrically produced magnetic poles facing a corresponding parallel array of magnets arranged with alternating magnetic polarity having their broad faces closest to the toothed assembly. A brush assembly is provided on the movable element for contacting a linear slip ring assembly on the stationary element for switching the polarity of voltage applied to energizing coils of the motor. Linear power pickup rails are used in conjunction with brushes and linear slip rings for feeding and controlling power to energizing coils. Furthermore, a brush and power pickup brush assembly is disclosed for feeding first and second electrical polarities to energizing coils which employs two identical comb-like structures for both picking up power from linear power pickup rails and for feeding power to the coils through a linear slip ring.

Another brush and rail power pick-up arrangement is disclosed in U.S. Patent No. 4,789,815. This patent discloses a movable stage having control and driver means for supplying electric power to coils in the movable stage. The electric power is delivered to the control and driver means through brushes which make contact with rails mounted on the frame. The direction and position of the movable stage are controlled through the supply of power to the rails (i.e. on, off, and polarity). The linear motor thus disclosed is directed toward the control of curtains in vehicles.

Thus, there is a growing commercial use of high performance, linear motors in various manufacturing and other applications. One recognized disadvantage of prior art linear motors is the cumbersome umbilical wires that connect the moving armature or stage to the controller and power source. For example, the umbilical for a prior art three-phase, brushless motor may have three power lines, five signal lines for the armature commutating signals, and eight signal lines for armature position signals.

FIG. 1 is a side view of a linear motor **100** in accordance with the prior art. The linear motor **100** includes a stage (or mover) **110** and a stator **120**. The stage (here, the armature) **110** includes coils **130** and the stator (here, the field) **120** includes magnets **140**. The linear motor **100** is controlled by an external driver/controller **150** that is connected to the linear motor **100** by umbilical wires (not shown). The umbilical wires include: three wires for U, V, and W signals **160** from the stage **110**; five wires for power, ground, and U, V and W signals from the Hall Effect sensor **170**; and, five wires for power, ground, and A, B and Z signals from the position sensor **180** on the stage **110**. The Hall Effect sensor **170** is used for detecting magnetic poles for commutation purposes.

Another recognized disadvantage is the need to remove heat from the moving stage (i.e. armature). Where a coolant is used, the umbilical includes, in addition to the wires, a tube to carry the coolant to a coolant coil embedded in the armature and a tube to carry the coolant from the coil. The result is a heavy, cumbersome, umbilical of wires and tubes, festooned along the path in which the stage moves.

To overcome these disadvantages, wireless or semi-wireless linear motors have been developed and have been disclosed, for example, in U.S. Patent Nos. 5,936,319 and 6,005,310. U.S. Patent No. 5,936,319 discloses a communications device on a movable stage which wirelessly informs a motor controller about the position and/or incremental motion of the movable stage. Any wireless transmission system may be used including radio and infrared. The movable stage includes a position encoder and permanent magnets. U.S. Patent No. 6,005,310 discloses a movable stage with a wireless transmitter (e.g. radio frequency or infrared) for transmitting commutating and position signals to an external motor controller. The motor controller is connected to the movable stage by an umbilical cord and the movable stage includes coils.

A need therefore exists for an improved wireless linear motor which overcomes at least some of the drawbacks of the prior art. Accordingly, it is an object of the present invention to provide such a linear motor.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention may best be understood by referring to the following description and accompanying drawings. In the description and drawings, line numerals refer to like structures or processes. In the drawings:

FIG. 1 is a side view of a linear motor in accordance with the prior art; and,

FIG. 2 is a side view of an integrated linear motor in accordance with an embodiment of the invention;

FIG. 3 is a block diagram illustrating an exemplary data processing system for implementing an embodiment of the invention;

FIG. 4 is a schematic diagram illustrating a linear motor having its driver/controller powered through brushes and collector rails in accordance with an embodiment of the invention;

FIG. 5 is a front view of a linear motor having its driver/controller powered through insulated linear guides in accordance with an embodiment of the invention;

FIG. 6 (a) is a front view of a linear motor having its driver/controller powered by magnetic induction in accordance with an embodiment of the invention; and,

FIG. 6 (b) is a perspective view of the magnets for use in the embodiment of FIG. 6 (a) in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, numerous specific details are set forth to provide a thorough understanding of the invention. However, it is understood that the invention may be practiced without these specific details. In other instances, well-known software, circuits, structures and techniques have not been described or shown in detail in order not to obscure the invention. The term “data processing system” is used herein to refer to any machine for processing data, including the computer systems and network arrangements described herein.

