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(54) **Title:** BRAKING SYSTEM

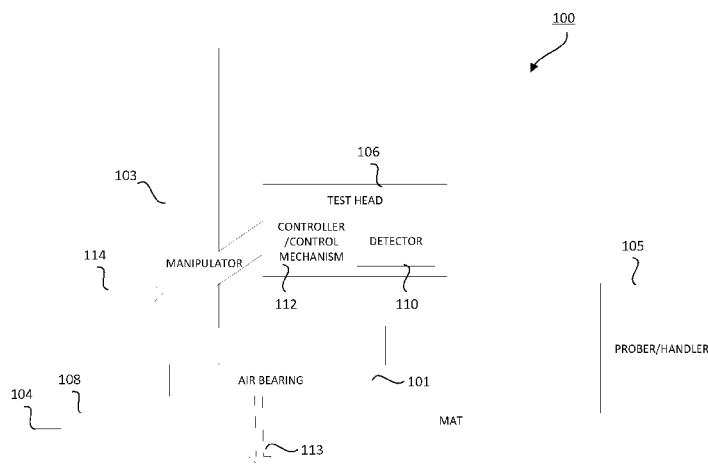


FIG. 1

(57) **Abstract:** An example method includes: for a component supported by an air bearing, detecting a speed of movement of the component relative to a predefined location, the air bearing generating an air flow to elevate the component relative to a ground plane; and controlling the air bearing based, at least in part, on the speed detected.

BRAKING SYSTEM

TECHNICAL FIELD

This specification relates generally to a safety braking system, for use, e.g., with an air bearing or other movement mechanism.

5

BACKGROUND

Automatic Test Equipment (ATE) refers to an automated, usually computer-driven, system for testing devices, such as semiconductors, electronic circuits, and printed circuit board assemblies. ATE typically includes large components, which
10 may weigh on the order of tons. Examples of such components are test heads, manipulators, handlers and wafer probers. During testing, these components may need to be moved from one location to another. The most complex motion interaction is the test head as it is brought into alignment to the handler or wafer prober. The manipulator provides this articulation, typically using expensive and
15 degree-of-freedom-limiting rail bearing sets.

SUMMARY

An example method may include: for a component supported by an air bearing, detecting a speed of movement of the component relative to a predefined
20 location, where the air bearing generates an air flow to elevate the component relative to a ground plane and controlling the freedom of motion of the device supported by the air bearing based, at least in part, on the speed detected. The

example method may include any one or more of the following features, either alone or in combination.

The example method may include: determining that the speed of movement of the component is greater than a threshold; and determining that the component is within a geographic area associated with the predefined location. Controlling the air bearing may include reducing an air flow into the air bearing so as to reduce the speed of movement of the component by removing some of the support provided by the air bearing and allowing a braking surface to contact the supporting floor. The example method may also include restricting a rate at which the air flow is reduced.

The example method may include: determining that the speed of movement of the component is less than a threshold; and determining that the component is within a geographic area associated with the predefined location. Controlling the air bearing may include maintaining an air flow of the air bearing so as to maintain the speed of movement of the component.

The example method may include: determining that the speed of movement of the component is greater than a threshold; and determining that the component is within a geographic area associated with a predefined location. Controlling the air bearing may include modulating the air flow of the air bearing so as to reduce the speed of movement of the component by allowing a braking surface to contact the supporting surface.

The example method may include: detecting the position of the component relative to the predefined location; and controlling the air bearing based also on the

position. The position may be detected relative to a mat having position markers. The position markers may comprise concentric shapes having pitches that decrease at increasing distances from a center. The position markers may be detected optically. The position may be detected using radio frequency detection, where a
5 transmitter is at the component and a receiver is at the location or where a receiver is at the component and a transmitter is at the location. The position may be detected using ultrasound. The position may be detected using tethers and potentiometers, where the tethers are connected to the component and are configured to move with the component. The lengths of the tethers corresponds to
10 resistance measured by the potentiometers, and the position is based on the length of the tethers. The position may be detected using a global positioning system or other appropriate position location methodology.

An example system may include: a component; an air bearing supporting the component, where the air bearing is configured to generate an air flow to elevate the
15 component relative to a ground plane; a detector to detect a speed of movement of the component on the air bearing; and a controller to output signals to control the air bearing based, at least in part, on the speed detected. The example system may include any one or more of the following features, either alone or in combination.

The controller may be configured to perform operations comprising:
20 determining that the speed of movement of the component is greater than a threshold; and determining that the component is within a geographic area associated with the predefined location; where controlling the air bearing comprises

reducing an air flow of the air bearing so as to reduce the speed of movement of the component. Controlling the air bearing may include restricting the rate at which the air flow is reduced.

The controller may be configured to perform operations comprising:

- 5 determining that the speed of movement of the component is less than a threshold; and determining that the component is within a geographic area associated with the predefined location, where controlling the air bearing comprises maintaining an air flow of the air bearing so as to maintain the speed of movement of the component.

The controller may be configured to perform operations comprising:

- 10 determining that the speed of movement of the component is greater than a threshold; and determining that the component is within a geographic area associated with the predefined location; where controlling the air bearing comprises reducing the air flow of the air bearing so as to reduce the speed of movement of the component.

- 15 The controller may be configured to perform operations comprising: detecting a position of the component relative to the predefined location; and controlling the air bearing based also on the position. The position may be detected relative to a mat having position markers. The position markers may include concentric shapes having pitches that decrease at increasing distances from a center. The detector
20 may include an optical detector to detect the position markers optically. The detector may include a radio frequency detector to detect a position using radio frequency detection, where a transmitter is at the component and a receiver is at the

location or where a receiver is at the component and a transmitter is at the location. The detector may include an ultrasound detector. The detector may include a tether and a potentiometer, where the tether is connected to the component and being configured to move with the component; and where a length of the tether
5 corresponds to resistance measured by the potentiometer, the position being based on the length of the tether. The detector may include a global positioning system.

Any two or more of the features described in this specification, including in this summary section, can be combined to form implementations not specifically described herein.

10 The test systems and techniques described herein, or portions thereof, can be implemented as/controlled by a computer program product that includes instructions that are stored on one or more non-transitory machine-readable storage media, and that are executable on one or more processing devices to control (e.g., coordinate) the operations described herein. The test systems and techniques
15 described herein, or portions thereof, can be implemented as an apparatus, method, or electronic system that can include one or more processing devices and memory to store executable instructions to implement various operations.

The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent
20 from the description and drawings, and from the claims.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of example automatic test equipment (ATE) that implements an air bearing and a mat-based braking system therefor.

Fig. 2 is a front view of an example mat used in an air bearing braking system.

5 Fig. 3 is a block diagram of example ATE that implements an air bearing and a radio frequency (RF)-based braking system therefor.

