USOORE34823E

United States Patent [19] [11] E Patent Number: Re. 34,823

Sakaida et al. [45] Reissued Date of Patent: Jan. 10, 1995

[54] DEVICE FOR MAGNIFYING DISPLACEMENT OF PIEZOELECTRIC ELEMENT OR THE LIKE AND METHOD OF PRODUCING SAME

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[73] Assignee: **Brother Kogyo Kabushiki Kaisha**, Aichi, Japan

[21] Appl. No.: **780,099**

[22] Filed: **Oct. 17, 1991**

Related U.S. Patent Documents

Reissue of:

[64] Patent No.: **4,874,978**
Issued: **Oct. 17, 1989**
Appl. No.: **202,035**
Filed: **Jun. 3, 1988**

[30] **Foreign Application Priority Data**

Jun. 9, 1987	[JP]	Japan	62-143530
Jun. 12, 1987	[JP]	Japan	62-90834
Jun. 16, 1987	[JP]	Japan	62-149535
Oct. 30, 1987	[JP]	Japan	62-277169
Jan. 23, 1988	[JP]	Japan	63-13229
Jan. 25, 1988	[JP]	Japan	63-14019
Jan. 29, 1988	[JP]	Japan	63-19844
Feb. 2, 1988	[JP]	Japan	63-23561

[51] **Int. Cl.**^{6} **H01L 41/08**

[52] **U.S. Cl.** **310/328**

[58] **Field of Search** 310/328, 346; 400/124; 101/93.05

[56] **References Cited**

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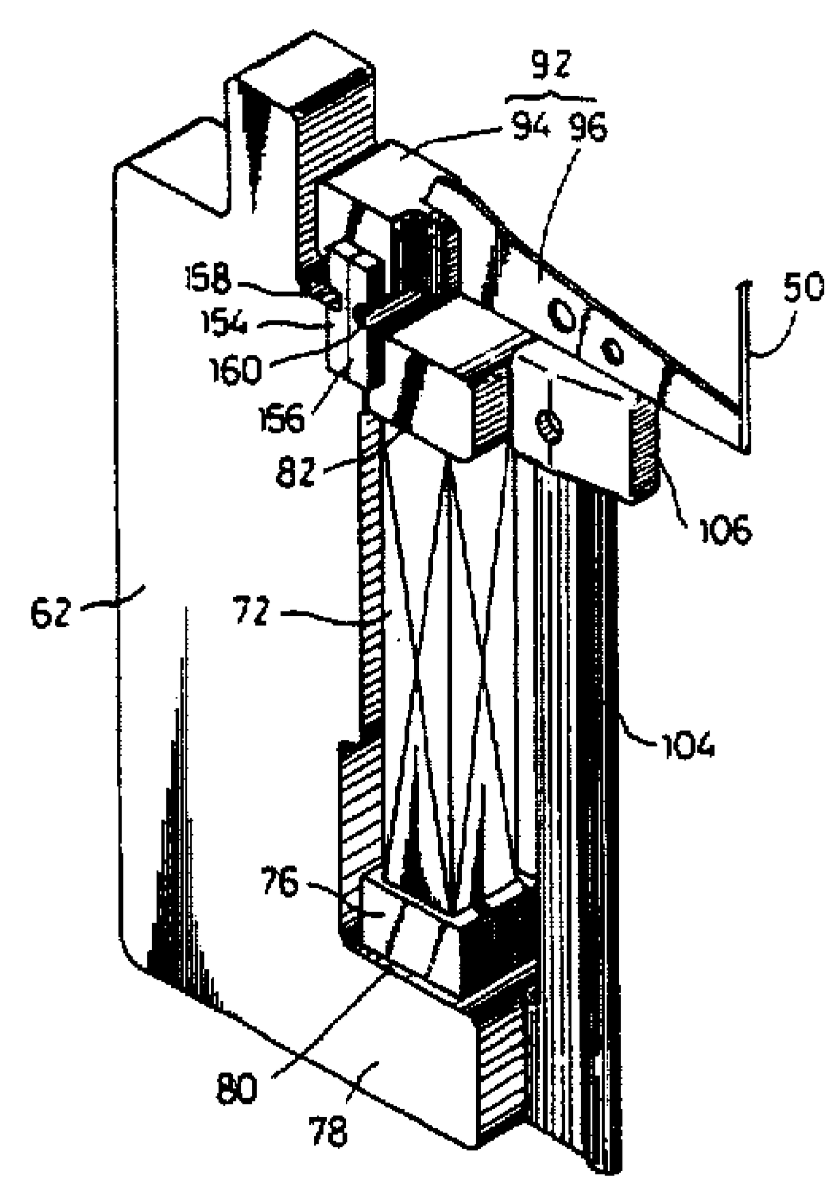
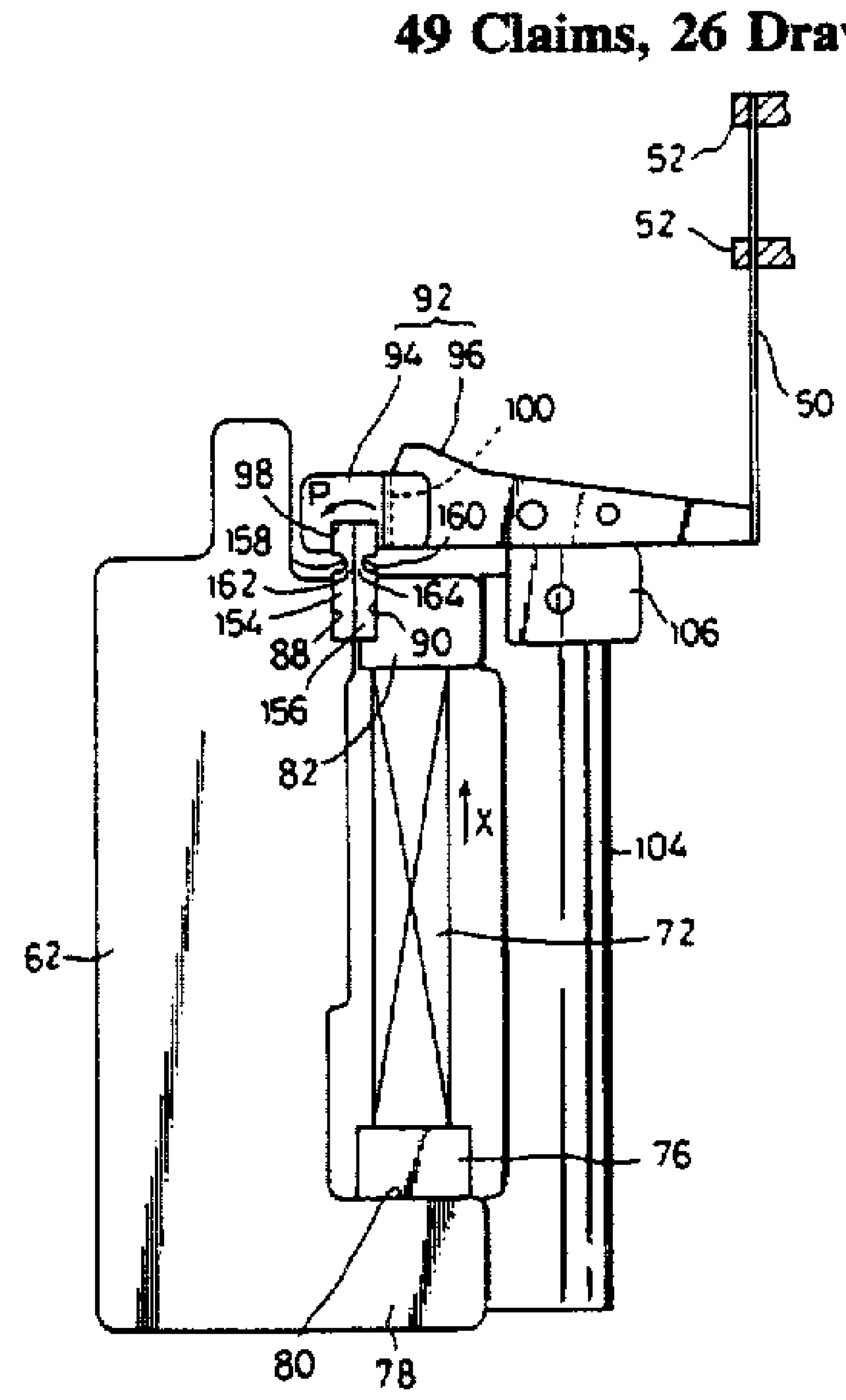
Primary Examiner—Mark O. Budd
Attorney, Agent, or Firm—Oliff & Berridge

[57] ABSTRACT

A device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element; a movable member fixed to a first end of the piezoelectric element with respect to the direction of displacement; a first mount surface formed on said frame and extending substantially parallel to the direction of displacement; a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, which second mount surface is opposed to the first mount surface; a first leaf spring mounted at a first end portion on the first mount surface and extending substantially parallel to the direction of displacement; a second leaf spring mounted at a first end portion on the second mount surface and extending substantially parallel to the direction of displacement; and a rolling member fixed to second end portions of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member.