FIG. 2 is a side view of an integrated linear motor **200** in accordance with an embodiment of the invention. The integrated linear motor **200** includes a stage **210** and a stator **220**. The stage **210** includes coils **230** and the stator **220** includes permanent magnets **240**. The stage **210** is adapted to move back and forth on the stator **220** which functions as a frame for the motor **200**. The stage **210** is mechanically supported on the frame by any one of a number of suitable structures including linear guides **510**, **520** (see FIG. 5).

The linear motor **200** is controlled by a driver/controller **250** that is mounted on the stage **210**. The driver/controller **250** includes a central processing unit or CPU, memory, a transceiver or transceiver interface, and I/O interfaces. The CPU may include dedicated coprocessors and memory devices. The memory may include RAM, ROM, databases, or disk devices. The transceiver or transceiver interface may include radio frequency, infrared, and power-line carrier transceivers or transceiver interfaces, respectively. And, the I/O interfaces may include interfaces for sensor inputs and coil outputs. In addition, the drive/controller **250** may support detachable input and display devices. The detachable input device may include a keyboard, mouse, trackball, or similar device. The detachable display may include a computer screen or terminal device. The driver/controller **250** has stored therein data representing sequences of instructions which when executed cause the method described herein to be performed. Of course, the driver/controller **250** may contain additional software and hardware a description of which is not necessary for understanding the invention.

The drive/controller **250** is in wireless data communication with a remote data processing system **300** (see FIG. 3). This wireless data communication is supported by a first transceiver (not shown) mounted on the stage **210** and coupled to or incorporated in the driver/controller **250** and a second transceiver **350** (see FIG. 3) associated with the data processing system **300**. The transceivers can include radio frequency ("RF"), infrared ("IR"), and power-line carrier (high frequency modulation) transceivers and various communication protocols can be supported including the Bluetooth, wireless LAN, and ADSL protocols.

FIG. 4 is a schematic diagram illustrating a linear motor **200** having its driver/controller **250** powered through brushes and collector rails in accordance with an embodiment of the invention. The driver/controller **250** receives electrical power from a power source **450** through power or collector rails **430**, **440** mounted on the frame **220** which are in contact with brushes **410**, **420** mounted on the stage **210**. To improve conductance, the brushes may be mounted on springs **460**, **470**. On the stage **210**, power from the brushes **410**, **420** is distributed to the driver/controller **250** and other stage mounted devices. Similarly, a collector ring arrangement (not shown) typical of subway trains and the like may be used to supply power to the stage **210**.

FIG. 5 is a front view of a linear motor **200** having its driver/controller **250** powered through insulated linear guides **510**, **520** in accordance with an embodiment of the invention. In this embodiment, the rail portion **511**, **521** of each linear guide **510**, **520** is connected to the power source **450**. The rail portion **511**, **521** is generally insulated from the frame **220** by first insulators **530**, **540**. The stage portion **512**, **522** of each linear guide **510**, **520** is connected to the stage **210** upon which is mounted the driver/controller **250**. The stage portion **512**, **522** is generally insulated from the stage **210** by second insulators **550**, **560**. The insulated linear guides **510**, **520** function to both support and provide power to the stage **210**. Ball bearings (not shown) provide the points of electrical contact between the rail **511**, **521** and stage **512**, **522** portions of the linear guides **510**, **520**.

FIG. 6 (a) is a front view of a linear motor **200** having its driver/controller **250** powered by magnetic induction in accordance with an embodiment of the invention; and, FIG. 6 (b) is a perspective view of the magnets **610**, **620** for use in the embodiment of FIG. 6 (a) in accordance with an embodiment of the invention. In this embodiment, the stage **210** and frame **220** have associated coils **611**, **621** wound on respective cores **610**, **620**. The frame coil **621** is connected to a power source **450**. When energized, the frame coil **621** causes a magnetic flux to link the stage core **610** and coil **611** and hence induce a voltage across the stage coil terminals. The stage coil terminals are connected to the driver/controller **250** and provide it with electric power. The stage and frame coils **611**, **621** and cores **610**, **620** may be integrated with the linear guides **510**, **520** and/or stage **210** and frame **220**.

According to another embodiment of the invention, the stage **210** is powered by a rechargeable battery (not shown).

Advantageously, no umbilical wires are used to connect the stage **210** or driver/controller **250** to the frame **220** or data processing system **300**.