Fig. 4 is a block diagram of example ATE that implements an air bearing and a tether-based braking system therefor.

Fig. 5 is a top view of example ATE like that of Fig. 4.

10 Like reference numerals in different figures indicate like elements.

DETAILED DESCRIPTION

Manufacturers may test devices at various stages of manufacturing.

Manufacturers have an economic incentive to detect and to discard faulty
15 components as early as possible in the manufacturing process. Accordingly, many manufacturers test integrated circuits at the wafer level, before a wafer is cut into dice. Defective circuits are marked and generally discarded prior to packaging, thus saving the cost of packaging defective dice. As a final check, many manufacturers test each finished product before it is shipped. Such a process tests parts in
20 packages which have had additional expense added to them over bare die. So, having accurate test results reduces the need to discard valuable parts.

To test quantities of components, manufacturers commonly use ATE (or "testers"). In response to instructions in a test program set (TPS), some ATE automatically generates input signals to be applied to a device under test (DUT), and monitors output signals. The ATE compares the output signals with expected responses to determine whether the DUT is defective. ATE typically includes a computer system and a test instrument or a single device having corresponding functionalities. In some cases, the test instrument provides power to a DUT.

Some types of ATE include a test head, which may include all or part of the tester functionality. In some cases, computer system functionality may also be incorporated into the test head. In some ATE, the test head mates to a prober or handler in order to perform test procedures on a DUT. A manipulator or other device is typically used to move and to position the test head. Typically, the combined manipulator and test head are quite heavy, e.g., on the order of hundreds or even thousands of pounds. Moving the combined manipulator and test head from one location to another can therefore be difficult. For the purposes of the following description, the manipulator is assumed to hold a test head and, therefore, the combined test head and manipulator is referred to simply as "the manipulator".

To facilitate movement of the manipulator, an air bearing may be used. In some examples, an air bearing is device that generates an air flow towards a ground plane to elevate the component relative to the ground plane. Referring to test system 100 shown in Fig. 1, an air bearing 101 may be mounted to the bottom of a manipulator 103 that faces the ground plane 104. Air flow generated from the air

bearing in the direction of arrow 113 forces the manipulator to lift off of the ground plane, thereby making the manipulator easier to move through application of horizontal force (roughly parallel to the ground plane along arrow 114). In some cases, the air bearing lifts the manipulator by one to five millimeters; however, the amount of lift achieved varies with the force created by the air flow.

In some cases, movement of the manipulator through use of horizontal force can create an amount of momentum that can make it difficult to stop the movement, when necessary. For example, as more force is applied, the speed of the manipulator increases, making it difficult to stop. This can be a safety hazard, given the size and weight of the manipulator and the test head it carries. Furthermore, this can cause damage to other test components, such as the prober or handler 105. For example, if the manipulator contacts the prober or handler 105 at an inappropriately high speed, the prober or handler and/or the test head and/or manipulator may be damaged.

Accordingly, safety features may be incorporated into the air bearing movement system to limit the speed at which the manipulator can be moved in general or in certain areas of a test facility. In some implementations, for safety reasons, the movement system may corral or stop the manipulator. In an example implementation, a mat 108 is used in a braking system to limit the speed at which the manipulator is moved. Fig. 2 shows an example of such a mat 200; however, mats having other configurations may be used. In this example, the mat covers at

least part of the test floor 202 or any other area where it is desired to limit the speed of movement of the manipulator supported by an air bearing.

As shown in Fig. 2, mat 200 includes position markers 206 (or simply, "markers"), which are detectable by a detector mechanism which, in combination
5 with a control mechanism, (both described below) controls operation of the air bearing. As shown in Fig. 2, in this example, the pitch of the markers varies from the center 210, as does their placement. In this example, the pitch decreases further away from center 210. In this example, center 210 may be positioned at roughly the center of the test area, with the edges 211 of mat 200 positioned near to the walls or
10 other defining features of a room containing the test area. In other examples, the mat may be placed at any appropriate location of a test floor.

In an example implementation, a detector 110 (which may, or may not, be part of a control mechanism 112) detects the pitch of markers 206 on the mat and the speed of movement of the manipulator. The detector and control mechanism
15 may be located on the manipulator, on the test head, or on both. Signals indicative of the pitch and speed are sent from the detector to the control mechanism. The control mechanism uses those signals to control operation of the air bearing. For example, if the speed of movement is below a threshold, then the control mechanism maintains the full air flow, e.g., the amount of air (and thus the amount of
20 force), generated by the air bearing regardless of the pitch of the markers underneath the air bearing. Thus, in this example, the air flow is maintained if the manipulator is within a geographic location defined by high-pitched markers 212 or

within a geographic location defined by low-pitched markers 213 (e.g., near to the center of the mat). In this context, “high” and “low” are relative values, and are not intended to have any specific numerical connotations. In this example, the air flow is maintained and there is no change, or substantially no change in the amount of horizontal force needed to move the air bearing across the test floor. A rationale for this is that the speed of movement of the manipulator is within a safe range and, therefore, the manipulator may continue on its present course at the same speed regardless of the location of the manipulator on the test floor.

If, however, the speed of movement is at or above a first threshold, and the manipulator is in a specific geographic location (e.g., the pitch of the markers underneath the air bearing is below a second threshold), then the control mechanism changes the amount of air (and thus the amount of lifting force) generated by the air bearing. For example, in area 217, the force generated by the air less than in area 218 if the speed exceeds the first threshold. The control mechanism may restrict the air flow by controlling the size of one or more apertures used to generate the air flow, or by changing the amount or pressure of the air being introduced into the air bearing. In an example implementation, the amount of air introduced into the air bearing (and thus the amount of force generated by the air bearing) is decreased, which will make it more difficult to move the manipulator via horizontal force or may make it easier to stop it completely (since the air bearing is closer to the ground plane). A rationale for this is that the speed of movement of the

manipulator is outside of a safe range and, therefore, the manipulator may need to be slowed or stopped.

In some implementations, as shown in Fig. 2, the pitch of the markers comprises concentric shapes (e.g., circles) having pitches that decrease at increasing distances from a center. In some implementations, the markers may not include concentric shapes, and the shapes may not be circular, but rather some form of quadrilateral or polygon. Generally, the markers may be arranged in any appropriate configuration and/or shape to achieve a desired level of speed control and to achieve a desired area over which speed is to be controlled. The control mechanism may likewise be programmable to achieve a desired level of speed control and to achieve a desired area over which speed is to be controlled based on the markers or any other appropriate detection mechanism.