49 Claims, 26 Drawing Sheets





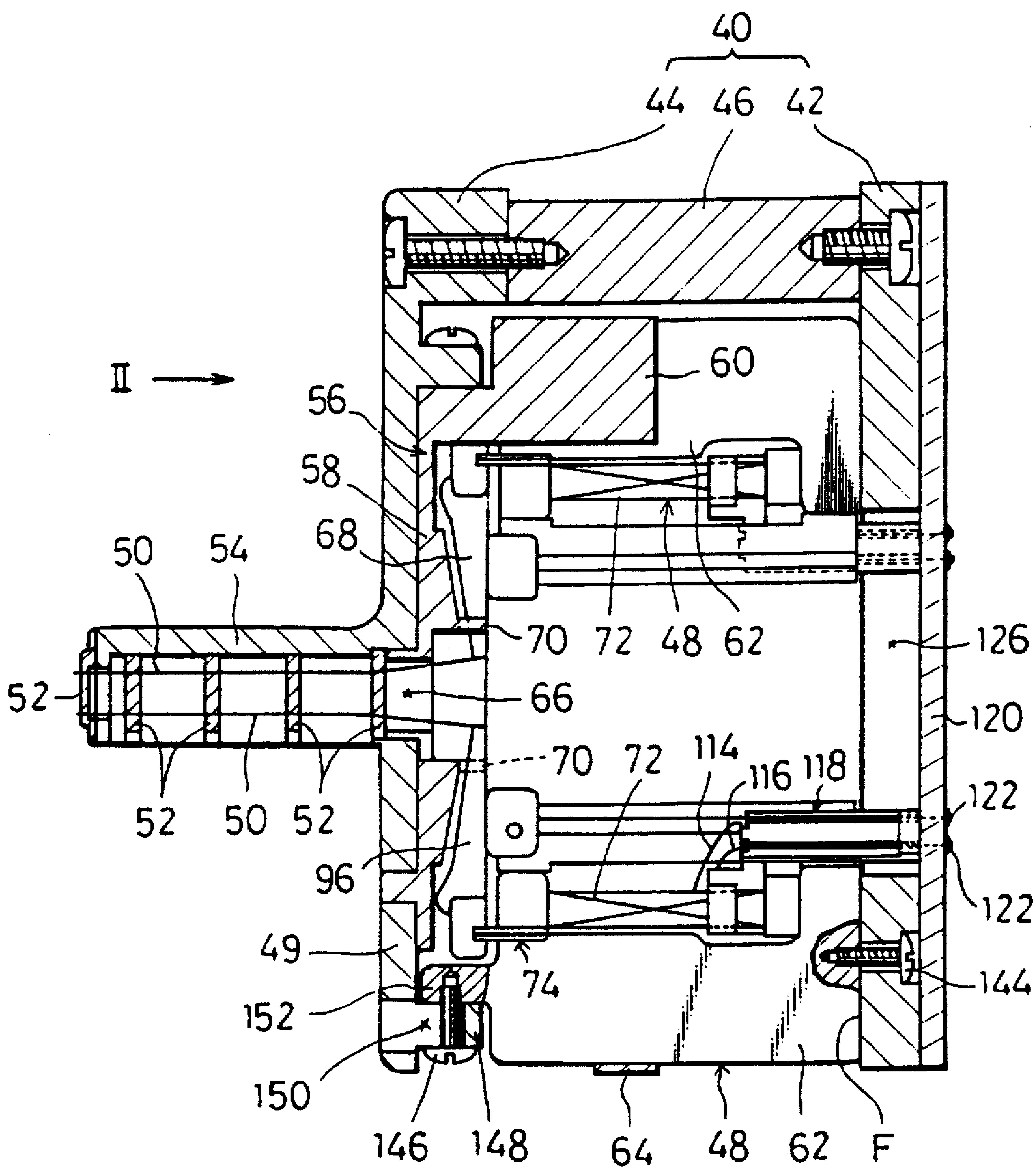

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FIG. 1

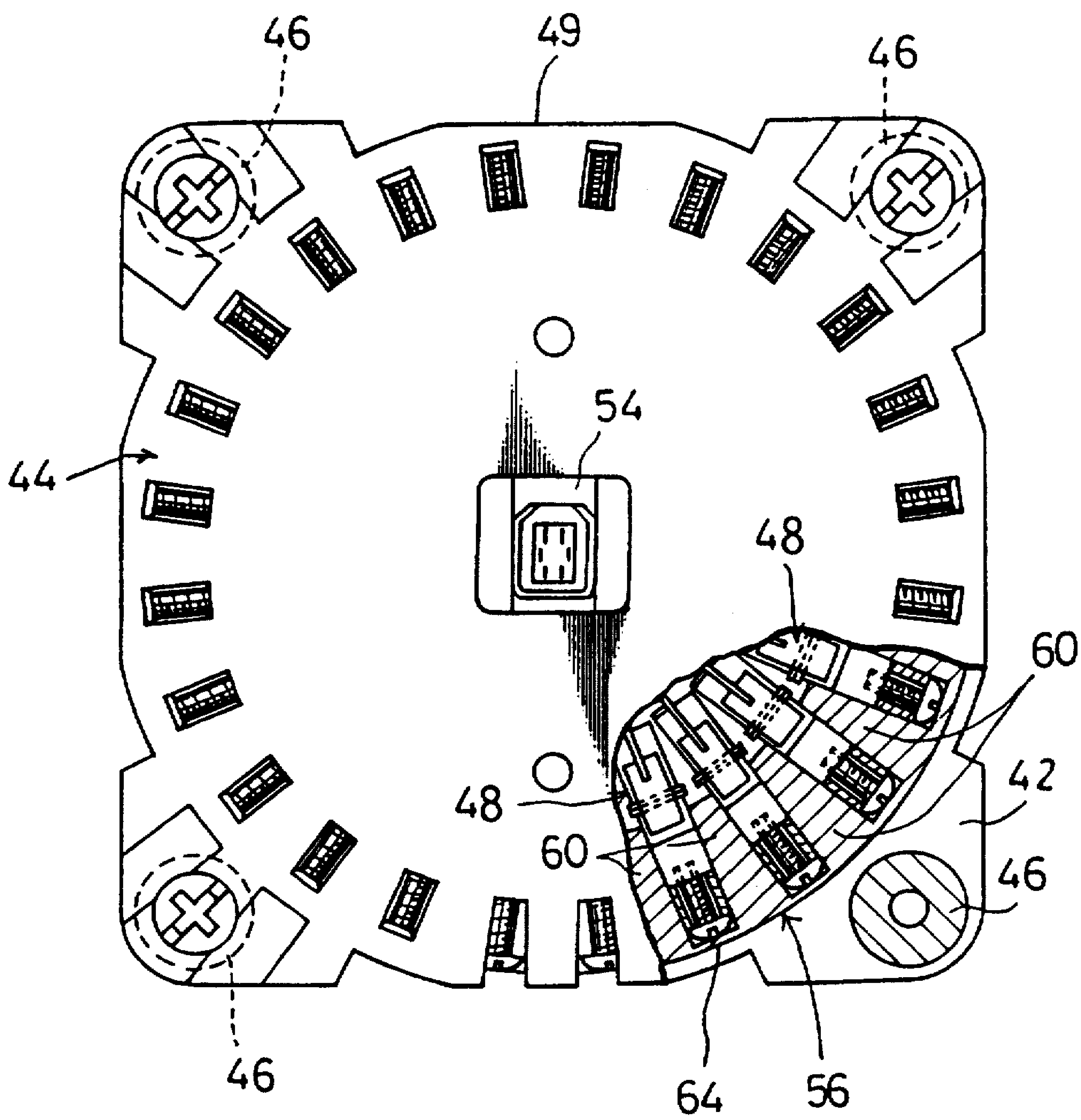

FIG.2

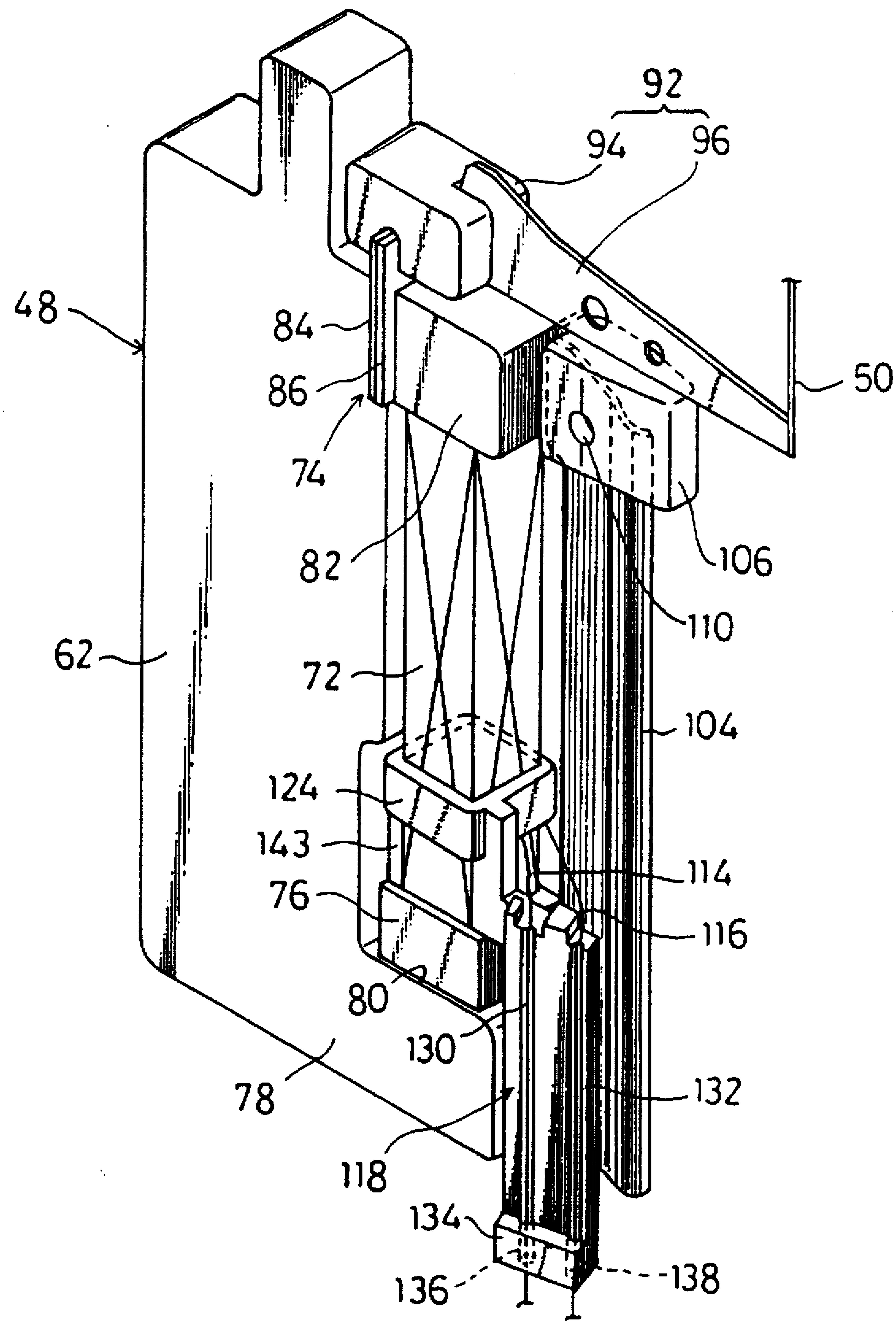
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FIG.3

