United States Statutory Invention Registration [19]

[11] Reg. Number: H63

[45] Published: May 6, 1986

Vogel et al.

[54] POSITIONING APPARATUS

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[73] Assignee: The United States of America as represented by the United States Department of Energy, Washington, D.C.

[21] Appl. No.: 511,702

[22] Filed: Jul. 7, 1983

[51] Int. Cl.[4] G01N 21/00

[52] U.S. Cl. 250/491.1; 376/192; 376/260

[58] Field of Search 74/479; 250/442.1, 491.1; 376/108, 192, 340, 341

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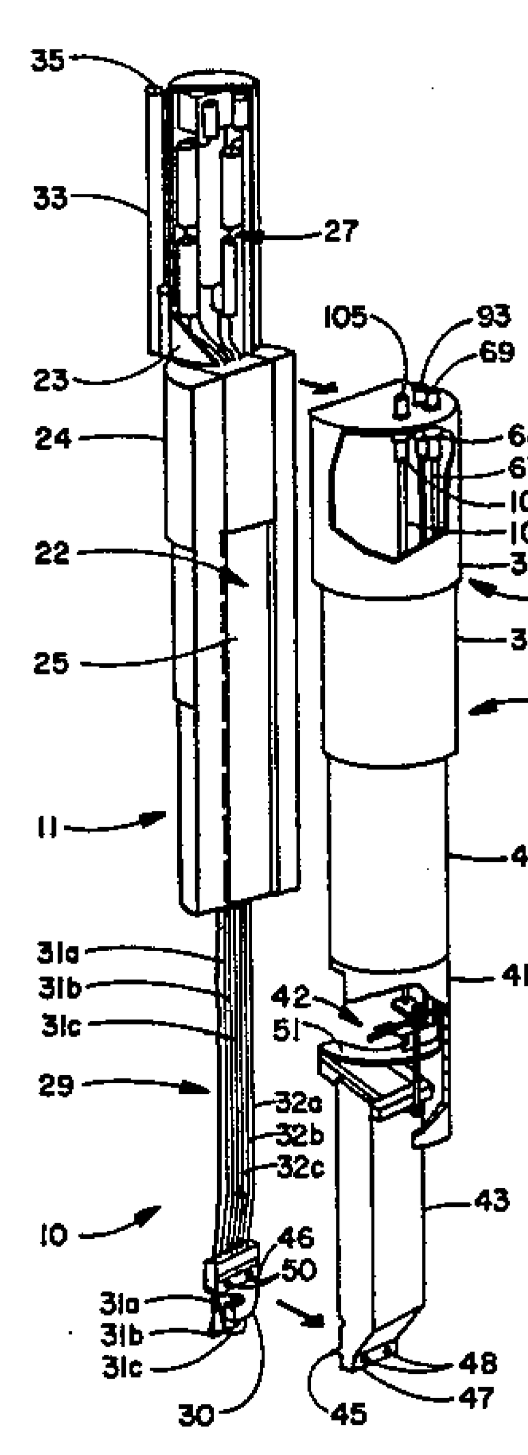
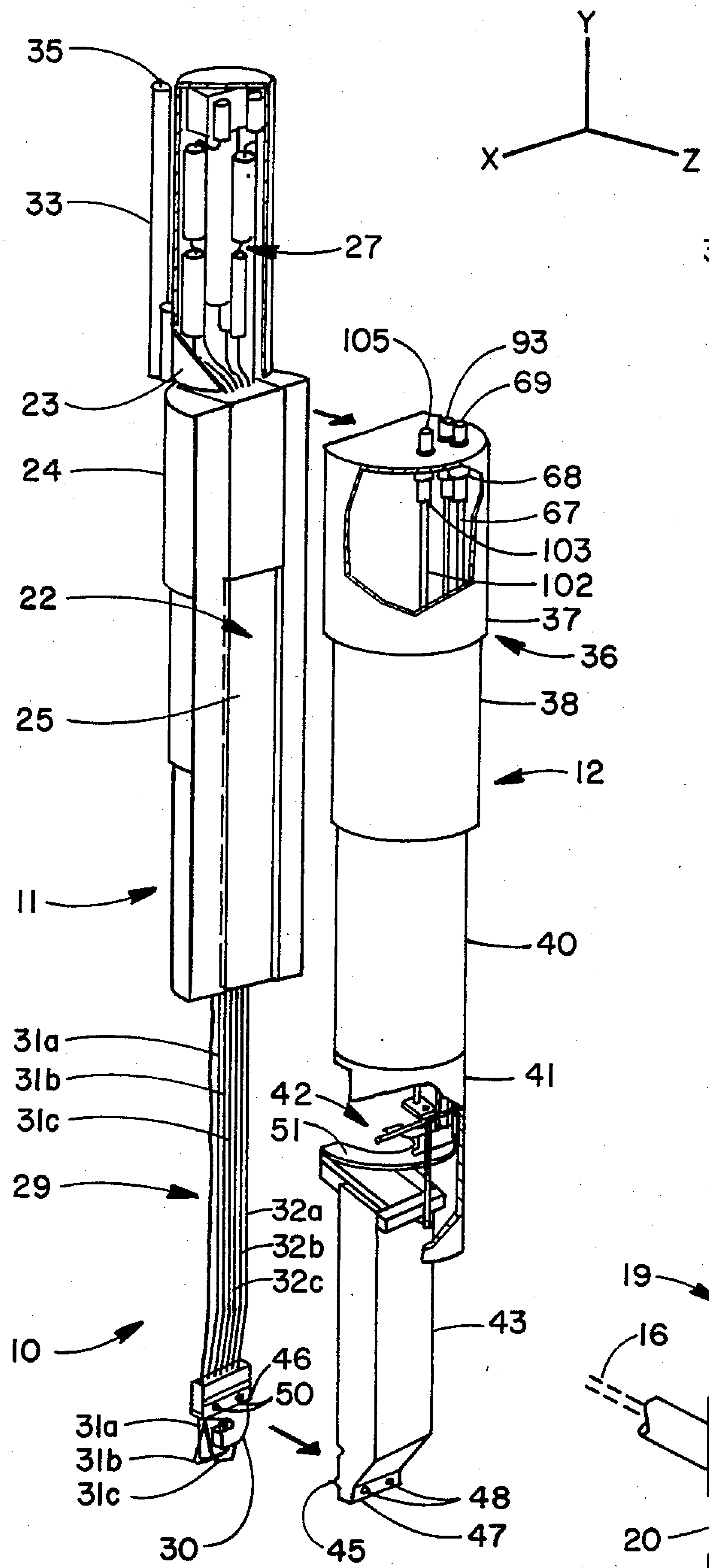
[57] ABSTRACT

An apparatus for precisely positioning materials test specimens within the optimum neutron flux path emerging from a neutron source located in a housing. The test specimens are retained in a holder mounted on the free end of a support pivotably mounted and suspended from a movable base plate. The support is gravity biased to urge the holder in a direction longitudinally of the flux path against the housing. Means are provided for moving the base plate in two directions to effect movement of the holder in two mutually perpendicular directions normal to the axis of the flux path.