In some implementations, the markers may be detected optically. For example, detector 110 may be an optical detector that detects the markers and their pitch using, e.g., an optical sensor, a light sensor, or any other appropriate optical detection mechanism. In some implementations, other mechanisms may be used to detect the markers and their pitch. For example, in some implementations, detector 110 may be or include thermal sensors, the markers may be heated relative to their surroundings, and the detector may detect the markers using thermal detection. In some implementations, detector 110 may be an electrical detector, the markers may contain a slight charge, and detector 110 may detect that charge. Any appropriate

detector system for detecting the markers and their pitch may be used. As noted above, detector 110 sends one or more detection signals to control mechanism 112.

In some implementations, the position of the manipulator may be detected using ultrasound. For example, detector 110 may be ultrasound transducers, which

5 may be positioned at the manipulator may be used to detect the position of the manipulator within an enclosed location (e.g., relative to a structure, such as the prober/handler, or a boundary, such as a wall). This may be done with or without the mat in place. When the transducer detects that the manipulator is at one of a number of specified locations (e.g., as the manipulator moves from a specified
10 center location), the transducer may signal the control mechanism to limit the air flow of the air bearing to the above effect, provided that the speed of the manipulator is above a threshold. As was the case, in this example, if the speed of movement is below a threshold, then the control mechanism may maintain the air flow, e.g., the amount of air (and thus the amount of force), generated by the air bearing
15 regardless of the location of the test head 106.

In some implementations, detector 110 may be, and/or include, a global positioning system (GPS) detector, and the position of the manipulator may be detected using GPS. This may be done with our without the mat in place. In an example, a GPS transceiver may be positioned at the manipulator and that GPS
20 transceiver may be used to detect the position of the manipulator within an enclosed location. When the GPS transceiver detects that the manipulator is at one of a number of specified locations (e.g., as the manipulator moves from a specified

center location), the GPS transceiver may signal the control mechanism to limit the air flow of the air bearing to the above effect, provided that the speed of the manipulator is above a threshold. As was the case, in this example, if the speed of movement is below a threshold, then the control mechanism may maintain the air flow, e.g., the amount of air (and thus the amount of force), generated by the air bearing regardless of the location of the test head.

In some implementations, the position of the manipulator may be detected using radio frequency detection, as shown in Fig. 3. This may be done with or without the mat in place. For example, a transmitter 301 may be positioned at the manipulator and one or more receivers 302 may be positioned outwardly from a center area where relatively unimpeded manipulator movement is permitted. As the receivers encounter signals from the transmitter indicating that the test head speed has passed a threshold and that the test head is in a specified position, the receivers may communicate with the control mechanism to control the air bearing to decrease the amount of air flow to the effect described above.

In some implementations, a receiver 305 may be positioned at the manipulator and one or more transmitters 306 may be positioned outwardly from a center area where relatively unimpeded manipulator movement is permitted. As the receiver encounters signals from the transmitters indicating that the test head speed has passed a threshold and that the test head is in a specified position, the receiver may communicate with the control mechanism to control the air bearing to decrease the amount of air flow to the effect described above. As in the example above, in

this example, if the speed of movement is below a threshold, then the control mechanism may maintain the air flow, e.g., the amount of air (and thus the amount of force), generated by the air bearing regardless of the location of the test head.

Referring to Fig. 4, in some implementations, the position of the manipulator
5 may be detected using tethers 401 and potentiometers 402. In some implementations, two potentiometers may be used to correlate the location of the manipulator. In the example of Fig. 4, tethers (one for each potentiometer) may be connected to the manipulator and may be configured to move with the manipulator. In an example, potentiometers 402 may be located at the manipulator and the
10 corresponding tethers may be anchored to stationary point on the test floor (as shown). In another example, potentiometers 402 may be anchored to a point on the test floor, and the corresponding tethers may be connected to the manipulator (not shown). Fig. 5 shows a top view of the structure of Fig. 4, which shows example locations for the two potentiometers on the manipulator.

15 In any case, a length of the tether corresponds to resistance measured by the potentiometer such that the position is based on the length of the tether.

Accordingly, using a computer or other appropriate processing device, it is possible to determine the resistance using the potentiometer, to determine the length of the tether using the resistance, and to determine the location of the manipulator using
20 the lengths of the two tethers. Thus, when the computer detects that the manipulator is at one of a number of specified locations (e.g., as the manipulator moves from a specified center location), the computer may signal the control

mechanism to limit the air flow of the air bearing to the above effect, provided that the speed of the manipulator is above a threshold, As was the case, in this example, if the speed of movement is below a threshold, then the control mechanism may maintain the air flow, e.g., the amount of air (and thus the amount of force), generated by the air bearing regardless of the location of the test head.

In some implementations, in any of the examples described herein, the defined areas of movement may be relative to a specified piece of equipment, such as a prober or handler. That is, the closer that the manipulator comes to the prober or handler (the location of which is known), the more that the air flow and/or pressure in the air bearing is restricted if the speed is above a certain threshold.

In some implementations, in any of the examples described herein, the amount of air flow in the air bearing may be reduced based solely on the location of the manipulator in a predefined area. That is, even if the speed is below a threshold, if the manipulator is near the edge of the area (e.g., in a tight-pitch area of the mat), then the amount of air flow in the air bearing may be reduced in order to reduce the speed of, or stop, movement of the manipulator.

In some implementations, movement of the manipulator is controlled via programmable rules, which may be executed by the control mechanism based, at least in part on detection signals from the detector, to implement the foregoing control operations. In some implementations, the rules may be non-symmetric. For example, a rule may indicate that a manipulator can only approach a prober or handler at a certain (e.g., relatively lower) speed, whereas another rule may indicate

that the manipulator may move away from the prober or handler at any appropriate (e.g., relatively higher) speed, which may be constrained by one or more other rules based on safety considerations.

Any appropriate rules may be used to govern operation of movement of the
5 test enclosure using an air bearing.

Any of the foregoing braking mechanisms, or features thereof, may be combined and/or used together, as appropriate.

Among the advantages of using an air bearing is that there is that it facilitates rotation of the manipulator on the test floor. That is, in some implementations (e.g.,
10 non-tether-based), the manipulator is not tied to any particular point that would inhibit its rotation. As a result, it may be easier to position the manipulator.

Although the examples described above are provided in the context of test equipment, the concepts described herein (e.g., use of an air bearing and control thereof according to any of the examples described herein) is not limited to the
15 testing context, and may be used in any appropriate context to move any appropriate equipment across any appropriate surface.

While this specification describes example implementations related to "testing" and a "test system," the devices and method described herein may be used in any appropriate system, and are not limited to test systems or to the example test
20 systems described herein.

The example control mechanism and/or detector may be implemented using hardware or a combination of hardware and software. For example, a test system

like the ones described herein may include various controllers and/or processing devices located at various points. A central computer may coordinate operation among the various controllers or processing devices. The central computer, controllers, and processing devices may execute various software routines to effect control and coordination of the control mechanism.