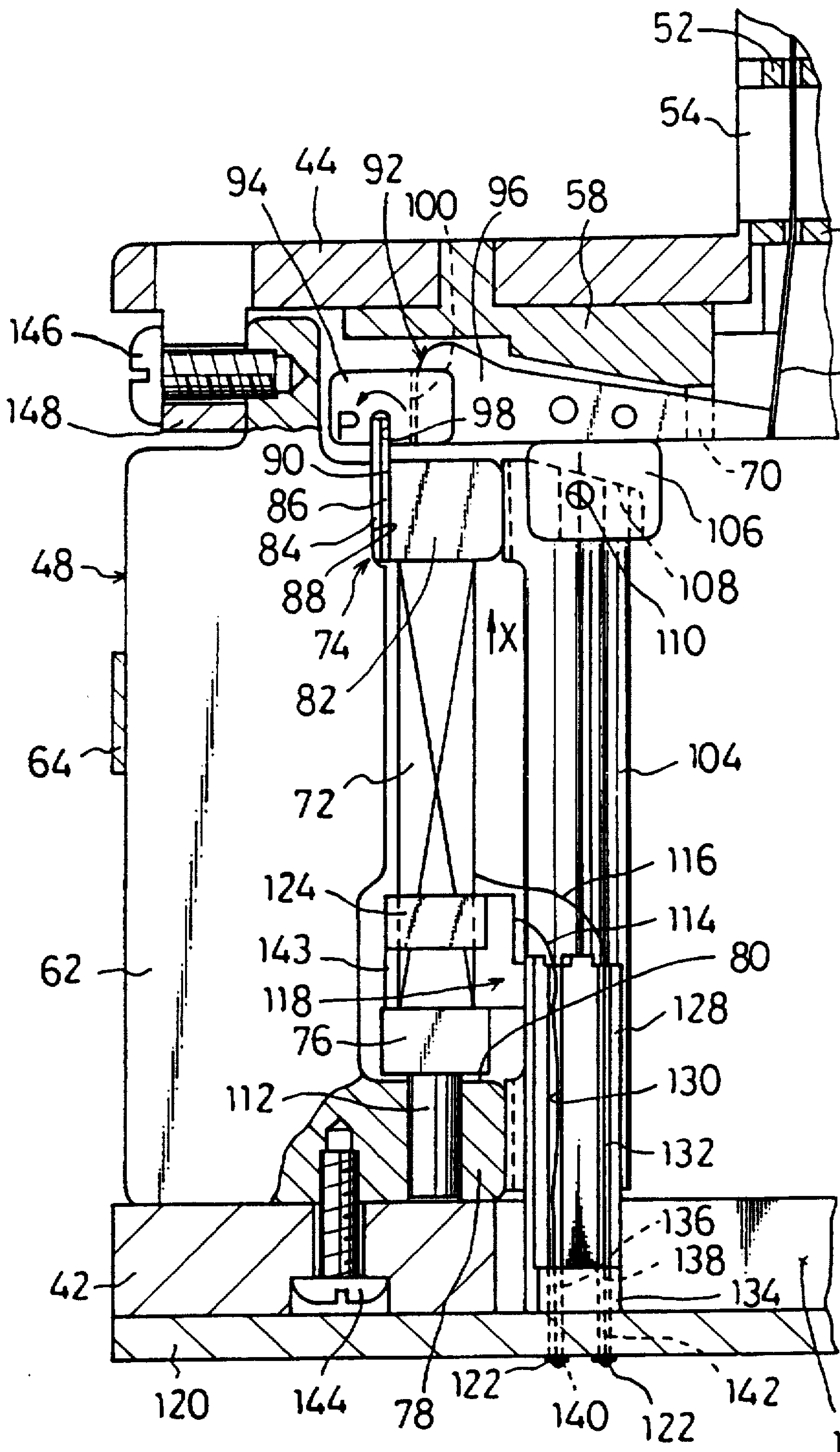
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FIG. 4

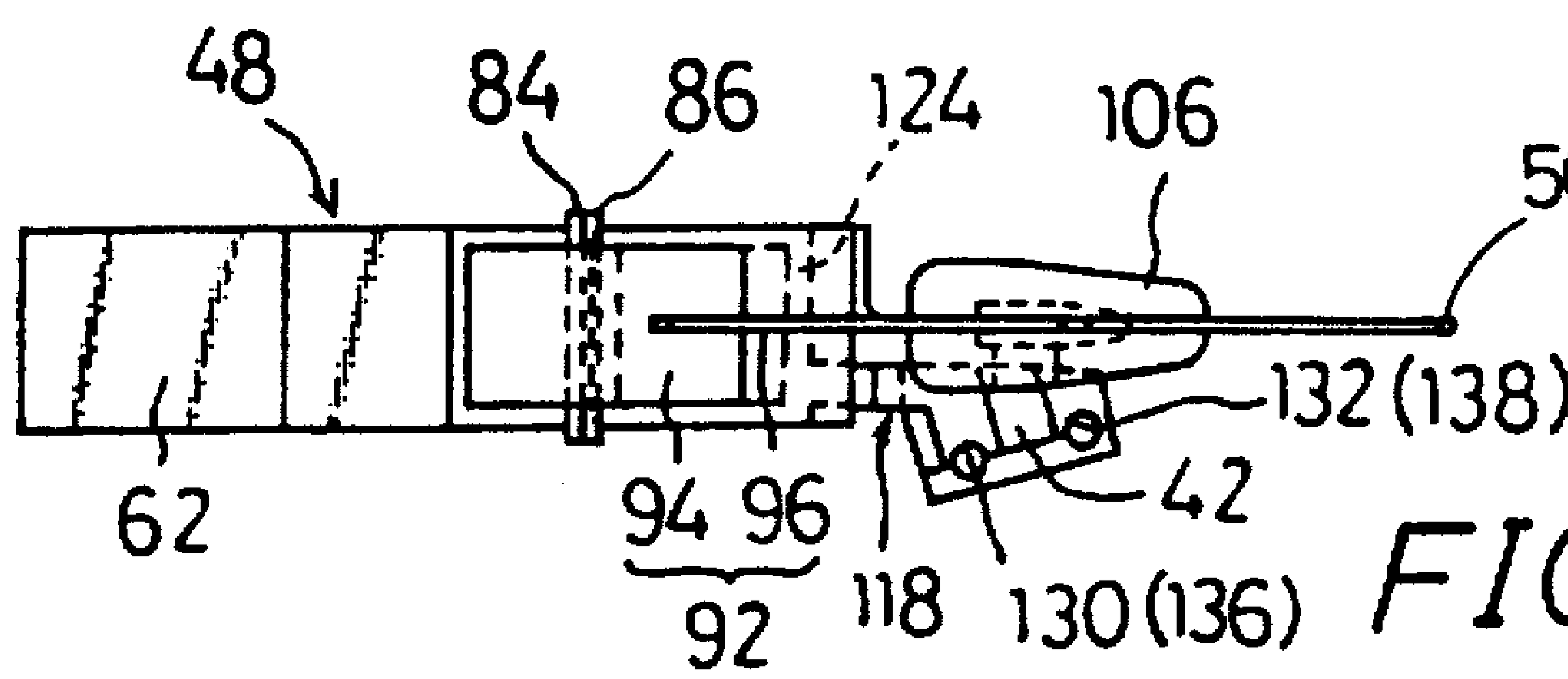
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FIG. 5