Referring again to FIG. 2, the stage **210** generally includes a metal or cast resin armature plate (not shown) in which the armature coils **230** are embedded. For a three phase motor, typically six coils are used three of which are shown in FIG. 2, in a non-overlapping arrangement, but, as will be appreciated by those skilled in the art, they could be disposed in an overlapping position. The armature plate is formed with a suitable thermally conductive metal or resin. A heat sink (not shown), made of a suitable thermally conductive material (e.g. aluminium) is attached by a heat conductive epoxy to the armature plate. Thermally conductive pins (not shown) can be used to help conduct heat from the armature coils **230** to the heat sink and also help secure the heat sink to the armature plate. One or more fans (not shown) can be attached to the heat sink to move air across the heat sink to help cool it and thereby aid in heat transfer away from the armature coils **230**. The heat sink typically includes fins (not shown) to aid in heat removal by providing an additional surface area over which air may pass.

Sensors **270** (e.g. Hall Effect sensors), attached to stage **210**, generate commutating signals indicating the position of the armature coils **230** relative to the stator permanent magnets **240**. As will be appreciated by those skilled in the art, these commutating signals are used to control sequential switching of power to the armature coils **230** by the driver/controller **250**. In a three-phase embodiment of the invention, three commutation position sensors **270** (e.g. three Hall Effect sensors) may be used. In addition, an armature position encoding sensor **280** is attached to stage **210**. The armature position encoder **280** may be, for example, an optical encoder.

Commutation signals from the sensors **270** and armature position signals from the armature position encoder **280** are coupled to the driver/controller **250**. The armature position signals, which indicate the position of the stage **210**, and the commutation signals, are decoded as necessary by the driver/controller **250** and used to control the supply of power to the armature coils **230**. Alternatively or additionally, the armature position and commutation signals may be received by the driver/controller **250** and transmitted via the coupled stage mounted transceiver to the data processing system **300**.

FIG. 3 is a block diagram of an exemplary data processing system **300** for implementing an embodiment of the invention. The data processing system is suitable for controlling and/or monitoring one or more integrated linear motors **200** in conjunction with a graphical user interface ("GUI"). The data processing system **300** includes an input device **310**, a central processing unit or CPU **320**, memory **330**, a display **340**, and a transceiver **350**. The input device **310** may include a keyboard, mouse, trackball, or similar device. The CPU **320** may include dedicated coprocessors and memory devices. The memory **330** may include RAM, ROM, databases, or disk devices. The display **340** may include a computer screen or terminal device. And, the transceiver **350** may include RF, IR, and power-line carrier transceivers. The data processing system **300** has stored therein data representing sequences of instructions which when executed cause the method described herein to be performed. Of course, the data processing system **300** may contain additional software and hardware a description of which is not necessary for understanding the invention.

In operation, the driver/controller **250** receives an instruction set from the data processing system **300** via the stage mounted transceiver and data processing system transceiver **350**. The instruction set specifies the position or path the stage **210** is to move to or over, respectively. The driver/controller **250** receives position and commutation signals from the position and commutation sensors **270**, **280**, respectively. From the received position signals, commutation signals, and instructions, the driver/controller **250** computes the drive signals to be provided to the armature coils **230** to complete the repositioning or movement specified by the instruction set. Using power provided by the frame mounted power rail, for example, the driver/controller **250** generates the necessary drive signals and provides these to the armature coils **230**. The driver/controller **250** continues to monitor the position and commutation sensors **270, 280** during movement of the stage **210**. After the stage **210** has been repositioned or moved in accordance with the instruction set, the driver/controller **250** reports instruction set completion and the new location of the stage **210** to the data processing system **300** and awaits a new instruction set. The driver/controller **210** may continually report stage position and other parameters (e.g. power consumption, temperature, etc.) to the data processing system **300** or these parameters may be reported upon request by the data processing system **300**.

Data Carrier Product. The sequences of instructions which when executed cause the method described herein to be performed by the driver/controller **250** and/or data processing system **300** can be contained in a data carrier product according to an embodiment of the invention. This data carrier product can be loaded into and run by the driver/controller **250** and/or data processing system **300**.

Computer Software Product. The sequences of instructions which when executed cause the method described herein to be performed by the driver/controller **250** and/or data processing system **300** can be contained in a computer software product according to an embodiment of the invention. This computer software product can be loaded into and run by the driver/controller **250** and/or data processing system **300**.

Integrated Circuit Product. The sequences of instructions which when executed cause the method described herein to be performed by the driver/controller **250** and/or data processing system **300** can be contained in an integrated circuit product including a coprocessor or memory according to an embodiment of the invention. This integrated circuit product can be installed in the driver/controller **250** and/or data processing system **300**.