The air bearing can be controlled (e.g., by the control mechanism), at least in part, using one or more computer program products, e.g., one or more computer programs tangibly embodied in one or more information carriers, such as one or more non-transitory machine-readable media, for execution by, or to control the operation of, one or more data processing apparatus, e.g., a programmable processor, a computer, multiple computers, and/or programmable logic components.

A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a network.

Actions associated with implementing all or part of the control mechanism and braking described herein can be performed by one or more programmable processors executing one or more computer programs to perform the functions described herein. All or part of the control mechanism and air braking described

herein can be implemented using special purpose logic circuitry, e.g., an FPGA (field programmable gate array) and/or an ASIC (application-specific integrated circuit).

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only storage area or a random access storage area or both. Elements of a computer (including a server) include one or more processors for executing instructions and one or more storage area devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from, or transfer data to, or both, one or more machine-readable storage media, such as mass PCBs for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Machine-readable storage media suitable for embodying computer program instructions and data include all forms of non-volatile storage area, including by way of example, semiconductor storage area devices, e.g., EPROM, EEPROM, and flash storage area devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks.

Any "electrical connection" as used herein may imply a direct physical connection or a connection that includes intervening components but that nevertheless allows electrical signals (including wireless signals) to flow between connected components. Any "connection" involving electrical circuitry mentioned herein, unless stated otherwise, is an electrical connection and not necessarily a

direct physical connection regardless of whether the word “electrical” is used to modify “connection”.

Elements of different implementations described herein may be combined to form other embodiments not specifically set forth above. Elements may be left out of the structures described herein without adversely affecting their operation.

5 Furthermore, various separate elements may be combined into one or more individual elements to perform the functions described herein.

What is claimed is:

1. A method comprising:

for a component supported by an air bearing, detecting a speed of movement of the component relative to a predefined location, the air bearing generating an air flow to elevate the component relative to a ground plane; and

5 controlling the air bearing based, at least in part, on the speed detected.

2. The method of claim 1, further comprising:

determining that the speed of movement of the component is greater than a threshold; and

10 determining that the component is within a geographic area associated with the predefined location;

wherein controlling the air bearing comprises reducing an air flow of the air bearing so as to reduce the speed of movement of the component.

15 3. The method of claim 2, further comprising restricting a rate at which the air flow is reduced.

4. The method of claim 1, further comprising:

20 determining that the speed of movement of the component is less than a threshold; and

determining that the component is within a geographic area associated with the predefined location;

wherein controlling the air bearing comprises maintaining an air flow of the air bearing so as to maintain the speed of movement of the component.

5. The method of claim 1, further comprising:

5 determining that the speed of movement of the component is greater than a threshold; and

determining that the component is within a geographic area associated with the predefined location;

10 wherein controlling the air bearing comprises maintaining an air flow of the air bearing so as to maintain the speed of movement of the component.

6. The method of claim 1, further comprising:

detecting a position of the component relative to the predefined location; and controlling the air bearing based also on the position.

15

7. The method of claim 6, wherein the position is detected relative to a mat having position markers.

8. The method of claim 7, wherein the position markers comprise concentric shapes having pitches that decrease at increasing distances from a center.

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9. The method of claim 7, wherein the position markers are detected optically.

10. The method of claim 6, wherein the position is detected using radio frequency detection, where a transmitter is at the component and a receiver is at the location or where a receiver is at the component and a transmitter is at the location.

11. The method of claim 6, wherein the position is detected using ultrasound.

12. The method of claim 6, wherein the position is detected using a tether and a potentiometer, or tethers and potentiometers, the tether or tethers being connected to the component and being configured to move with the component; wherein a length of the tether corresponds to resistance measured by the potentiometer, the position being based on the length of the tether, or wherein lengths of the tethers correspond to resistances measured by the potentiometers, the position being based on the lengths of the tethers.

13. The method of claim 6, wherein the position is detected using a global positioning system.

14. A system comprising:
a component;

an air bearing supporting the component, the air bearing being configured to generate an air flow to elevate the component relative to a ground plane;

a detector to detect a speed of movement of the component on the air bearing; and

5 a controller to output signals for controlling the air bearing based, at least in part, on the speed detected.

15. The system of claim 14, wherein the controller is configured to perform operations comprising:

10 determining that the speed of movement of the component is greater than a threshold; and

determining that the component is within a geographic area associated with the predefined location;

15 wherein controlling the air bearing comprises reducing an air flow of the air bearing so as to reduce the speed of movement of the component.

16. The system of claim 15, wherein controlling the air bearing comprises restricting a rate at which the air flow is reduced.

20 17. The system of claim 14, wherein the controller is configured to perform operations comprising:

determining that the speed of movement of the component is less than a threshold; and

determining that the component is within a geographic area associated with the predefined location;

5 wherein controlling the air bearing comprises modulating air flow of the air bearing so as to reduce the speed of movement of the component by allowing a braking surface to contact the supporting surface.

10 18. The system of claim 14, wherein the controller is configured to perform operations comprising:

determining that the speed of movement of the component is greater than a threshold; and

determining that the component is within a geographic area associated with the predefined location;

15 wherein controlling the air bearing comprises modulating air flow of the air bearing so as to reduce the speed of movement of the component by allowing a braking surface to contact the supporting surface.

20 19. The system of claim 14, wherein the controller is configured to perform operations comprising:

detecting a position of the component relative to the predefined location; and
controlling the air bearing based also on the position.

20. The system of claim 19, wherein the position is detected relative to a mat having position markers.

5 21. The system of claim 19, wherein the position markers comprise concentric shapes having pitches that decrease at increasing distances from a center.

 22. The system of claim 19, wherein the detector comprises an optical
10 detector to detect the position markers optically.

 23. The system of claim 19, wherein the detector comprises a radio frequency detector to detect a position using radio frequency detection, where a transmitter is at the component and a receiver is at the location or where a receiver
15 is at the component and a transmitter is at the location.

 24. The system of claim 19, wherein the detector comprises an ultrasound detector.

20 25. The system of claim 19, wherein the detector comprises a tether and a potentiometer, or tethers and potentiometers, the tether or tethers being connected to the component and being configured to move with the component;

wherein a length of the tether corresponds to resistance measured by the potentiometer, the position being based on the length of the tether, or wherein lengths of the tethers correspond to resistances measured by the potentiometers, the position being based on the lengths of the tethers.