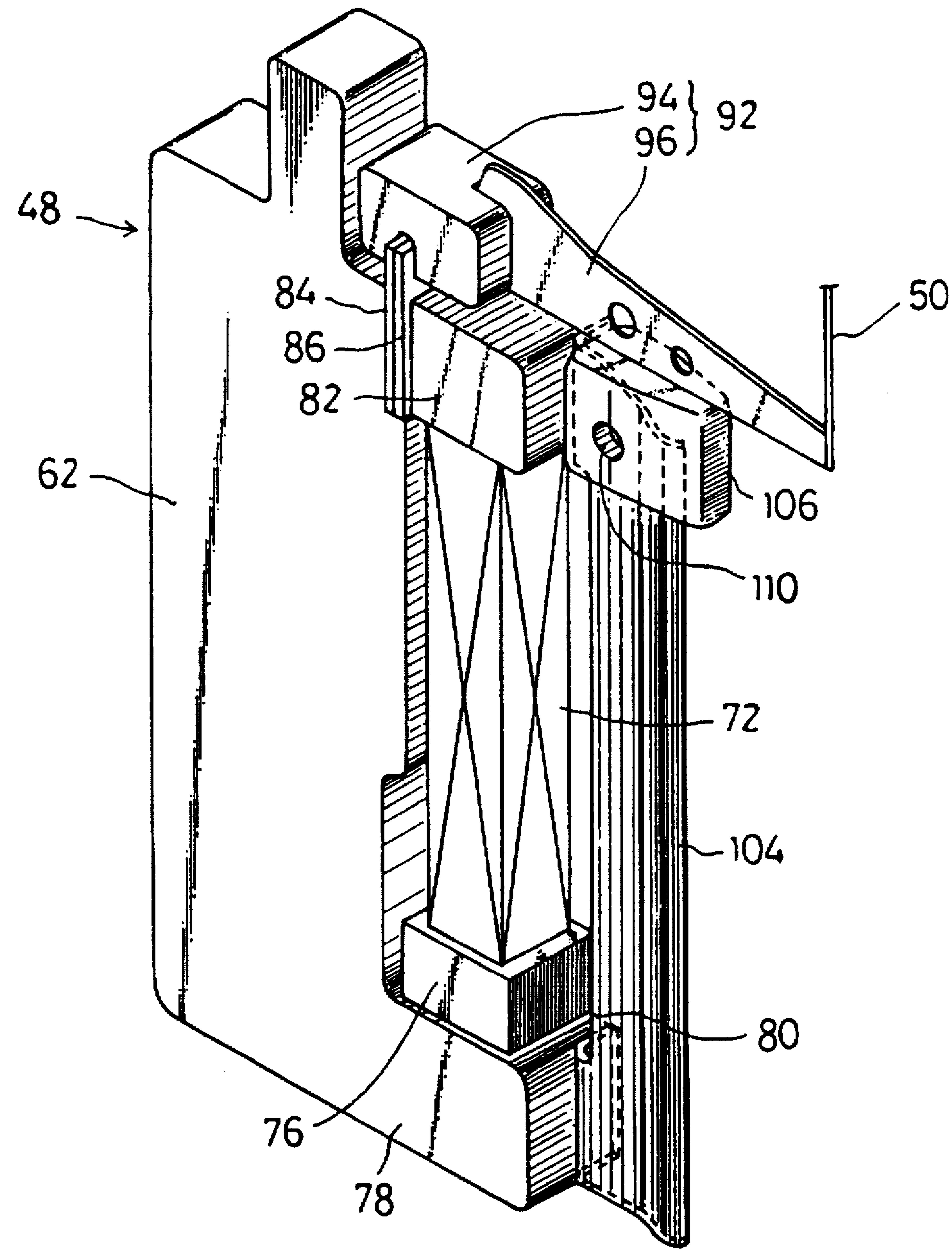


FIG.6

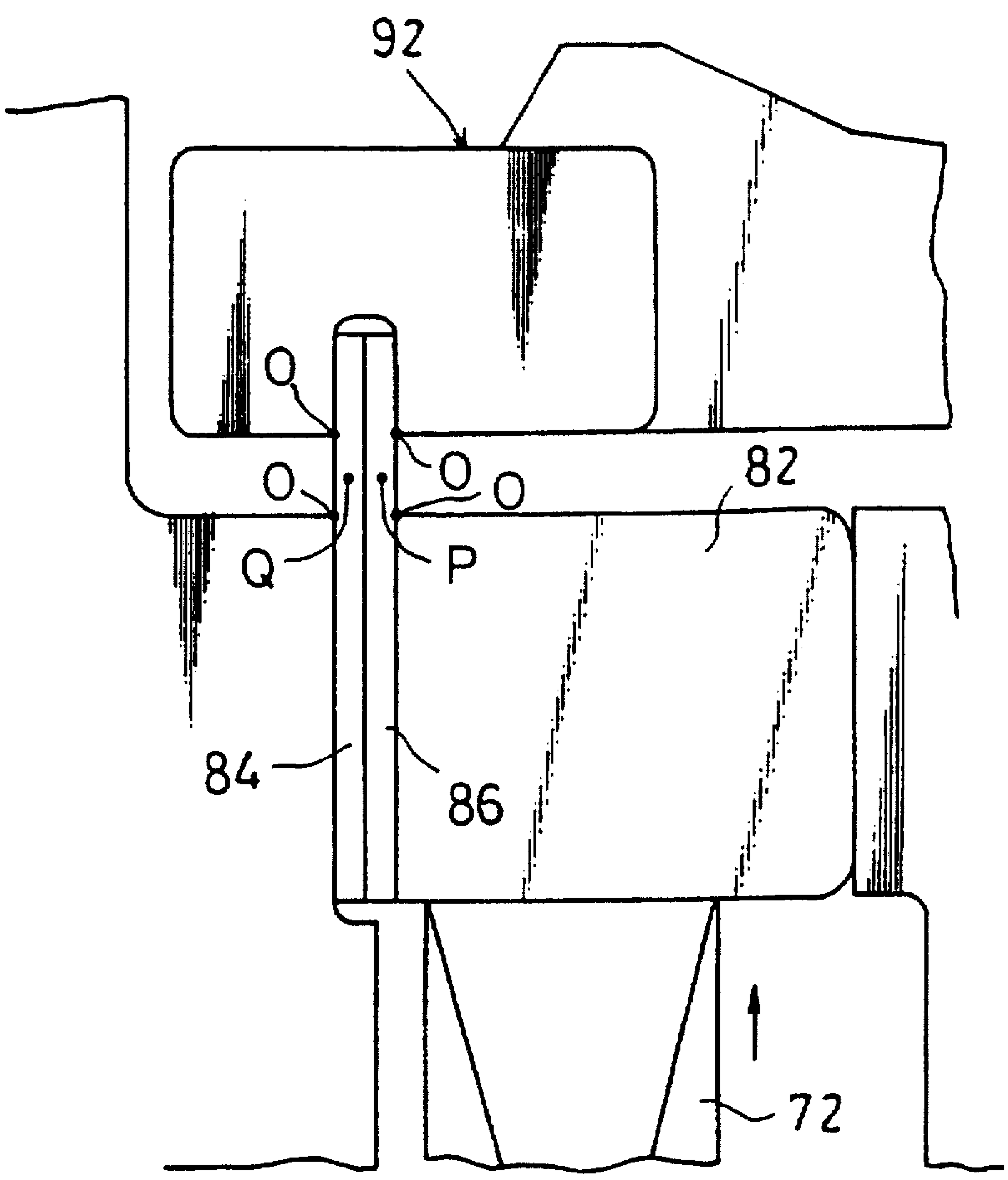
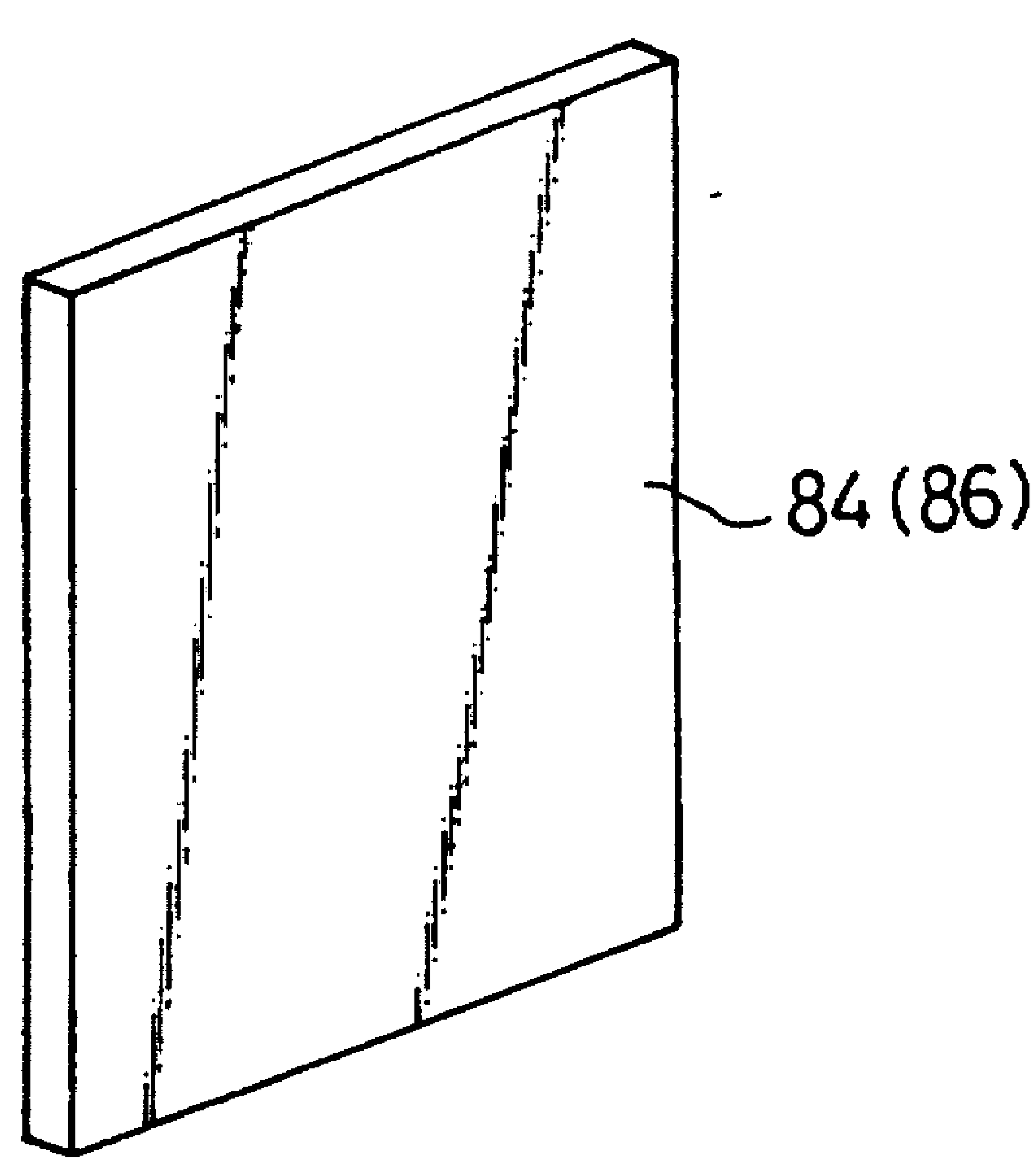