9 Claims, 7 Drawing Figures

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31b
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FIG. 1

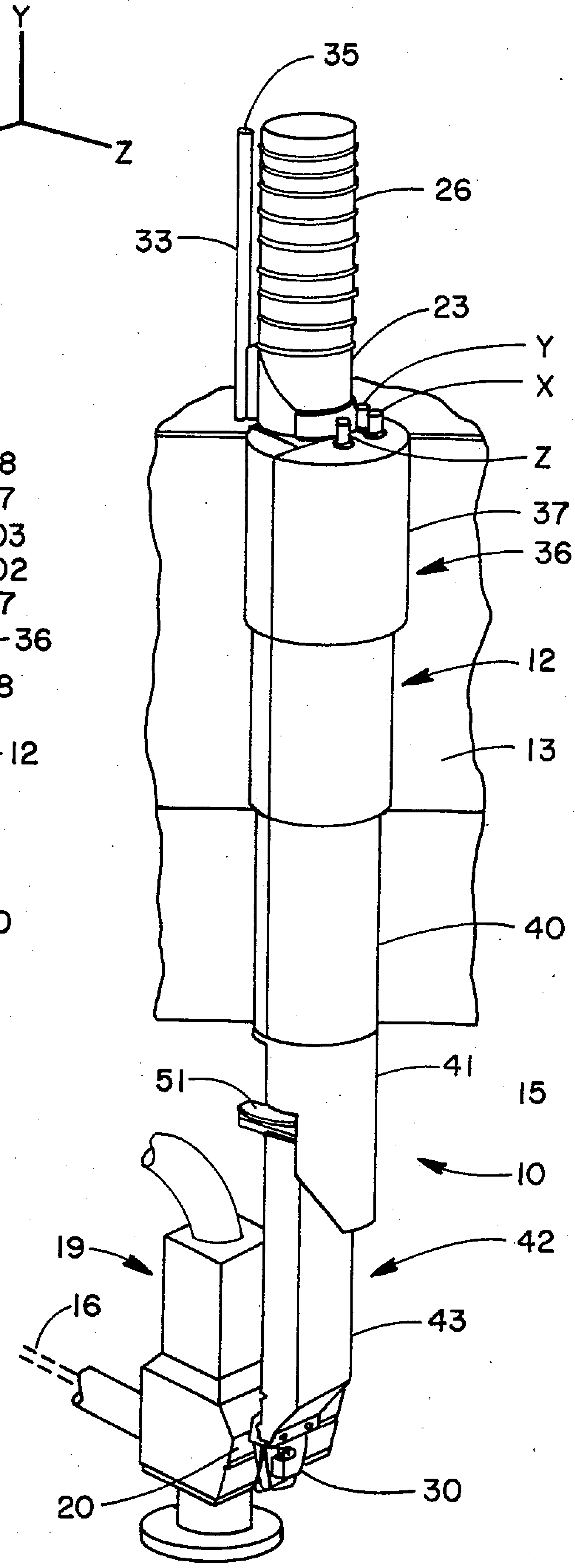
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FIG. 2