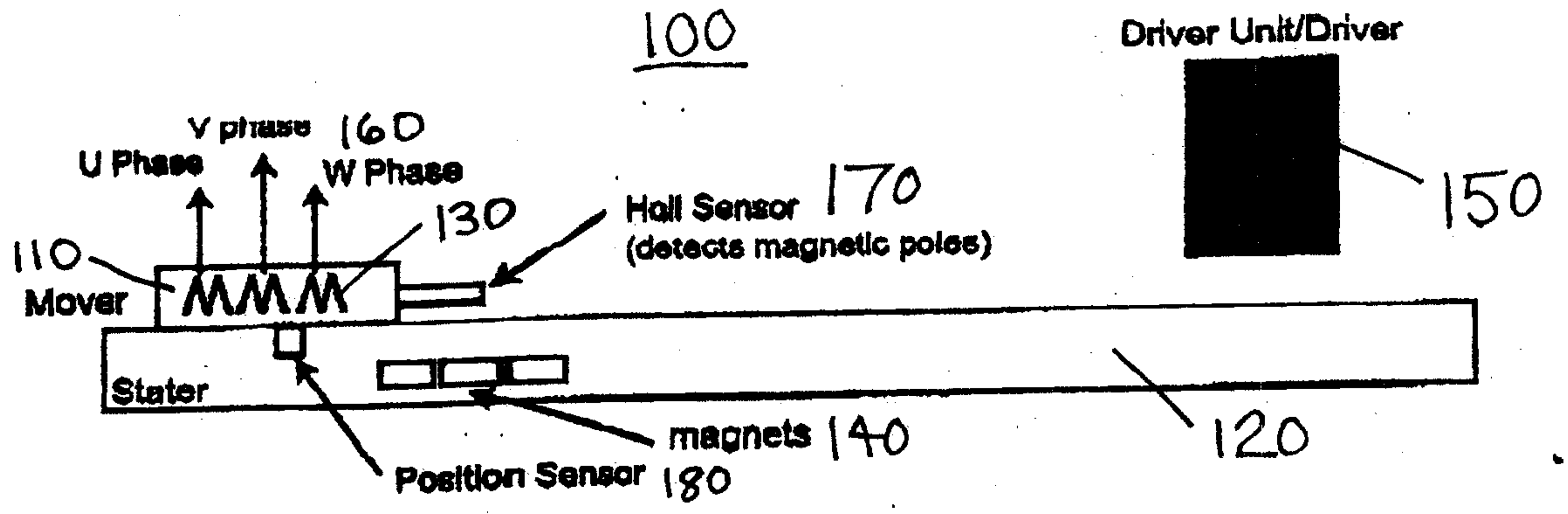


FIG. 1
PRIOR ART

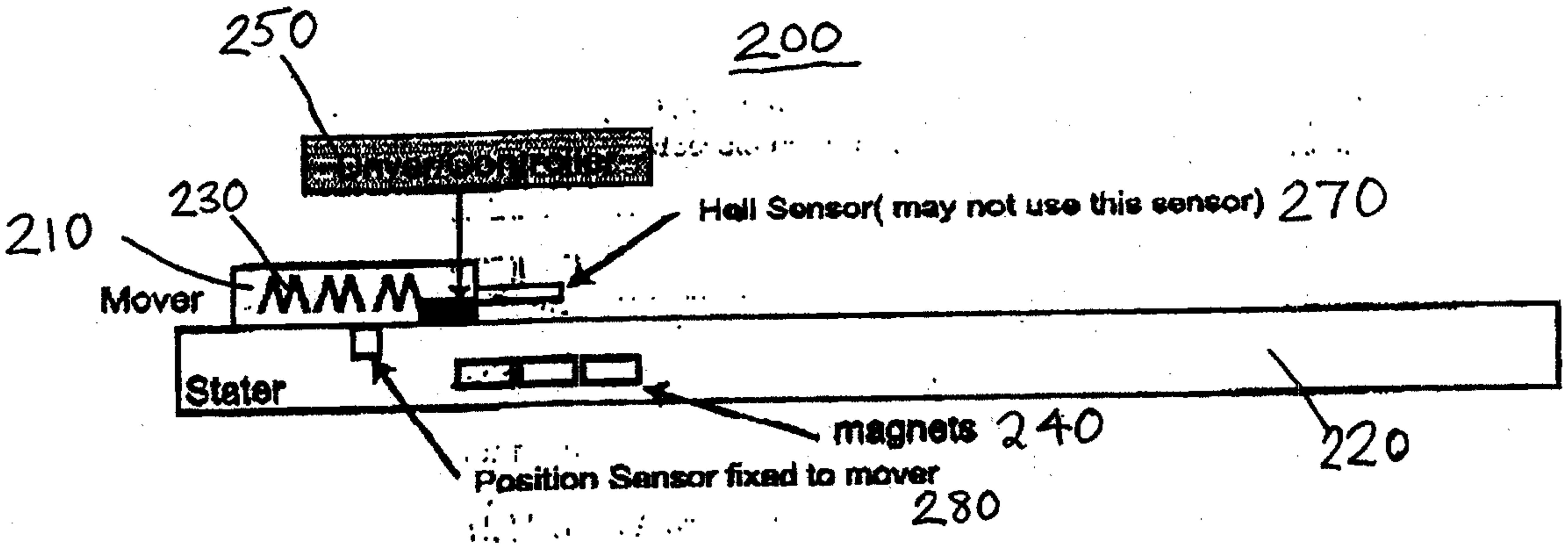


FIG. 2

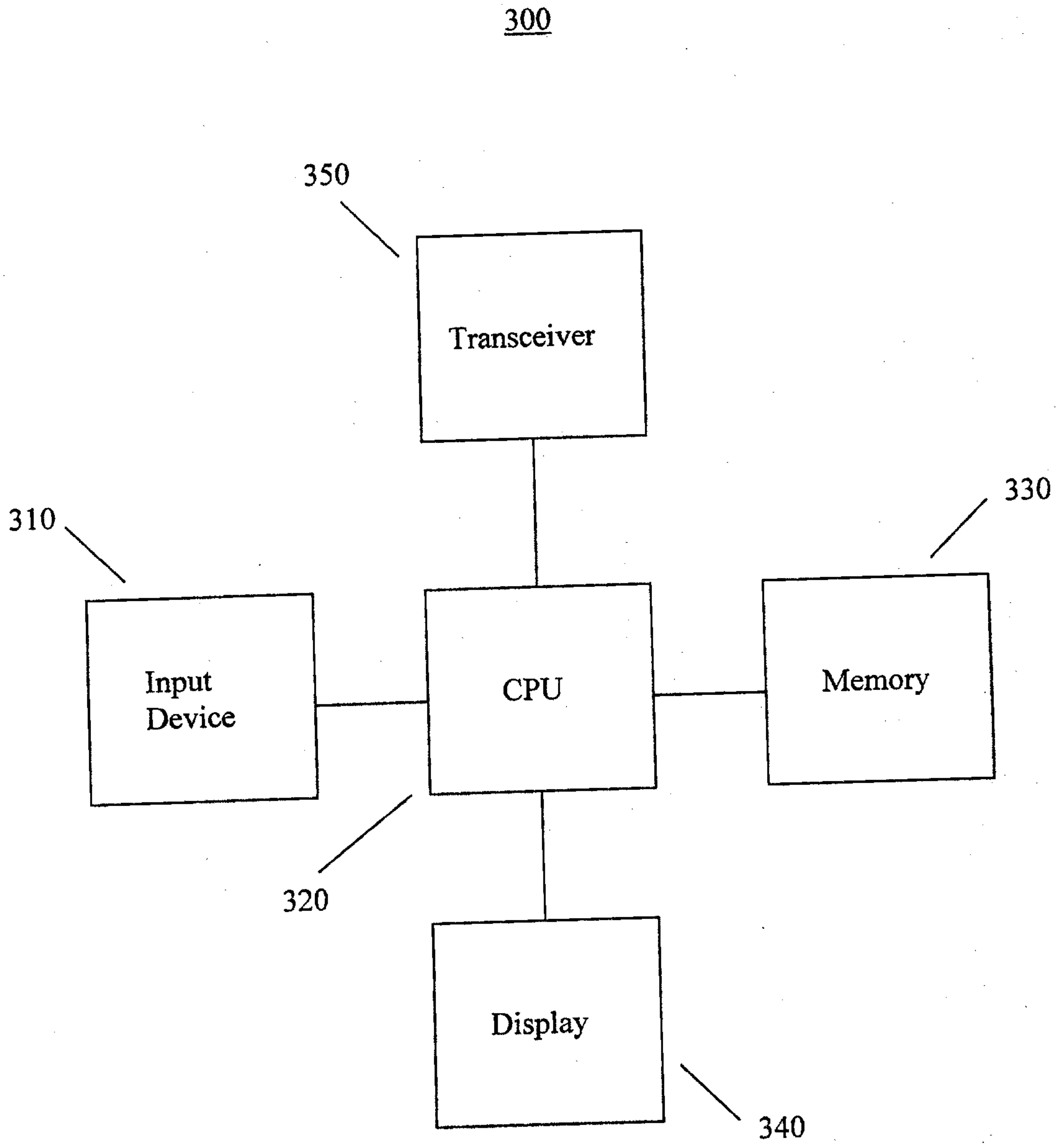

300
350
Transceiver