5

26. The system of claim 19, wherein the detector comprises a global positioning system.

27. An apparatus comprising:

10

a test head manipulator configured to hold a test head; and

an air bearing mounted to a bottom of the test head manipulator adjacent to a ground plane, the air bearing being configured to generate air flow towards the ground plane resulting in force that causes the test head manipulator to lift off of the ground plane and to maintain an elevation relative to the ground plane;

15

wherein the elevation of the test head manipulator relative to the ground plane enables movement of the test head manipulator relative to, and above, the ground plane.

20

28. The apparatus of claim 27, wherein the test head manipulator is configured to mate the test head to a prober or to a handler for performance of test procedures.

29. The apparatus of claim 27, wherein movement of the test head manipulator is in three degrees of freedom in response to force applied to the test head manipulator.

5 30. The apparatus of claim 27, wherein movement of the test head manipulator is at least partly rotational.

31. The apparatus of claim 27, wherein a speed of the movement of the test head manipulator is variable.

10

32. The apparatus of claim 27, wherein the elevation is at least one millimeter.

33. The apparatus of claim 27, wherein the elevation is up to five millimeters.

15

34. The apparatus of claim 27, wherein the test head manipulator comprises:
a detector to detect a speed of movement of the test head manipulator
relative to the ground plane; and

a controller to output signals for controlling the air bearing based, at least in
20 part, on the speed detected.

35. The apparatus of claim 34, wherein the controller is configured to perform operations comprising:

determining that the speed of movement of the test head manipulator is greater than a threshold; and

5 determining that the test head manipulator is within a geographic area;

wherein controlling the air bearing comprises reducing an air flow of the air bearing so as to reduce the speed of movement of the test head manipulator.

36. The apparatus of claim 27, wherein the test head manipulator comprises:
10 a controller to output signals to control the air bearing to control an amount of the air flow and thus the elevation relative to the ground plane.

37. The apparatus of claim 27, wherein the test head manipulator comprises a safety feature to limit a speed at which the test head manipulator moves.

15

38. A system comprising:

a first device configured to move a test head, the first device comprising (i) a test head manipulator configured to hold a test head, and (ii) an air bearing mounted to a bottom of the test head manipulator adjacent to a ground plane, the air bearing
20 being configured to generate air flow towards the ground plane resulting in force that causes the test head manipulator to lift off of the ground plane and to maintain an elevation relative to the ground plane, the elevation enabling movement of the test

head manipulator in response to horizontal force, the movement of the test head manipulator being enabled in both horizontal and rotational directions relative to the ground plane; and

a second device configured to mate to the test head, the test head
5 manipulator being movable relative to the second device to enable mating of the test head to the second device.

39. The system of claim 38, wherein the second device comprises a prober.

10 40. The system of claim 38, wherein the second device comprises a handler.

41. The system of claim 38, wherein the first device comprises a safety mechanism configured to limit movement of the first device relative to the second device.

15

42. The system of claim 41, wherein the safety mechanism comprises:
a detector to detect a speed of movement of the test head manipulator; and
a controller to output signals for controlling the air bearing based, at least in part, on the speed detected.

20

43. The apparatus of claim 42, wherein the controller is configured to perform operations comprising:

determining that the speed of movement of the test head manipulator is greater than a threshold; and

determining that the test head manipulator is within a geographic area;

wherein controlling the air bearing comprises reducing an air flow of the air

5 bearing so as to reduce the speed of movement of the test head manipulator.