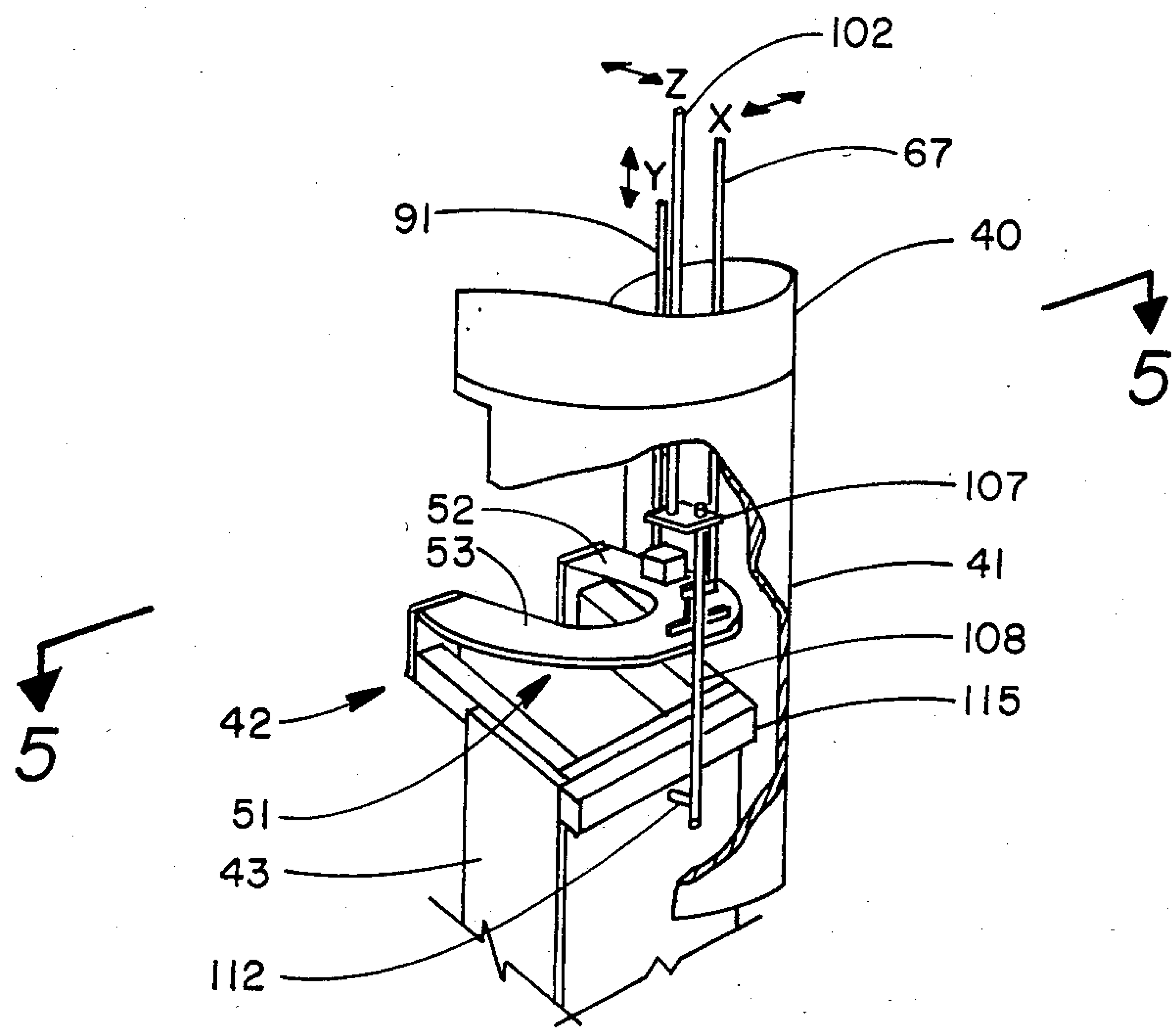
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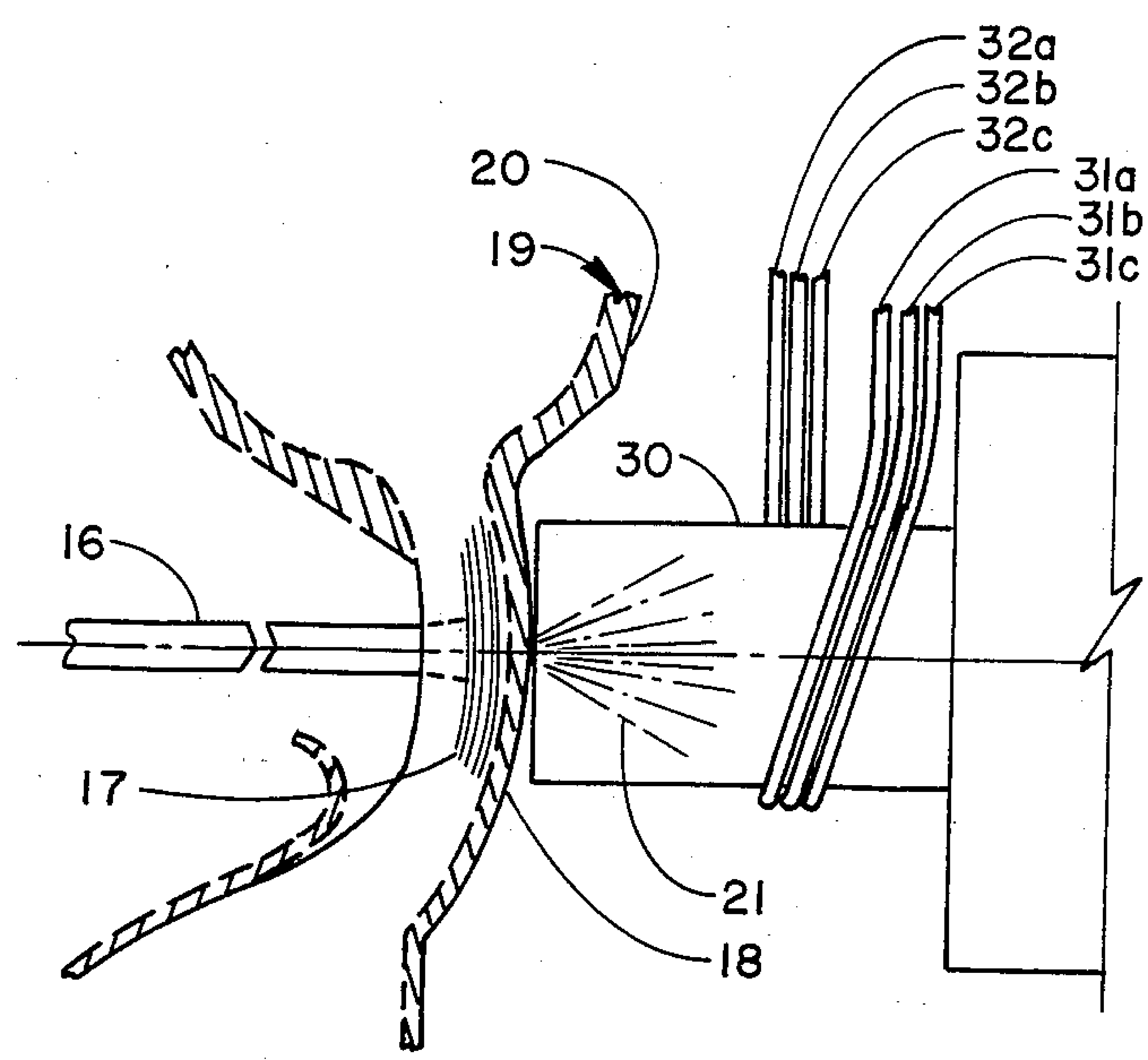
FIG. 3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17
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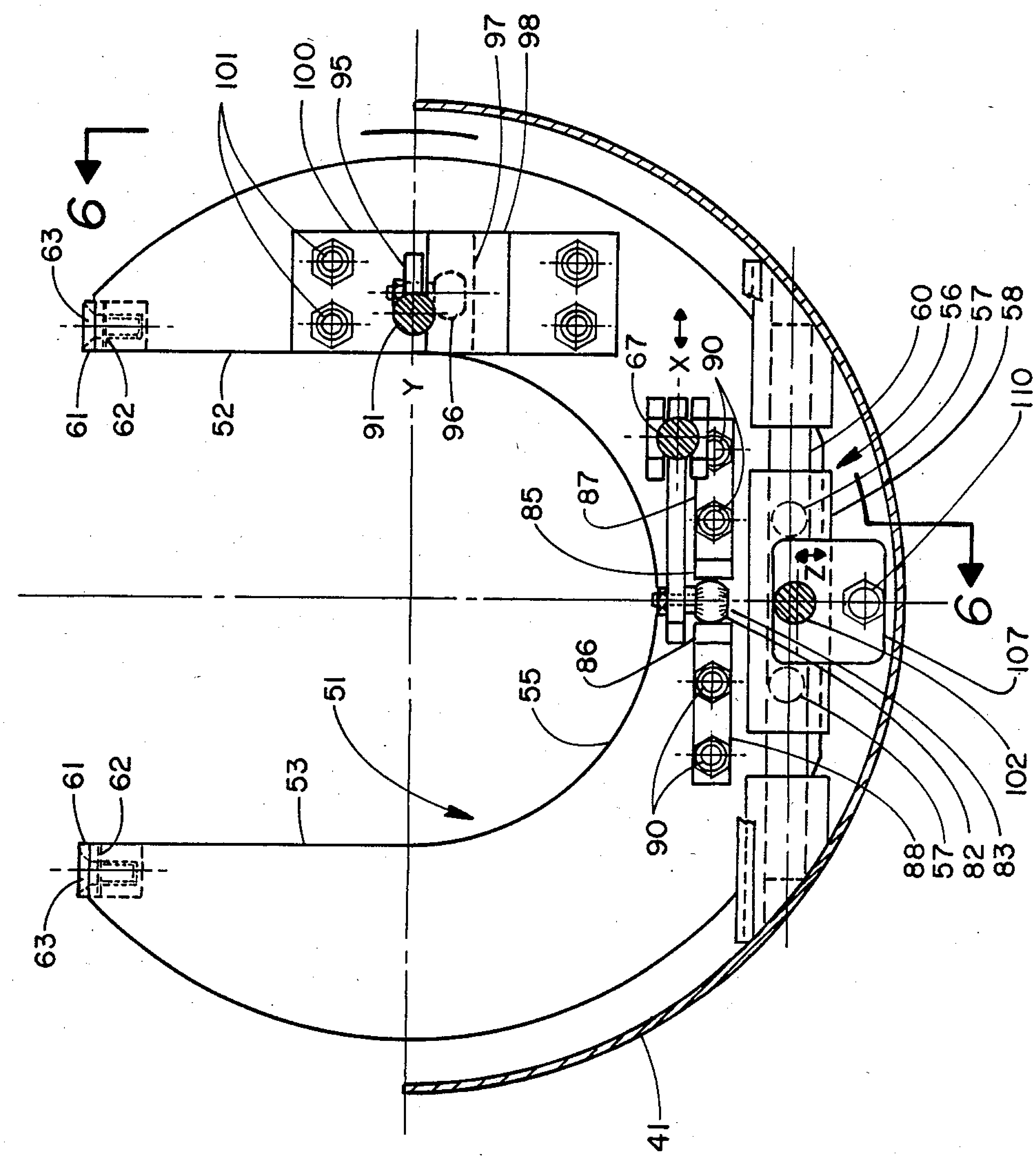
FIG. 4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58