310
Input Device
CPU
330
Memory
320
Display
340

FIG. 3

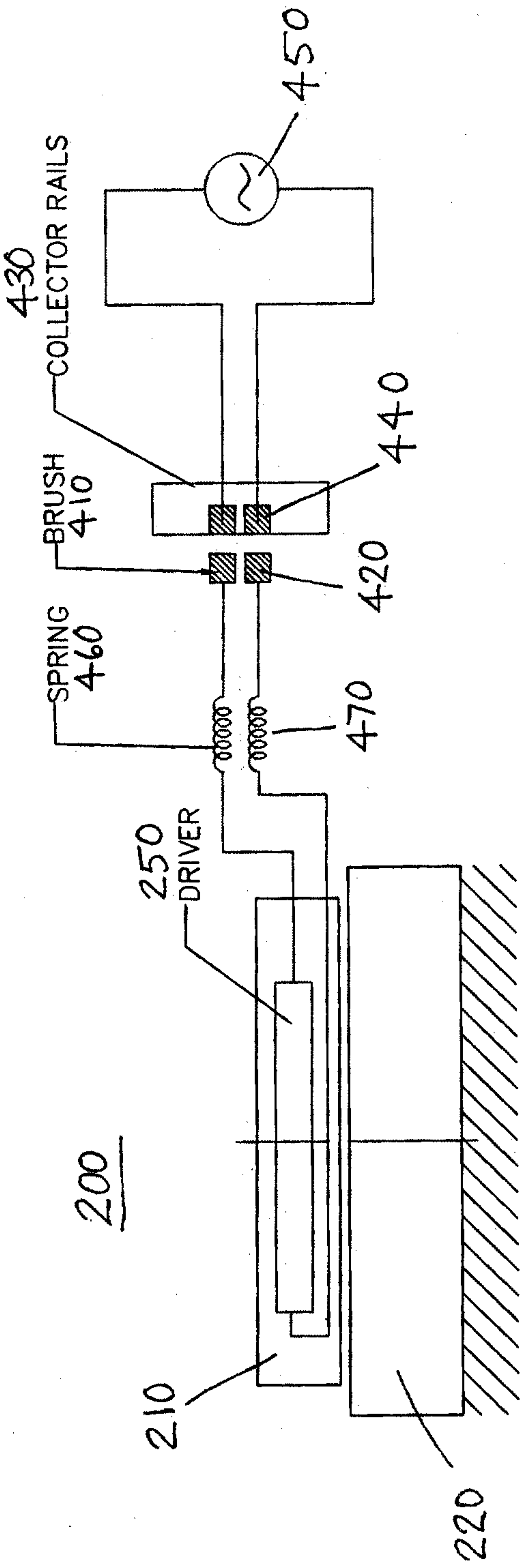

450
430
COLLECTOR RAILS
440
BRUSH
410
420
SPRING
460
470
250
DRIVER
200
210