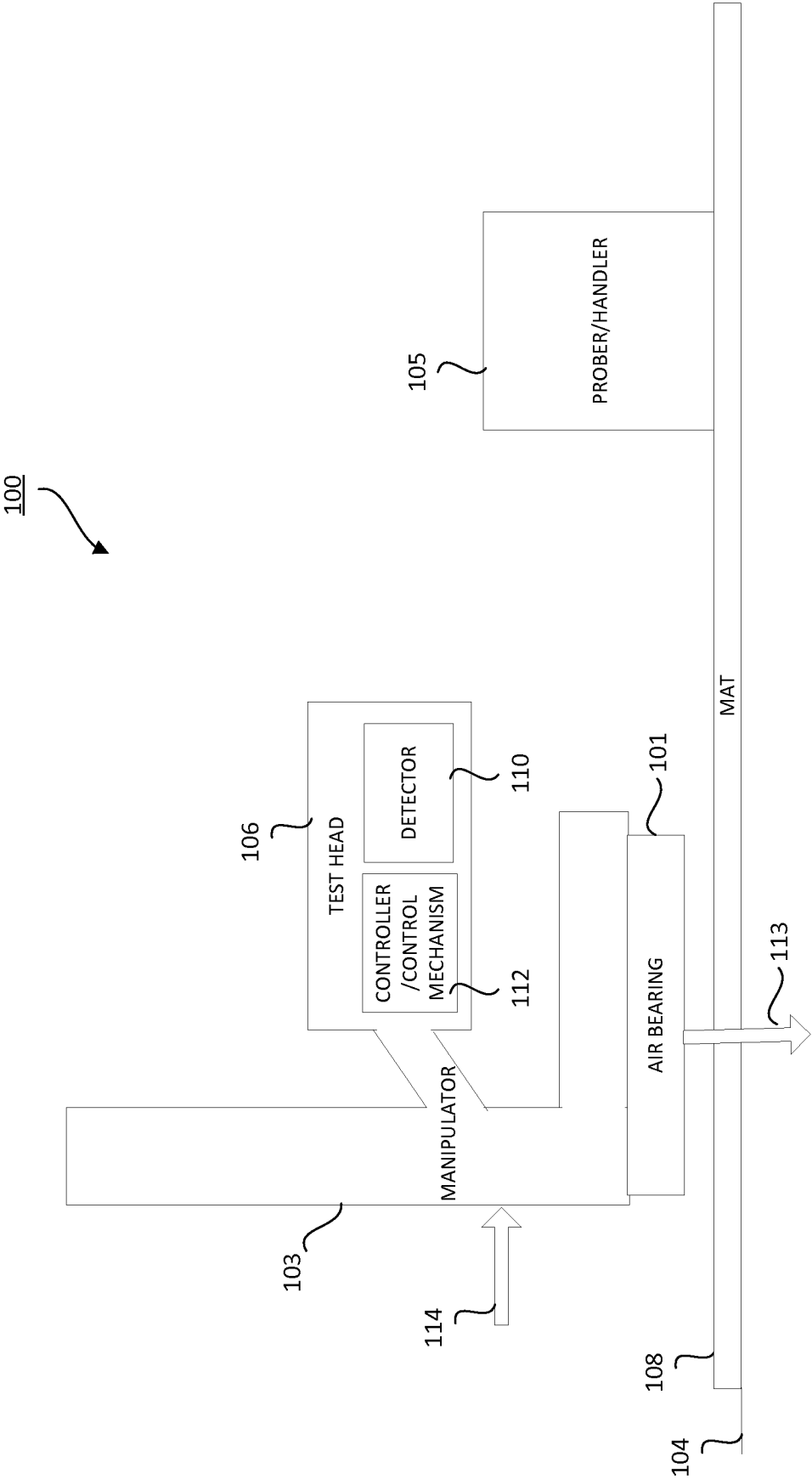
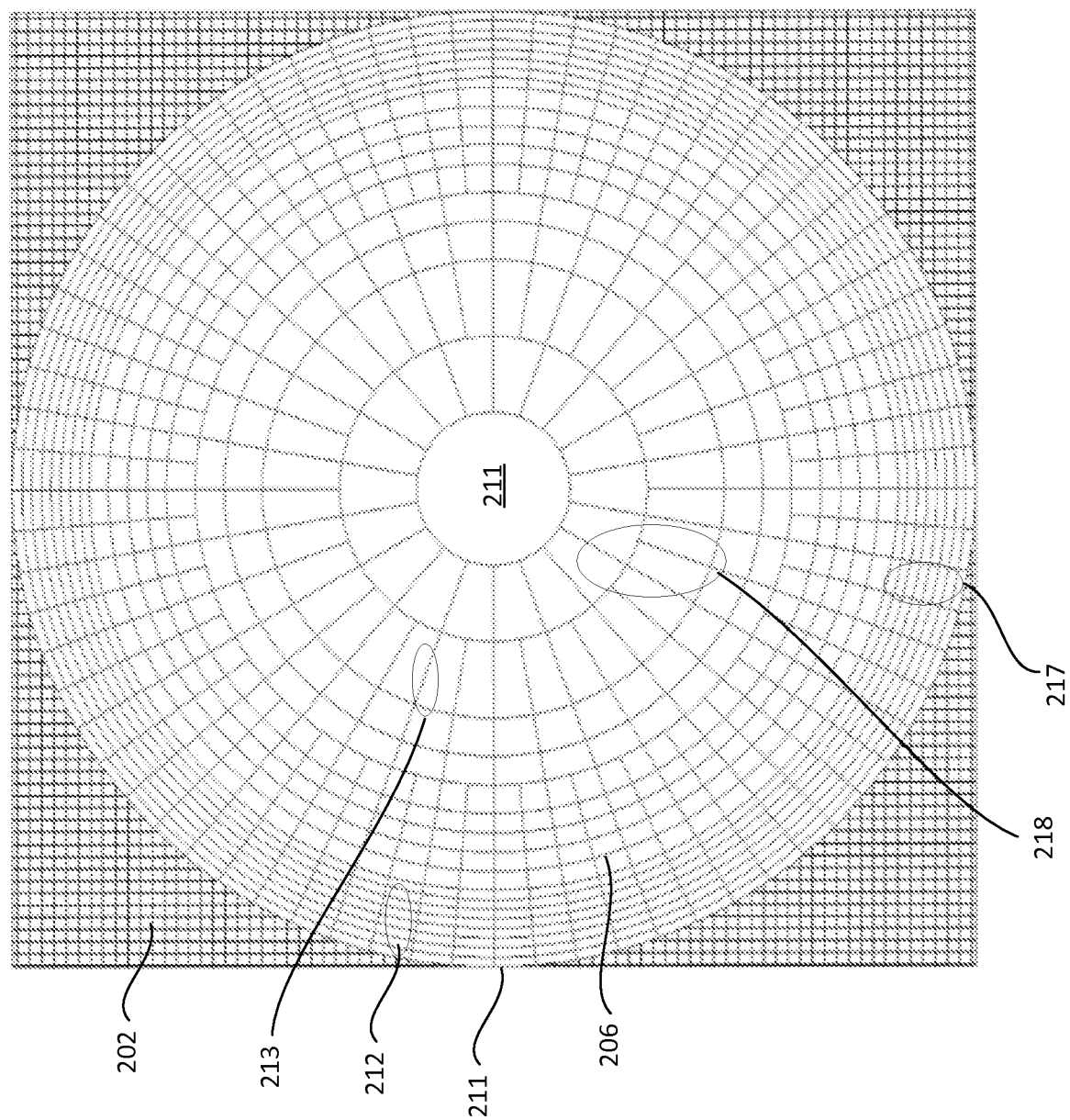


FIG. 1

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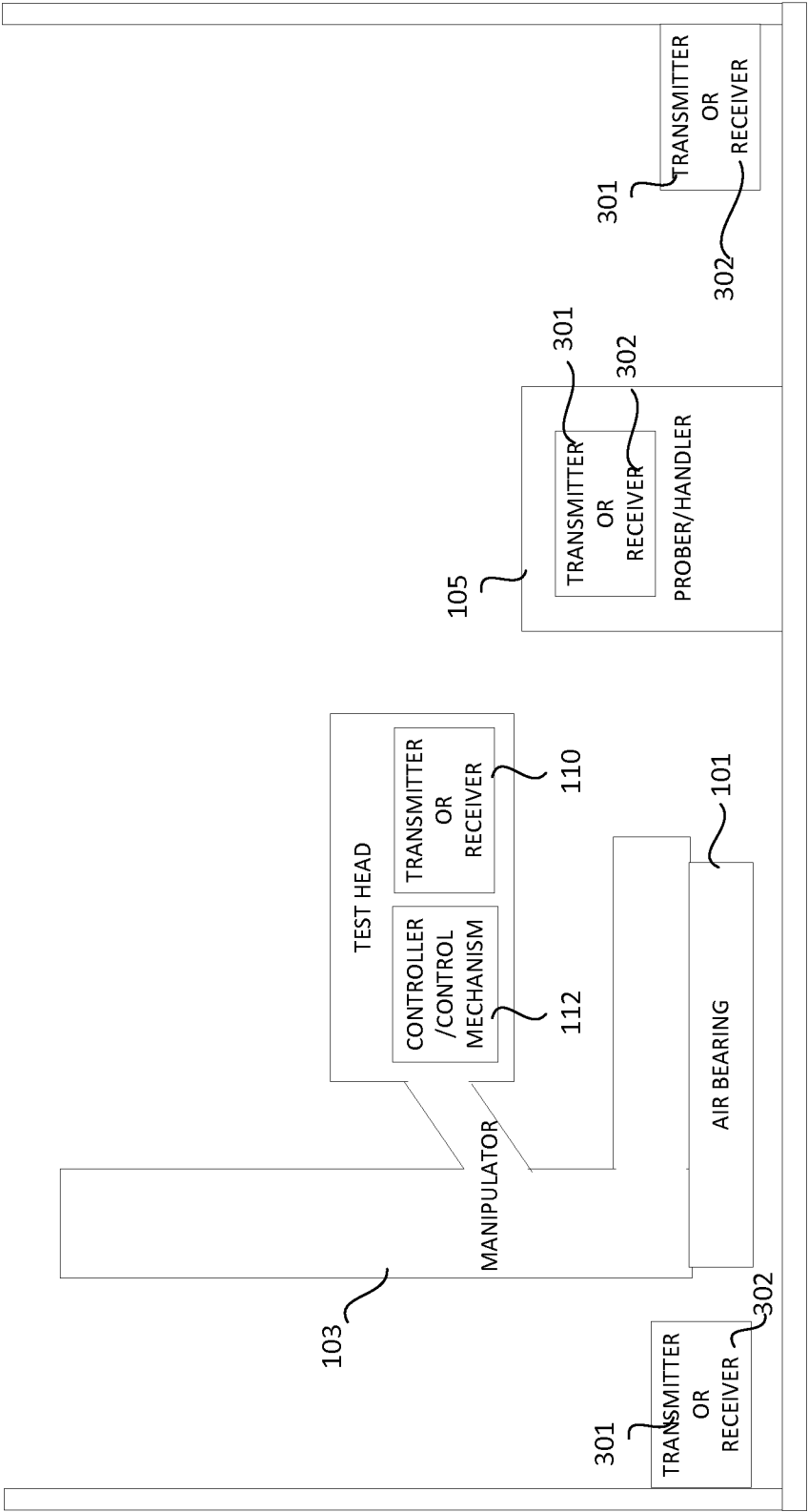