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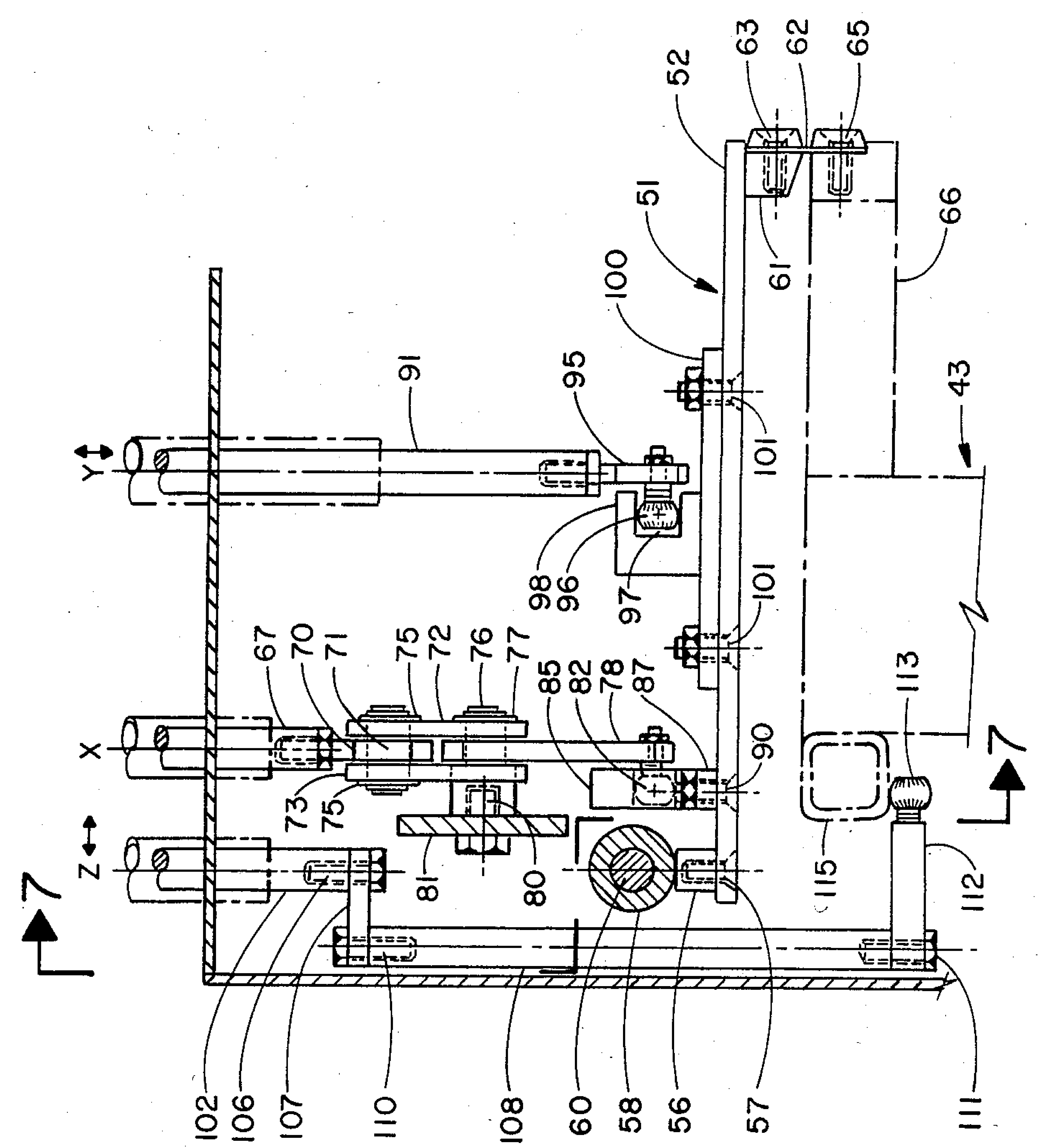
FIG. 5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X
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82
78
87
90
113
73
75
81
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Z
115
112
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7
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FIG. 6