FIG.7



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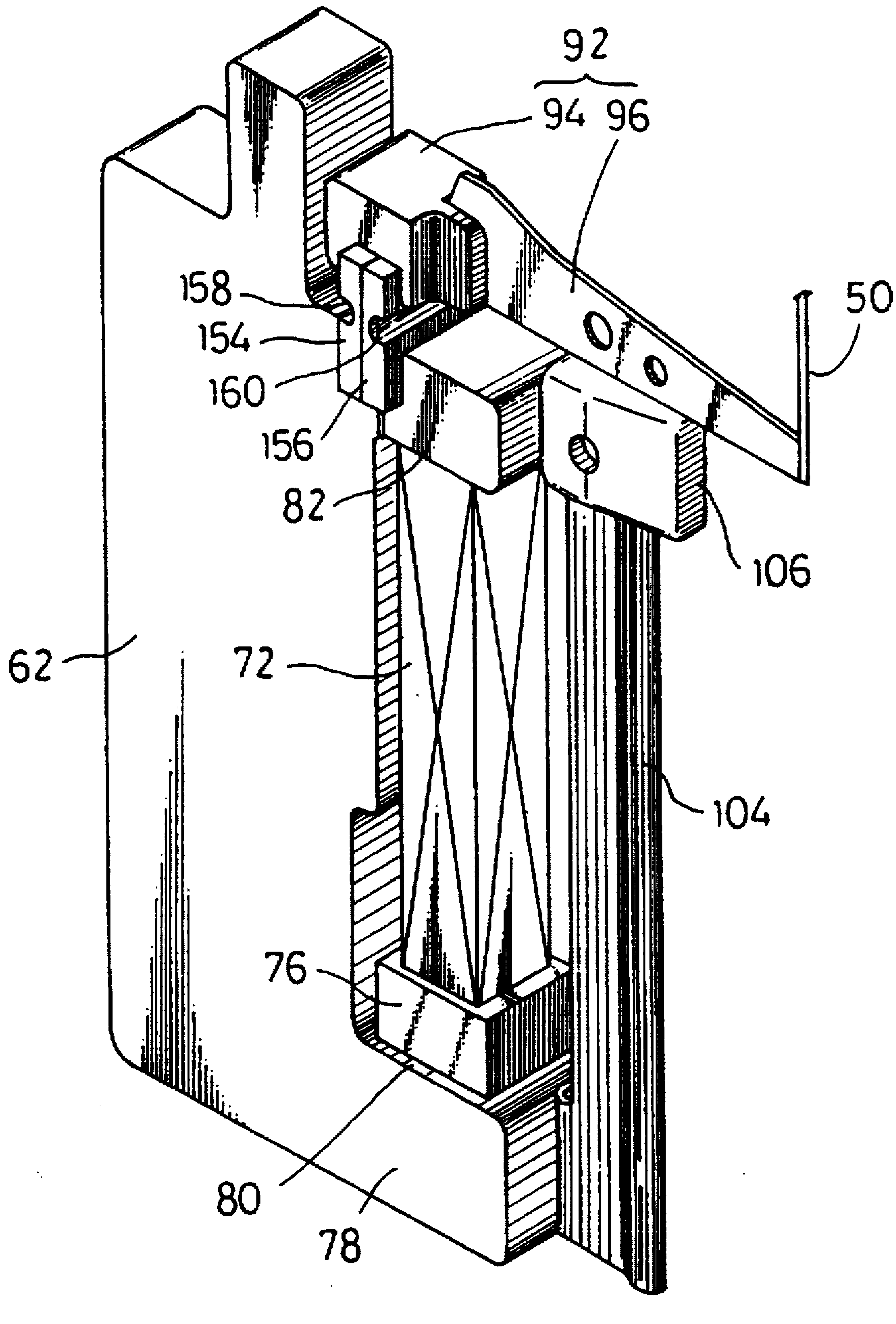

FIG.9

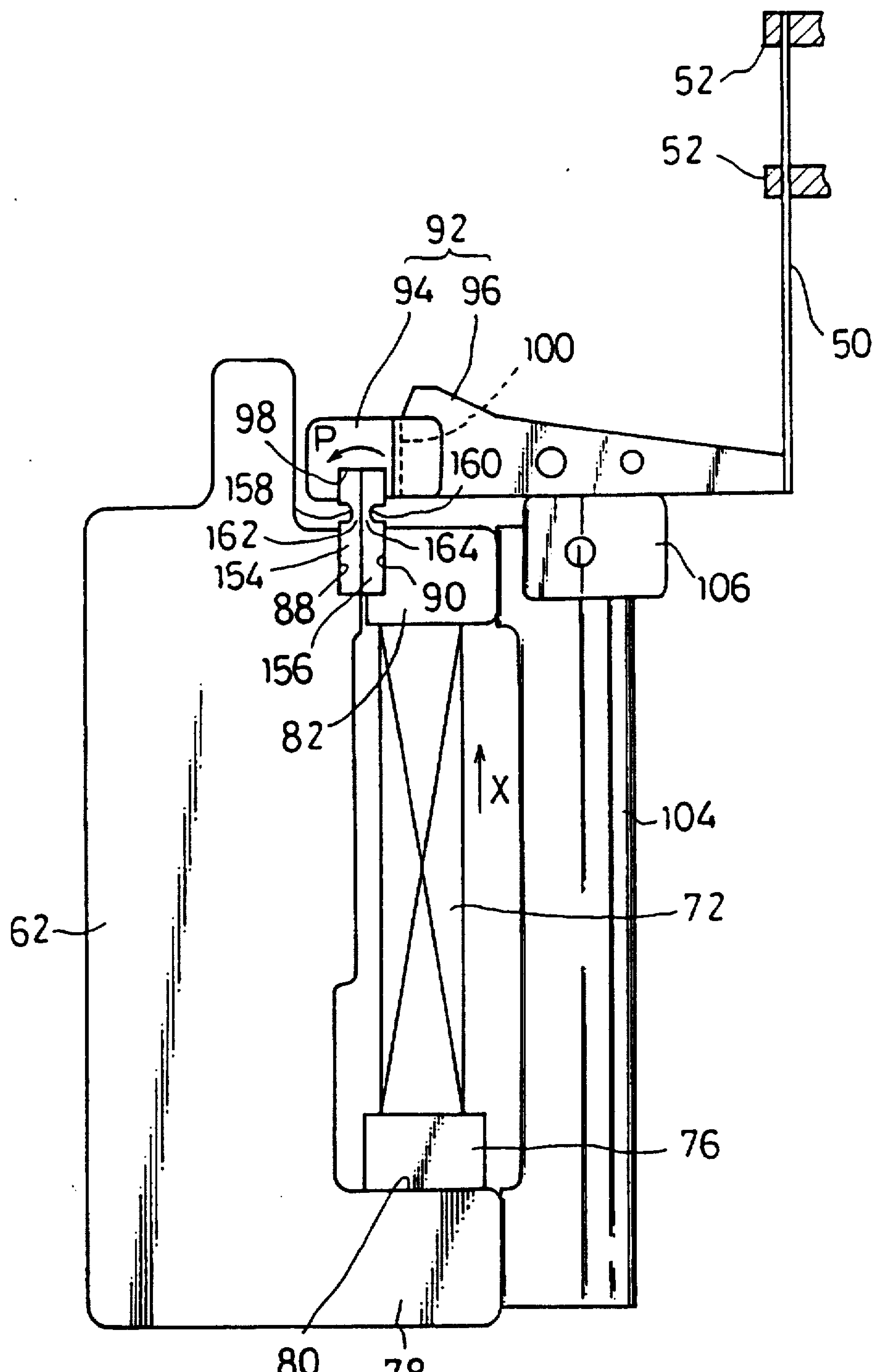
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FIG.10