FIG. 3

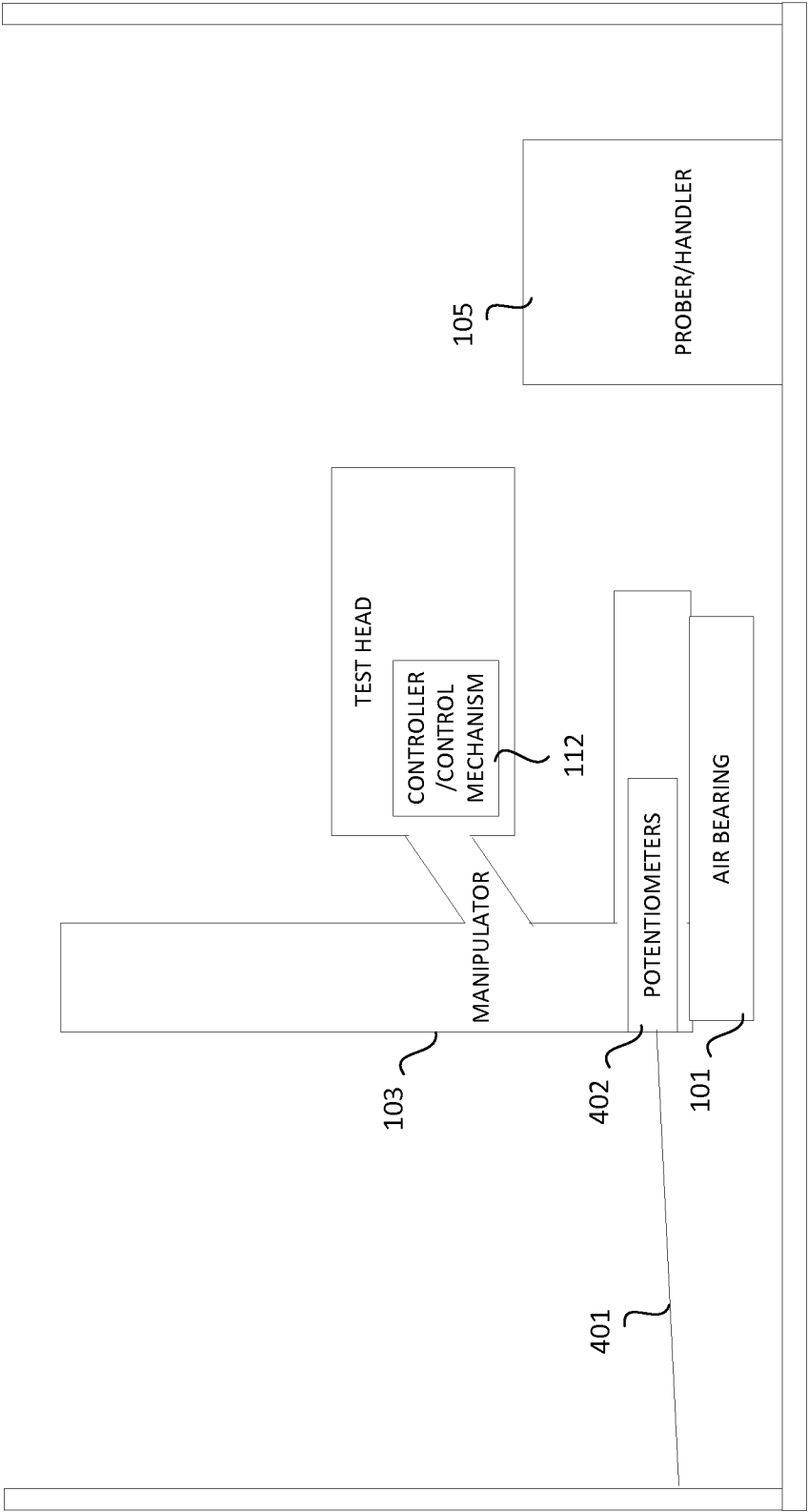


FIG. 4

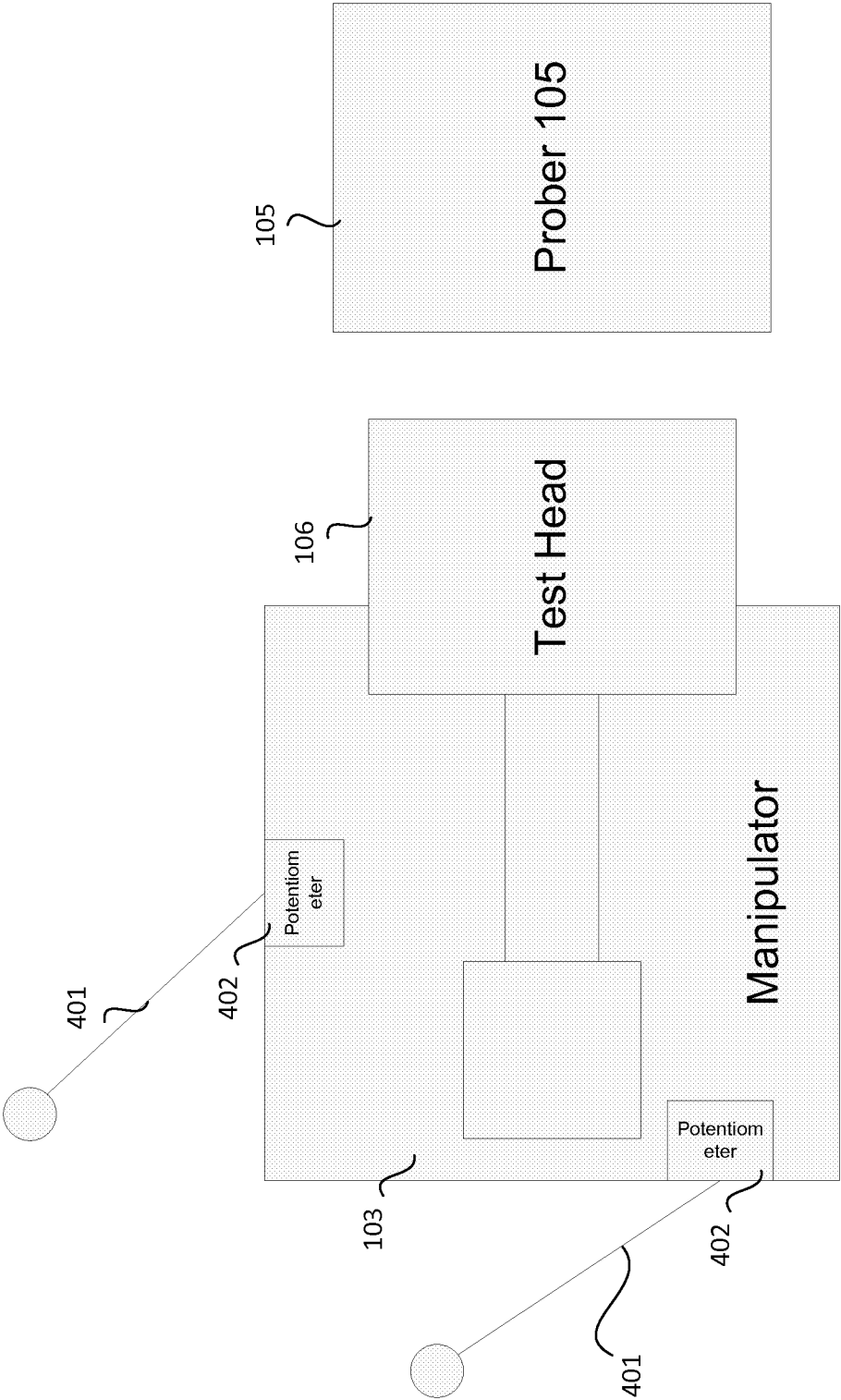


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/061507**A. CLASSIFICATION OF SUBJECT MATTER****G01M 13/04(2006.01)i, G01R 15/04(2006.01)i, G01R 27/02(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01M 13/04; B25J 9/18; G01R 31/26; G01R 31/00; B25J 15/06; B60V 1/00; B25J 5/00; G05B 19/19; G01R 15/04; G01R 27/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: manipulator, test equipment, speed, test head, prober, handler, air bearing and air flow

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0174563 A1 (RIESNER, STEFAN) 21 July 2011 See abstract, paragraphs [0035]-[0051], claim 1 and figures 1A-2C.	27-33,36-41
Y		1, 6, 10-11, 13-14, 19 , 23-24, 26, 34, 42
A		2-5, 7-9, 12, 15-18 , 20-22, 25, 35, 43
Y	US 6801008 B1 (CHARLES J. JACOBUS et al.) 05 October 2004 See abstract, column 5, lines 19-63, claims 1-9 and figures 1-6B.	1, 6, 10-11, 13-14, 19 , 23-24, 26, 34, 42
A	US 8035406 B2 (MUELLER, CHRISTIAN) 11 October 2011 See abstract, column 9, line 10 - column 10, line 35 and figures 1-7.	1-43
A	US 2007-0152695 A1 (BRIAN J. BOSY et al.) 05 July 2007 See abstract, paragraphs [0021]-[0030], [0048] and figures 1-9.	1-43
A	US 2002-0130524 A1 (MCILWRAITH et al.) 19 September 2002 See abstract, paragraphs [0032]-[0036] and figure 2A.	1-43



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

04 March 2016 (04.03.2016)

Date of mailing of the international search report

04 March 2016 (04.03.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

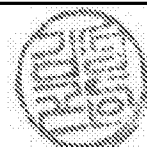
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/061507