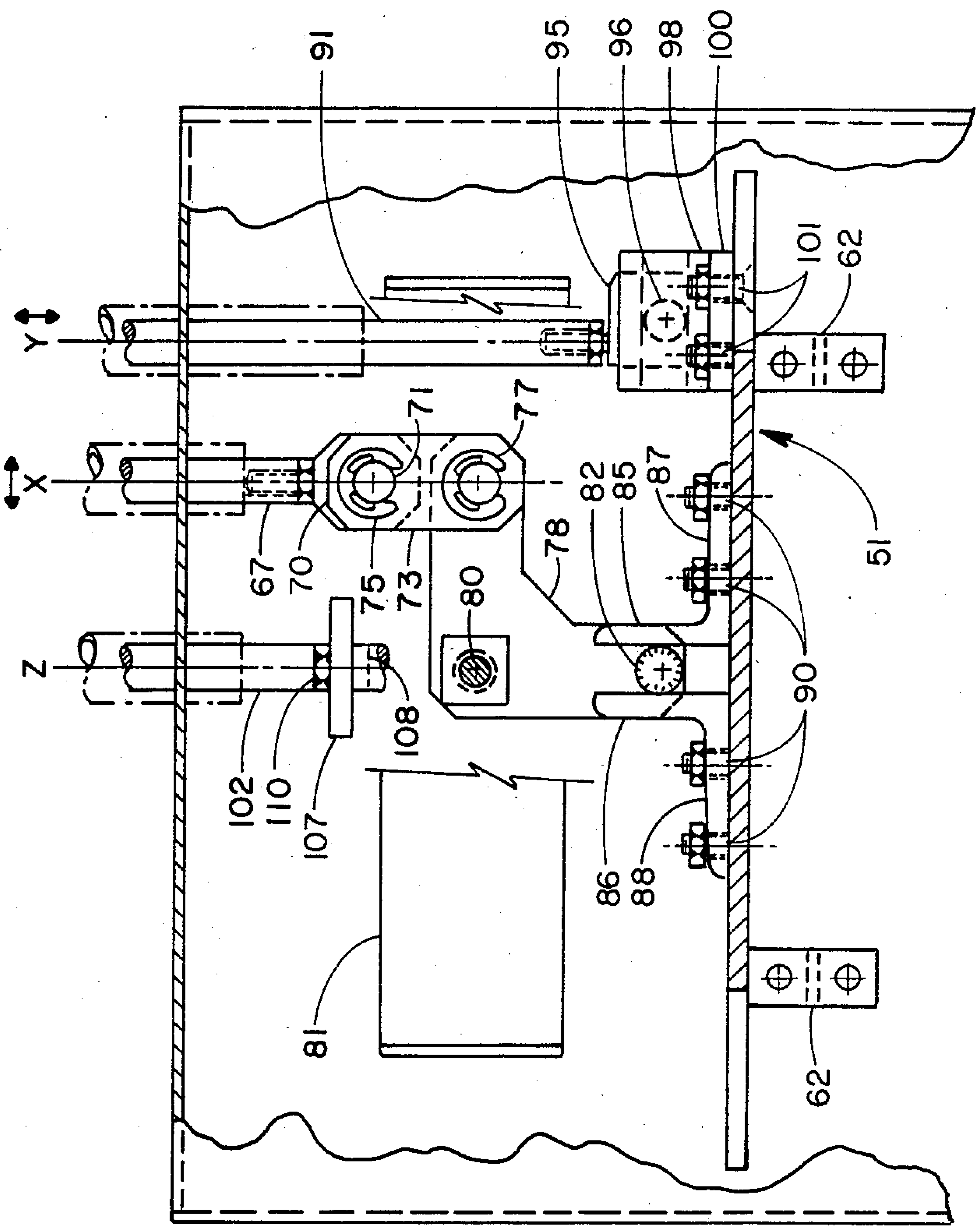

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FIG. 7

POSITIONING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates generally to a positioning apparatus and, more particularly, to an apparatus for positioning materials test specimens in a desired location relative to a neutron flux beam. The United States Government has rights in this invention pursuant to Contract No. DE-AC14-76FF02170 between the U.S. Department of Energy and Westinghouse Electric Corporation.

In support of the development of fusion energy, there is presently being designed an irradiation test facility for the purpose of determining the effect of high energy neutrons on candidate fusion materials. This facility will provide users or experimenters with the capability of irradiating a variety of test specimens at damage rates commensurate with those anticipated in future fusion reactors. This facility utilizes an accelerated deuteron-lithium stripping reaction to generate a high energy neutron source housed in a heavily shielded test cell. Basically, an accelerator deuteron beam is focused onto a flowing liquid lithium target in the form of a jet stream flowing down a curved wall of a chamber. The interaction of the deuterons with the flowing lithium target produces a high energy neutron source which is forwardly biased i.e., emerging from the target in a direction away from but parallel to the deuteron beam direction. The region of highest neutron flux flow and associated neutron damage is located directly behind the lithium target i.e., the side opposite the incoming deuteron beam. It is important to precisely position the fusion materials test specimens in this region adjacent the target for maximum neutron flux exposure.

However, the precise positioning of the test specimens relative to the optimum neutron flux path poses problems since the location of the streams of neutrons in this region is not completely predictable and may change during operation. Other changes in the relative positioning between the test specimens and target can occur as a result of thermal expansion and from dimensional fabrication and/or installation tolerances. Moreover, since the test specimens are located in a radiation shielded test cell and preferably lowered thereinto through plugs in the top wall of the cell, positioning must be performed by remote means. This is further complicated by an outwardly projecting obstruction forming a part of the nozzle through which the lithium stream flows and which is located immediately above the target.

Conventional solutions and apparatus were investigated to overcome the above noted problems but did not prove satisfactory. For example, stacked ball slides were found to be bulky and required complex shafting with gearing arrangements to translate motion. Another apparatus considered was a two-axis "wobble" plate operated by three vertically oriented shafts. This apparatus not only required complex coordinated three rod translation to achieve a Y direction motion for example, but also produced undesirable interaction between motions, and was not able to compensate for operational errors. Still other devices contemplated utilized springs to either bias components or to prevent backlash. The use of springs in an irradiation environment is not desirable because they become embrittled in a neutron flux environment with consequent loss of resiliency.

Accordingly, it is a primary object of the present invention to provide a new and useful positioning apparatus for precisely orienting articles relative to a target zone.

It is another object of this invention to provide a new and useful remotely operated positioning apparatus providing movement in three directions for locating and orienting test specimens within an optimum neutron flux flow path in an irradiation environment.

It is still another object of the present invention to provide retraction of the test article along the beam axis to facilitate installation and removal of the article relative to the neutron source.

It is yet another object of this invention to provide precise independent movement of the test specimens in two directions perpendicular to the neutron beam axis.

It is a further object of the present invention to employ a gravity loading technique which eliminates backlash in at least two of the aforementioned directions.

It is still a further object of this invention to facilitate actuation of the foregoing positioning apparatus in a simple and straightforward manner utilizing simple mechanical components operable to achieve movements in three directions.

The foregoing and other objects, advantages, and characterizing features of the present invention will become clearly apparent from the ensuing detailed description of an illustrated embodiment thereof, taken together with the accompanying drawing wherein like reference numerals denote like parts throughout the various views.