220

FIG. 4

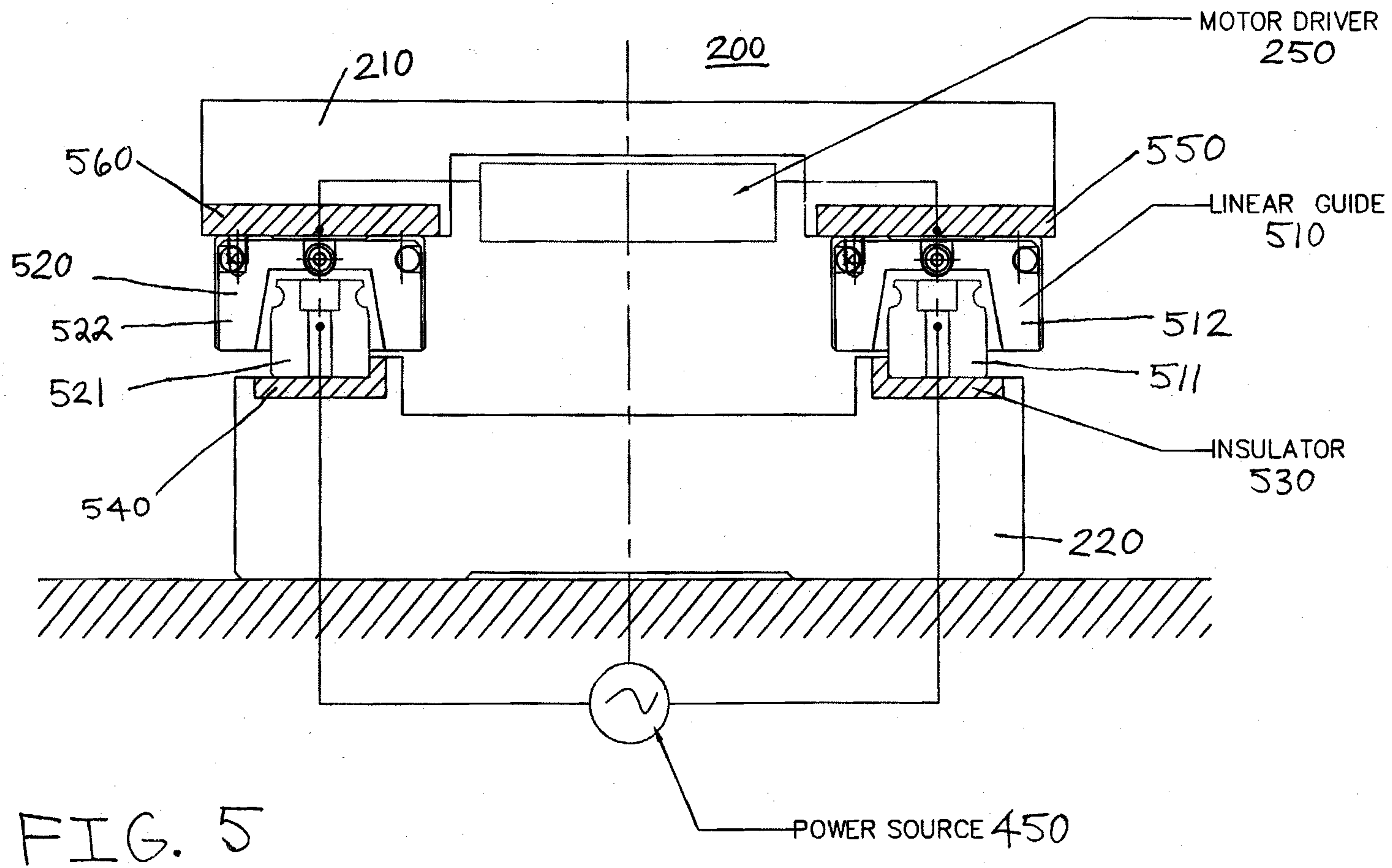

MOTOR DRIVER
250
200
210
560
550
LINEAR GUIDE
510
520
522
512
521
511
INSULATOR
530
540
220
POWER SOURCE 450

FIG. 5