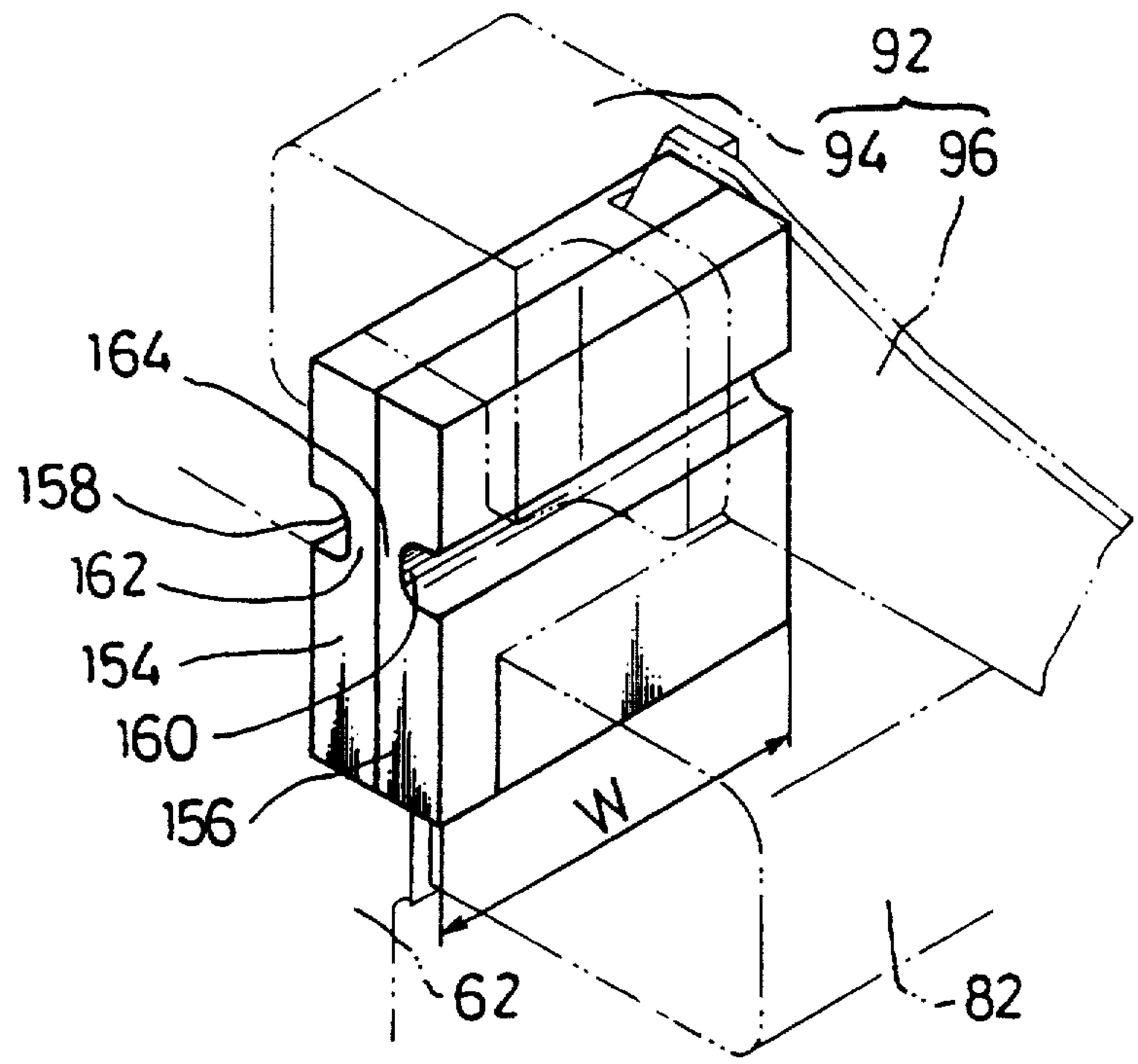
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FIG.11

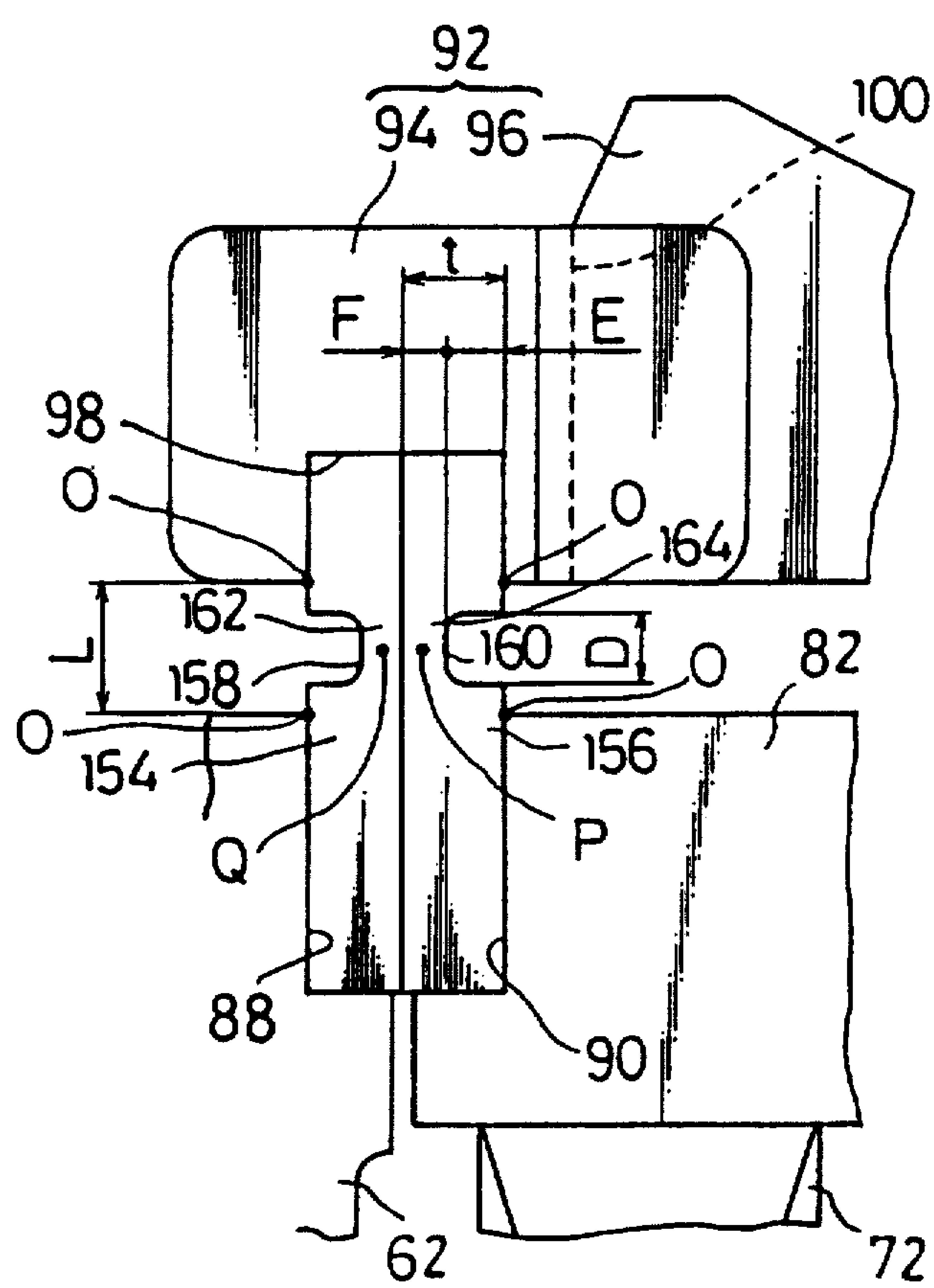
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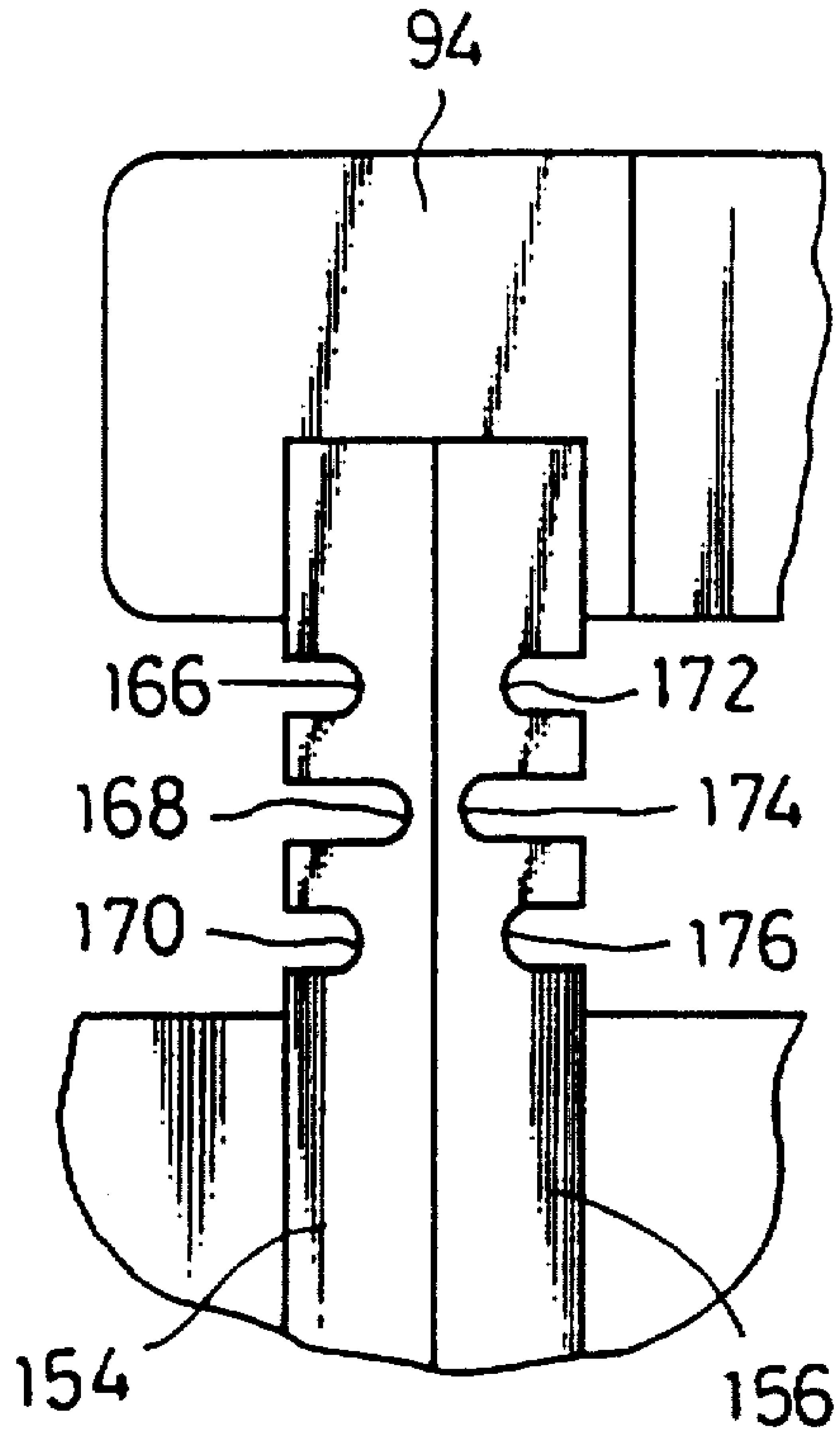
FIG.12