SUMMARY OF THE INVENTION

An apparatus is provided for precisely adjusting the position of an article relative to a beam emerging from a neutron source disposed in a housing. The apparatus includes a support pivotably mounted on a movable base plate and freely suspended therefrom. The support is gravity biased toward the housing and carries an article holder movable in a first direction longitudinally of the axis of said beam and normally urged into engagement against said housing. Means are provided for moving the base plate in two directions to effect movement of the suspended holder in two mutually perpendicular directions, respectively, normal to the axis of the beam.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a test stalk and shield plug shown prior to assembly and embodying the novel positioning apparatus of this invention;

FIG. 2 is a perspective view showing the test stalk and shield plug in an assembled relation to form a test assembly, shown installed within a test cell;

FIG. 3 is an enlarged, fragmentary, schematic view of the mechanical control assembly for effecting movements of the article in various directions;

FIG. 4 is an enlarged side elevational view of the article support or holder relative to the axis of a neutron beam;

FIG. 5 is a horizontal sectional view, on an enlarged scale, taken along line 5—5 of FIG. 3;

FIG. 6 is a vertical sectional view, taken along line 6—6 of FIG. 5; and

FIG. 7 is a vertical sectional view, taken along line 7—7 of FIG. 6.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in detail to the illustrative embodiment depicted in the accompanying drawings, there is shown in FIGS. **1** and **2** a test assembly, designated in its entirety by reference numeral **10** and embodying the novel features of this invention for precisely positioning test specimens in an optimum neutron flux path. The test assembly **10** includes a test stalk **11** and a shield plug **12** (FIG. 1) fitted together to form the test assembly **10** (FIG. 2) shown installed and mounted in the thickly shielded top wall **13** of a test cell **15**, wherein an accelerated deuteron-lithium stripping reaction occurs to generate a high energy neutron source. The test stalk **11** and shield plug **12** have complementary, abutting faces that fit flush against each other in the assembled relation and are secured together by suitable fasteners (not shown).

As earlier noted, a fusion materials irradiation test facility is being developed to create a neutron environment typical of a fusion reactor for the purpose of testing candidate fusion materials and gaining an understanding of their behavior in such an environment. Basically, the facility includes an accelerator (not shown) for producing a continuous wave deuteron beam **16** which is focused onto a flowing lithium target **17** (FIG. 4) guided through a specially configurated nozzle **18** mounted within a suitable housing **19** and located beneath a projection **20** forming a part of the housing **19**. The interaction of 35 MeV deuterons with a molten lithium target yields two neutron-producing reactions; namely, a stripping reaction and a compound nucleus reaction. The compound nucleus reactions produce neutrons isotropically while the stripping reaction produces predominantly forward-directed neutrons i.e., neutrons emerging away from but in the direction of and parallel to the deuteron beam. The stripping reaction is dominant and thus, the majority of neutrons or maximum neutron flux produced in the target emerge in the forward direction as shown at **21** in FIG. 3. The test specimens preferably are located adjacent to the target in the path of this maximum neutron flux flow for optimum irradiation. For purposes of this description, this maximum or optimum neutron flux flow will hereinafter be referred to as "neutron beam" **21**.

The test stalk **11** of assembly **10** is the vehicle for supporting the materials test specimens in the high energy irradiation environment and includes a cooling system for controlling the temperature of specimens in the presence of neutron and associated prompt gamma heat deposition. The test stalk **11** includes a housing **22** comprised of an upper cylindrical portion or shroud **23**, an intermediate partial cylindrical segment **24** and a lower partial cylindrical segment **25**. The upper portion **23**, which is located above the test cell **15** is a compartment referred to as a "service cell", is surrounded by a cooling coil **26** (FIG. 2) and houses a thermal control system, generally designated **27**, comprising various components such as an electromagnetic pump, a heat exchanger, a heater and the necessary connections therebetween.

Extending downwardly from the thermal control system **27** is a conduit or piping system **29** for circulating a liquid metal coolant, preferably sodium potassium (NaK), through an article holder referred to as a "test module" **30** mounted at the lower end of the piping system **29**. Preferably, the module **30** is divided into three chambers, each of which contains numerous test specimens adapted to be irradiated. Three of the conduits constitute supply lines **31*a*, 31*b*,** and **31*c*** connected to passages extending through the chambers, respectively, of the module **30** while the other three conduits **32*a*, 32*b*,** and **32*c*** form return lines leading from the module chambers to the thermal control system **27**.

A suitable, elongated tubular conduit **33**, substantially coextensive with the housing upper portion **23**, is provided for the passage of electrical leads or connectors **35** therethrough for connecting suitable instrumentation from the test module **30** to manned areas (not shown) outside the service cell.

The shield plug **12** comprises an elongated housing **36** having an upper partial cylindrical segment **37**, an intermediate partial cylindrical segment **38**, and a lower cylindrical portion **40**, all adapted to be fixedly and sealably mounted within the shielded top wall **13**. A lower extension **41**, partially broken away, projects downwardly from housing portion **40** and serves as both a shroud and a support for the positioning apparatus, generally designated **42**.

The positioning apparatus **42**, constructed in accordance with this invention, includes a supporting frame **43** adapted to carry the specimen holder or module **30** and is suspended from a portion of the positioning apparatus **42** for movement in various directions as will hereinafter be described in detail. The lower end of the frame **43** is formed with a transversely extending rib **45** adapted to be mated with a complementary transverse recess **46** formed in the module **30** when the test stalk **11** is fitted to the shield plug **12**. An abutment member **47** at the lower end of frame **43** is formed with laterally spaced openings **48** aligned with spaced openings **50** in module **30** for receiving suitable fasteners (not shown) therethrough for rigidly securing the module **30** to the supporting frame **43**. Thus, the module **30** is mounted on the frame **43** for selective movement therewith into a desired position relative to the neutron beam **21**. The conduits forming the piping system **29** are sufficiently flexible to accommodate the small movements imparted to module **30** via the supporting frame **43**. Preferably, the conduits are formed of a suitable material capable of withstanding high pressures and the high temperatures encountered in an irradiation environment.