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0174563 A1	21/07/2011	CN 102105276 A	22/06/2011
		CN 102105276 B	07/05/2014
		DE 202008009838 U1	23/10/2008
		EP 2326466 A1	01/06/2011
		EP 2326466 B1	20/06/2012
		JP 2011-528627 A	24/11/2011
		US 08464820 B2	18/06/2013
		WO 2010-009878 A1	28/01/2010
US 6801008 B1	05/10/2004	US 05389865 A	14/02/1995
		US 05459382 A	17/10/1995
		US 05459382 B1	09/06/1998
		US 05629594 A	13/05/1997
		US 05769640 A	23/06/1998
		US 05831408 A	03/11/1998
		US 05844392 A	01/12/1998
		US 05872438 A	16/02/1999
		US 06104158 A	15/08/2000
		US 06131097 A	10/10/2000
		US 06374255 B1	16/04/2002
		US 07191191 B2	13/03/2007
		US 07345672 B2	18/03/2008
		US 07765182 B2	27/07/2010
		US 2002-0109708 A1	15/08/2002
		US 2004-0164960 A1	26/08/2004
		US 2007-0130212 A1	07/06/2007
		WO 1995-002233 A1	19/01/1995
US 8035406 B2	11/10/2011	CN 100768271 A	03/05/2006
		CN 100768271 B	05/05/2010
		CN 101806817 A	18/08/2010
		CN 101806817 B	08/01/2014
		DE 04758607 T1	13/07/2006
		EP 1618394 A2	25/01/2006
		JP 05183061 B2	17/04/2013
		JP 05564004 B2	30/07/2014
		JP 2007-524814 A	30/08/2007
		JP 2011-149950 A	04/08/2011
		KR 10-2005-0109615 A	21/11/2005
		SG 158747 A1	26/02/2010
		SG 162618 A1	29/07/2010
		US 2004-0227534 A1	18/11/2004
		US 2008-0122432 A1	29/05/2008
		US 2010-0264907 A1	21/10/2010
		US 7235964 B2	26/06/2007
		US 7728579 B2	01/06/2010
		WO 2004-090558 A2	21/10/2004
		WO 2004-090558 A3	19/05/2005

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/061507

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0152695 A1	05/07/2007	TW I336427 B US 7598725 B2 WO 2007-078721 A2 WO 2007-078721 A3	21/01/2011 06/10/2009 12/07/2007 30/08/2007
US 2002-0130524 A1	19/09/2002	US 6601888 B2	05/08/2003