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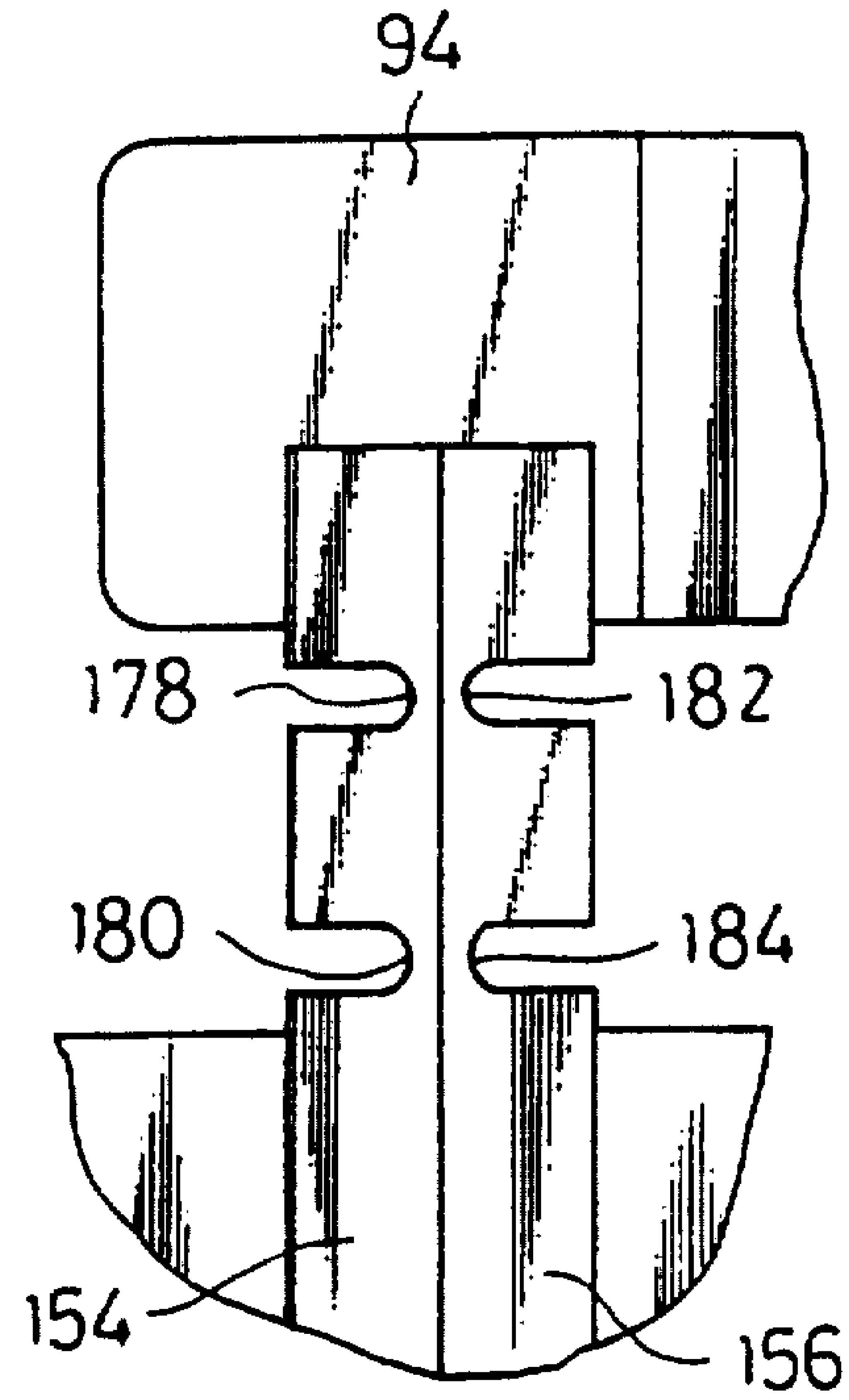

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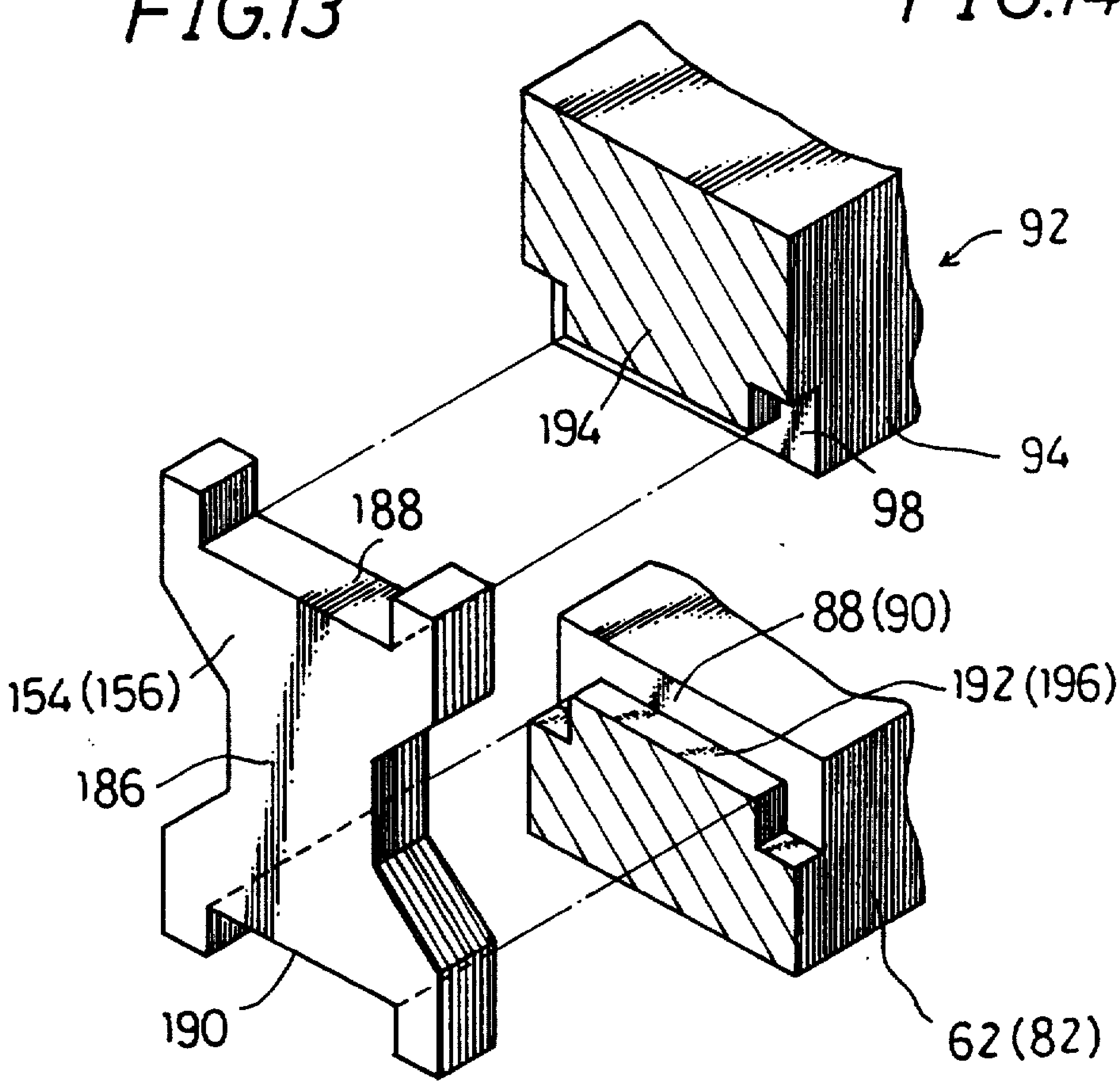