The positioning apparatus **42** includes a pivotal base member or plate **51** having a generally U-shaped configuration in plan (FIG. **5**) comprised of a pair of spaced legs **52** and **53** connected together by a web portion **55**. As best shown in FIGS. **5** and **6**, a bearing block **56** is mounted on the upper surface of web portion **55**, as by screws **57** for example, and is provided with a bearing sleeve **58** welded thereon for receiving a pivot pin **60** rigidly mounted at its opposite ends in extension **41**. Lugs **61** are welded or otherwise fixedly secured to the other side of plate **51** adjacent the free ends of legs **52** and **53**, respectively, for mounting thin metallic hinge strips **62** thereto by suitable fasteners **63**. The lower portions of hinge strips **62** are connected, as by fasteners **65**, to a bracket **66** forming a part of the supporting frame **43**. These hinge strips **62** are formed of a suitable metal which is relatively rigid but sufficiently flexible to serve as a hinge, permitting swinging or pivoting movement of the supporting frame **43** in a single arcuate path relative to base plate **51** about a generally horizontal axis. Thus, the supporting frame **43** is supported solely by the hinge strips **62** and, due to its center of gravity, is biased in a counterclockwise direction as viewed in

FIG. 6 about strips **62** into engagement at its lower end with the housing **19** in the region of neutron beam **21**.

The positioning apparatus **42** of this invention is capable of precisely controlling or finely adjusting the position of the module **30** and thereby the test specimens relative to the neutron beam **21**. To this end, apparatus **42** includes means for moving the module **30** in a horizontally lateral or X direction relative to and perpendicular to the neutron beam **21**. Such means comprises an elongated, vertically extending control rod **67** provided at the upper end thereof with a lead screw-nut arrangement **68** (FIG. 2) having a drive portion **69** projecting upwardly through the housing **36** for connection to and rotation by suitable remotely located drive means to effect vertical reciprocal movement of the rod **67**. Of course, drive portion **69** can be manipulated manually by hand or an appropriate hand tool, if desired.

The lower end of rod **67** is provided with a fitting **70** (FIGS. **6** and **7**) for connection to a pin **71** mounted adjacent its opposite ends in the upper portion of a pair of laterally spaced links **72** and **73** (FIG. **6**) held in place on the pin **71** by retainer rings **75**. The lower ends of the links **72** and **73** are connected to a pin **76** and secured in place thereon by retainer rings **77**. One end of a bell crank **78** is connected to pin **76** between the links **72** and **73** and is mounted for pivotal movement about a pivot pin **80** secured to a bracket **81** connected to the frame of extension **41**. The other end of bell crank **78** is provided with an actuator in the form of a roller **82** having rounded edges and which is captively held in a key way or slot **83** formed by the spacing between the opposed upright legs **85** and **86** of a pair of angle members **87** and **88** secured, as by fasteners **90**, to the base plate **51**.

With the above arrangement, it will be observed that lowering of control rod **67** by rotation of the drive portion **69** in the proper direction causes the bell crank **78** to pivot about pin **80** in a clockwise direction as viewed in FIG. 7 to shift the cam roll **82** toward the left against the abutment defined by leg **86** of angle member **88**. This moves the base plate **51** in the same direction and carries therewith the connected supporting frame **43** horizontally leftwardly to effect corresponding lateral movement of the module **30** in a similar horizontal transverse direction along the X axis. Of course, raising the control rod **67** effects translation of the module **30** in the opposite lateral transverse direction along the X axis. Thus, fine adjustment of the module **30** transversely relative to the neutron beam **21** is accomplished by actuation of the control rod **67** in the appropriate vertical direction.

The positioning apparatus **42** also is provided with means operative to move the module **30** in a vertical or Y direction relative to the axis of the neutron beam **21**. To this end, such means include an elongated, vertically extending control rod **91** also provided at its upper end with a lead screw-nut assembly (not shown) having a drive portion **93** protruding upwardly through the housing **36** for connection to a suitable direct or remotely located drive control to effect vertical reciprocal movement of the rod **91**. The lower end of rod **91** is provided with a fitting **95** threaded axially into the end of rod **91** and carrying a roller **96** disposed in a horizontal slot **97** formed in a guide block **98** welded or otherwise fixedly secured to a mounting plate **100** affixed to the base plate **51** by fasteners **101**. Thus, vertical displacement of the control rod **91** effects raising or lowering of the base plate **51** about pin **60** carrying along therewith the supporting frame **43** to, in turn, shift the module **30** vertically or in a Y direction relative to the neutron beam **21**. The pivotal movement of the base plate **51** about pin **60** is translated, via hinge strips **62**, into vertical movement of the frame **43** and module **30**, which is normally biased against the target housing **19** as will hereinafter be described.

Referring to FIG. 7, it will be seen that the slot **83** allows the base plate **51** to be raised or lowered without displacing roller **82** or otherwise disturbing the linkage imparting horizontal movement to base plate **51**. Likewise, the slot **97** provides horizontal play between the latter and roller **96** to accommodate movement of the base plate **51** in a horizontal direction upon actuation of control rod **67** without displacing the roller **96** or otherwise affecting the linkage imparting vertical movement to base plate **51**. Thus, movements in either the X or Y directions are completely independent of each other whereby movement in either direction does not influence movement of the base plate **51** in the other direction.

Means also are provided for moving the module **30** in a third direction toward and away from target **17**. Although the travel of module **30** in this direction follows a slight arcuate path about a relatively large radius, such slight arcuate movement will be identified as movement in a Z direction for purposes of this description since the travel for all practical purposes is substantially parallel to the neutron beam **21**.

The means for imparting movement of module **30** in this Z direction includes an elongated, vertically extending control rod **102** provided at its upper end with a lead screw-nut assembly **103** (FIG. **1**) having a drive portion **105** thereof extending upwardly through the housing **36** for connection to a suitable drive train to impart vertical reciprocal movement to the rod **102**.

The lower end of control rod **102** is attached by fastener **106** to a horizontally extending link **107**, in turn connected to the upper end of a connecting rod **108** by a fastener **110**. The lower end of connecting rod **108** is secured, as by a fastener **111**, to a support **112** provided with an actuator in the form of a roller **113**. The roller **113** is adapted to engage an abutment member **115** rigidly attached to the upper end of supporting frame **43**. The roller **113** is normally disposed beneath the member **115** in spaced relation thereto so that the supporting frame **43** is freely suspended from hinge strips **62** and counterweighted by gravity for urging the module **30** attached thereto into engagement with housing **19** adjacent target **17**. When desired to displace the module **30** away from the housing **20**, control rod **102** is raised by proper manipulation of the drive portion **105** to effect lifting, via connecting rods **102** and **108**, of roller **113** into engagement with abutment member **115** to pivot the supporting frame **43** in a clockwise direction (FIG. **6**) about the hinge strips **62**. Movement of module **30** in the Z direction can be actuated independently of the X and Y movements. While such Z movement has no effect on the X position of the module, it will result in a slight displacement of the module in the Y direction which can be readily corrected, if necessary. Once the module is freely suspended for engagement by gravity against the housing, it can be independently moved in either the X or Y direction without affecting the other.