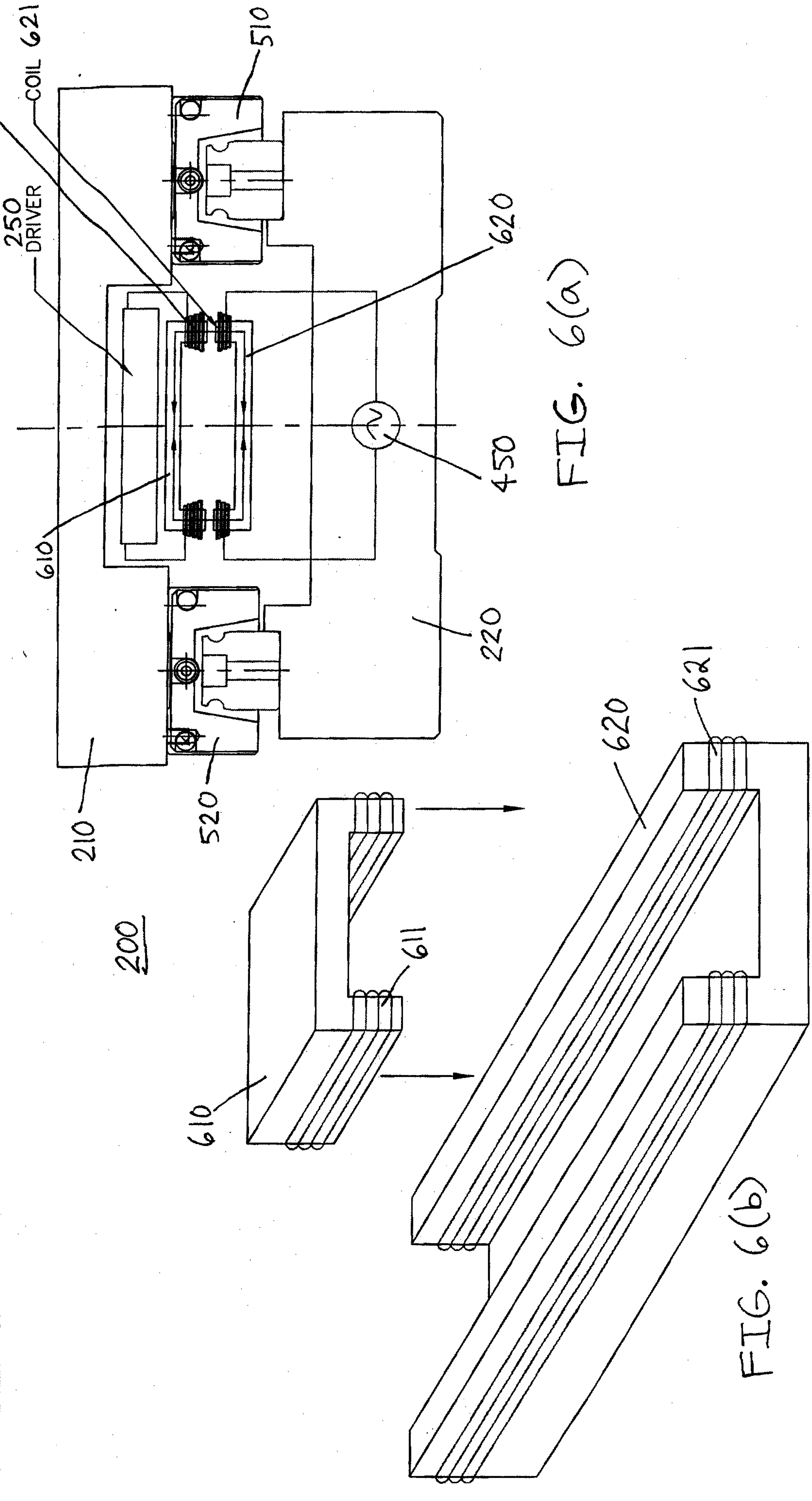
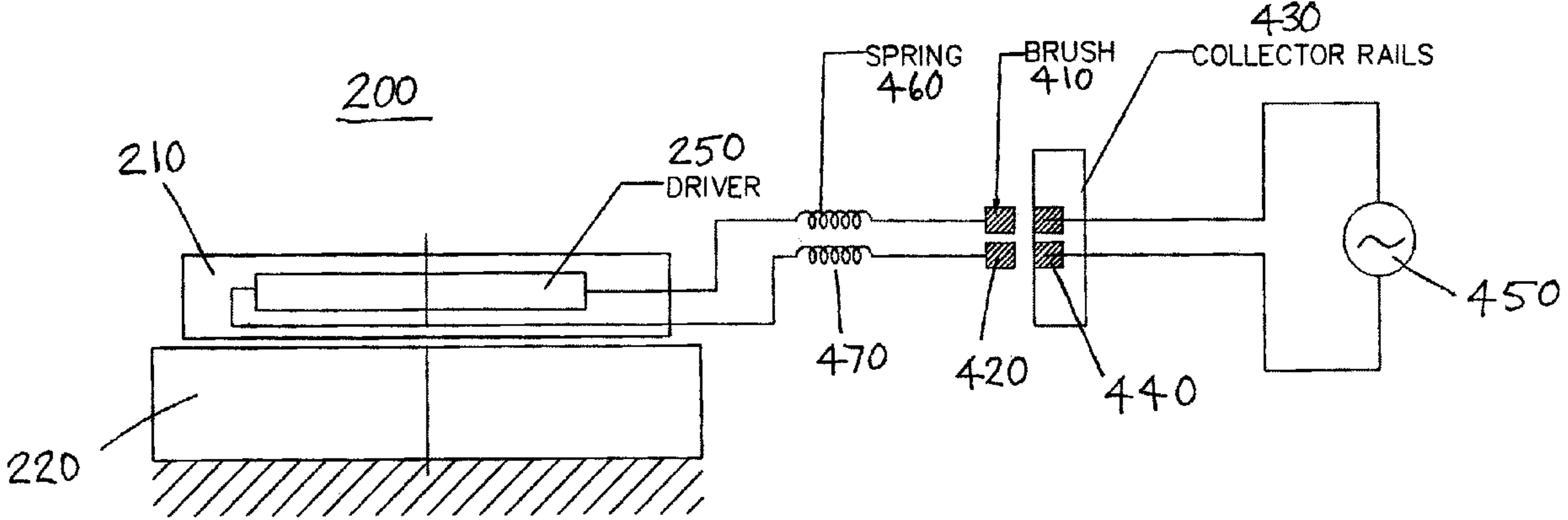

611
COIL 621
510
250
DRIVER
620
610
450
220
210
520
200
620
621
611
610

FIG. 6(a)

FIG. 6(b)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SPRING
460
BRUSH
410
COLLECTOR RAILS
200
210
250
DRIVER
450
470
420
440
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