In use, the test stalk **11** and shield plug **12** are assembled and fitted together in the so-called "service cell", which is a large, shielded area or compartment directly above the test cell **15** for housing the support equipment employed for the insertion, removal, assembly, disassembly, and maintenance of test assemblies **10**. The test assembly **10** is adapted to be lowered vertically as a unit through a suitable port formed in the top wall **13** of test cell **15** with the upper drive portions **69**, **93** and **105** of the three control rods **67**, **91** and **102** projecting thereabove into the service cell for selective manual control or connection to a suitable drive train operatively controlled from a remote station (not shown).

Before the assembly **10** is lowered into the test cell **15**, the roller **113** is urged, via control rod **102**, against abutment member **115** to dispose the lower portion of supporting frame **43** and module **30** rearwardly in a position clearing the projection **20** of housing **19** as the module descends therepast. Moreover, this maintains the supporting frame **43** in a stable, non-swinging position as it is being lowered. When fully lowered, the drive portion **105** is rotated in the proper direction via lead screw-nut assembly **103** to slowly lower the control rod **102** and the associated roller **113**, allowing the supporting frame **43** to swing by gravity about hinge strips **62** for gingerly easing the module **30** into engagement against the housing **19**. Upon engagement of the module **30** with housing **19**, the roller **113** is further lowered to provide a clearance between the latter and abutment member **115**, permitting the module to rest freely against the housing.

Once the test assembly **10** has been inserted into test cell **15** with module **30** resting against the housing **19**, the module **30** must be aligned with the anticipated path of the neutron beam expected to emerge from the target **17**. This anticipated path can be predetermined by known methods and, in most instances, will be centered on the center line of the deuteron beam **16**. The alignment of the module **30** is effected by actuating control rods **67** and/or **91** independently to move the module **30** in the corresponding X and/or Y directions, respectively, as required. Once the module **30** is properly aligned with the anticipated path of the forwardly-biased neutron beam, the accelerator can be energized to generate the deuteron-beam **16**, a condition referred to as "beam-on".

During beam-on, only little, if any, further positioning adjustment of the module **30** will be required as long as the deuteron-beam remains stable to within approximately ± 1 mm. With beam-on, the location of the axis of the forwardly biased, high density, neutron beam **21** relative to the module can be determined by proper instrumentation mounted on the test assembly **10** or by neutron heating data generated within the test assembly **10**. If during beam-on, the module **30** becomes slightly misaligned relative to the neutron beam **21**, as may be occasioned by slight shifting of the latter, thermal expansion or improper installation alignment, either or both of the control rods **67** and **91** can be actuated to effect corresponding correctional movements of module **30** in the proper X and Y directions to precisely position the same within the optimum neutron flux of beam **21**. When desired to remove the test assembly **10** from test cell **15**, control rod **102** is raised to lift roller **113** into engagement with member **115** to withdraw the module **30** away from the housing **19** sufficiently to clear projection **20** and thereby permit smooth and easy vertical retraction of the test assembly **10** upwardly from test cell **15** without interference or obstruction by the projection **20**.

While it has been convenient to describe the positioning apparatus of this invention preferably in connection with the positioning of test specimens relative to the neutron flux path of a neutron source, it should be understood that the apparatus of this invention is not restricted thereto, but has utility in any application where it is desired to precisely or finely adjust by remote means in inaccessible locations the position of articles in three directions relative to an axis or target zone.

From the foregoing, it is apparent that the objects of the present invention have been fully accomplished. As a result of the present invention, a new and useful positioning apparatus is provided for precisely orienting test specimens within the optimum neutron flux flow path of a forwardly biased neutron source. The positioning apparatus incorporates simple mechanical components for imparting independent motion in three substantially perpendicular directions, namely the X, Y and generally Z directions. The range of motion in these three directions compensates and corrects for any misalignment occurring between the test specimens and the optimum neutron flux flow path resulting from thermal expansion differences and fabrication tolerances therebetween. The apparatus provides accurate positioning predicated on gravity loading which eliminates all backlash in the Y and Z directions. Moreover, the gravity counter weighting also eliminates the need for springs in an irradiation environment. Also, the pivotal hinge strip arrangement provides for retraction of the test module **30** from underneath the housing projection to allow for unobstructed vertical insertion and removal of the test assembly **10** into and from the test cell. Moreover, the gravity loading in the Z direction allows the test module **30** to slide over the target housing in the event such module is inadvertently raised without prior Z direction retraction.

It is to be understood that the form of the invention herein shown and described is to be taken as an illustrative embodiment only of the same, and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of the invention.

We claim:

1. An apparatus for precisely adjusting the position of an article relative to a beam emerging from a housing comprising: a frame, a base plate mounted on said frame for movement relative thereto, a support, means pivotably mounting said support adjacent one end thereof on said base plate, an article holder detachably mounted on the other end of said pivotable support, said support being freely suspended from said base plate and normally biased by gravity toward said housing for urging said holder in a first direction substantially parallel to said beam against said housing, means on said frame for shifting said base plate to effect movement of said holder in a second direction perpendicular to said beam axis, and means on said frame for pivoting said base plate to effect movement of said holder in a third direction substantially normal to said first and second directions.

2. An apparatus according to claim **1**, including means for moving said support and holder away from said housing.

3. An apparatus according to claim **2**, wherein said moving means comprises an actuator engagable with said support for moving said support in a direction opposite said gravity biased direction.

4. An apparatus according to claim **3**, wherein said moving means includes a reciprocal control rod operatively connected to said actuator for selectively urging said actuator into engagement and disengagement with said support.

5. An apparatus according to claim **1**, wherein said shifting means and said pivoting means are independently operable to effect movement of said holder in the associated direction irrespective of the position to which said holder has been moved in the other direction.

6. An apparatus according to claim **2** wherein said base plate and pivotal support are mounted in an irradiation test cell and said shifting means, pivoting means, and moving means are provided with separate actuating means extending to the exterior of said test cell.

7. An apparatus according to claim **1**, wherein said shifting means comprises a reciprocal control rod connected at one end thereof to a bell crank for transmitting vertical motion into horizontal motion, said bell crank having an actuator disposed in a vertical slotted guideway mounted on said base plate for displacing said base plate horizontally upon actuation of said control rod.

8. An apparatus according to claim **1**, wherein said pivoting means comprises a vertically reciprocal control rod having one end connected to an actuator disposed in a horizontal slotted guideway mounted on said base plate for pivoting said base plate upon actuation of said control rod.

9. An apparatus according to claim **1**, wherein said pivotal mounting means comprises a pair of hinge strips connecting said support to said base plate.

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