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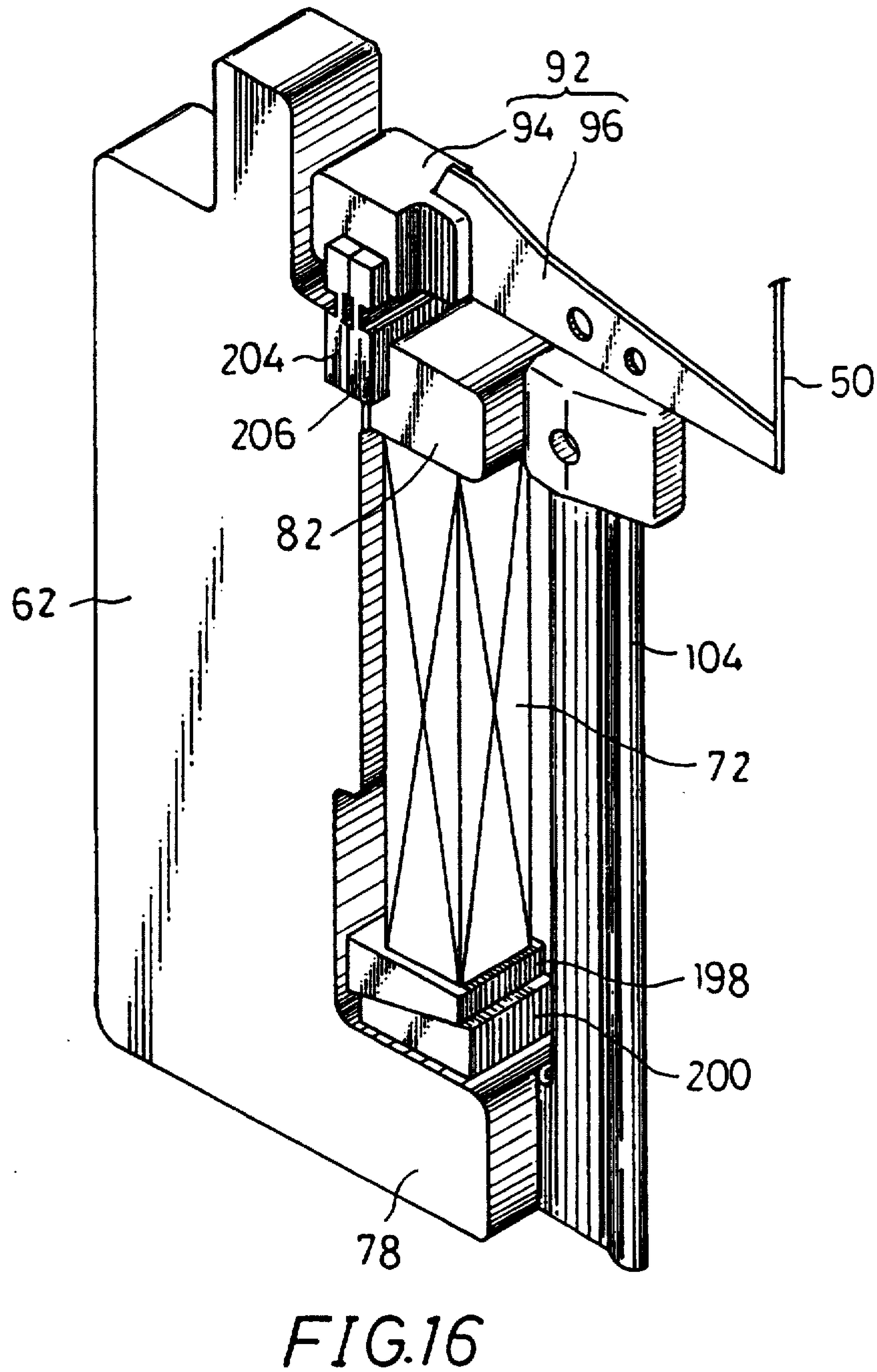

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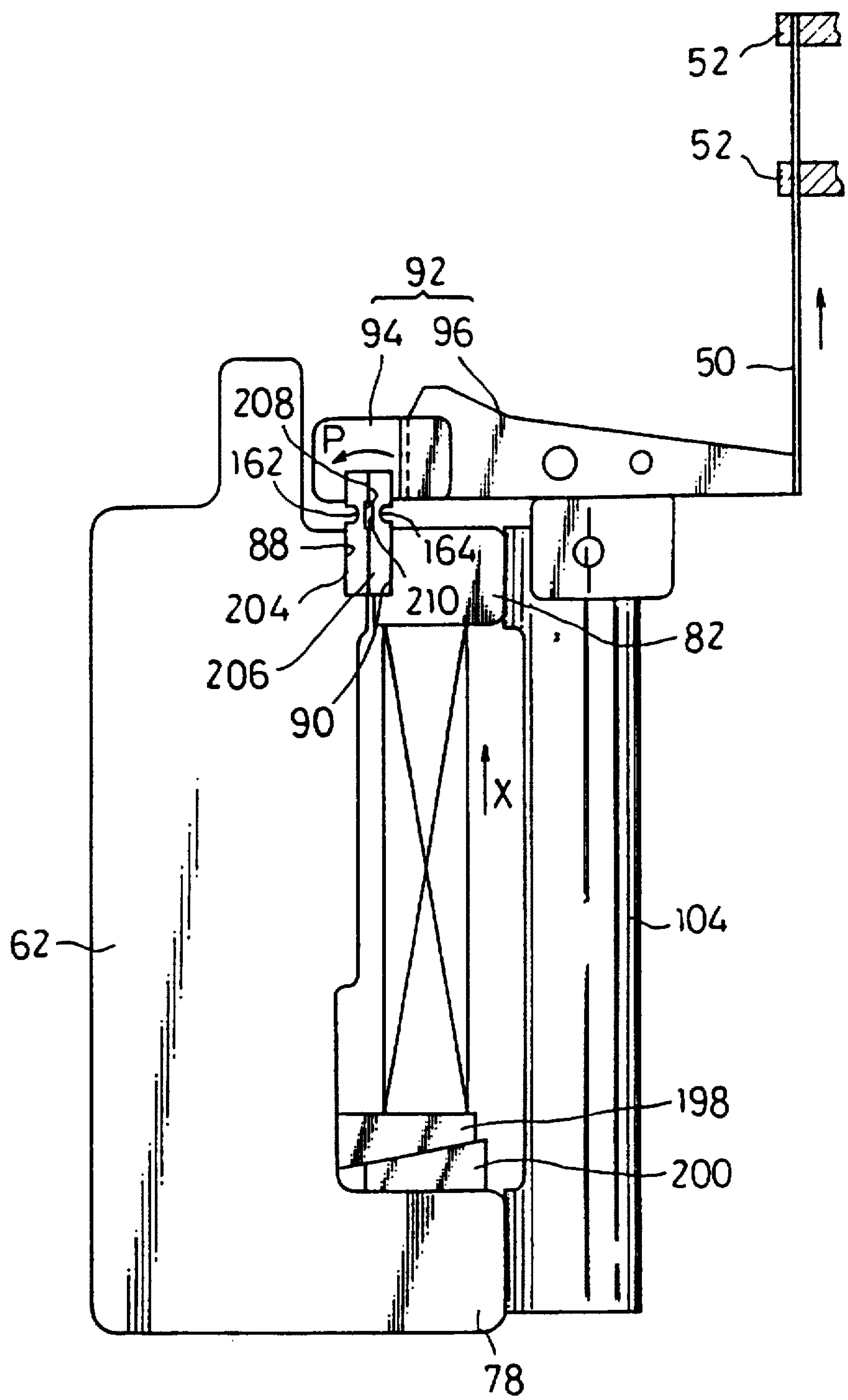
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FIG.17

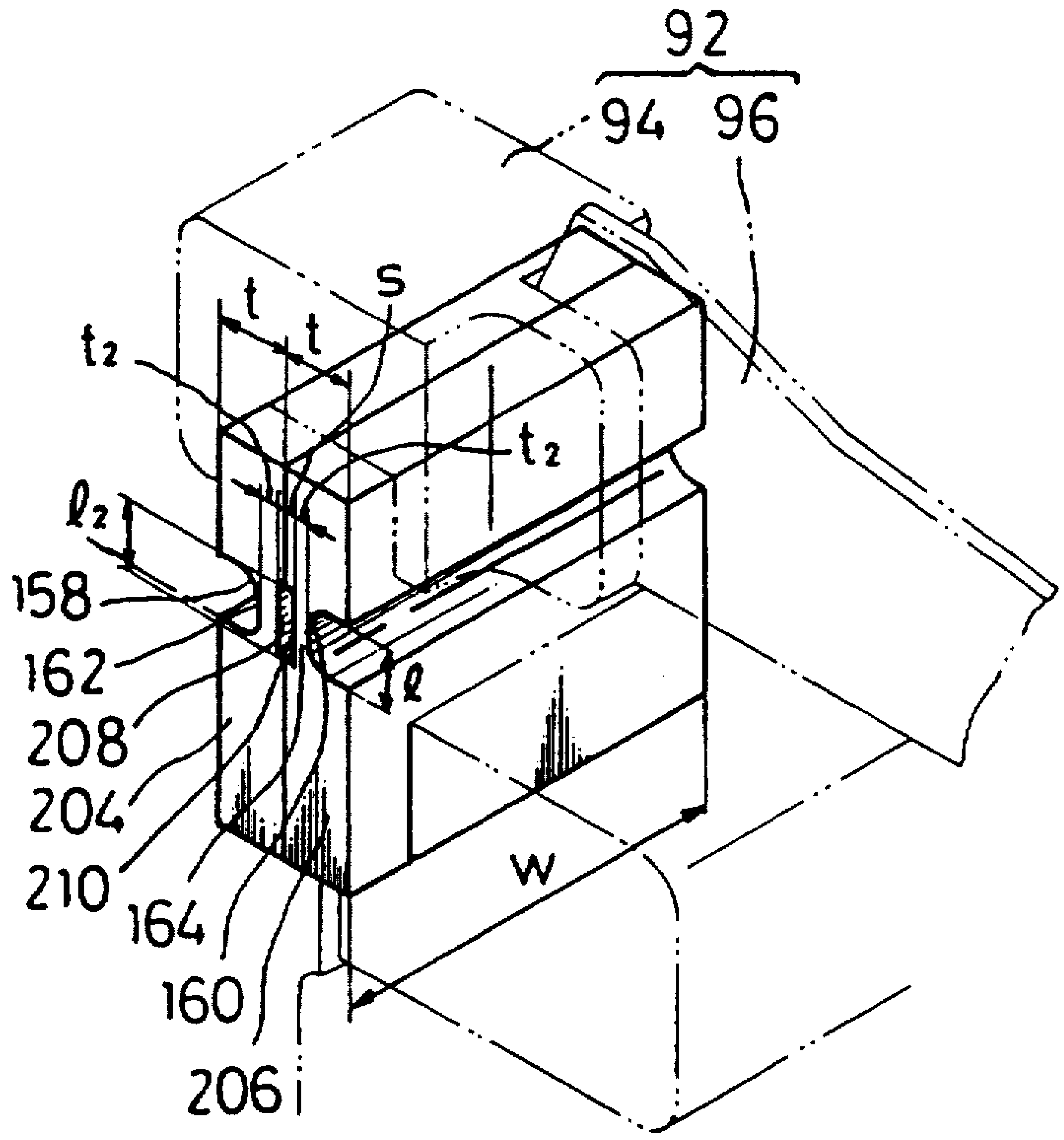

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FIG.18

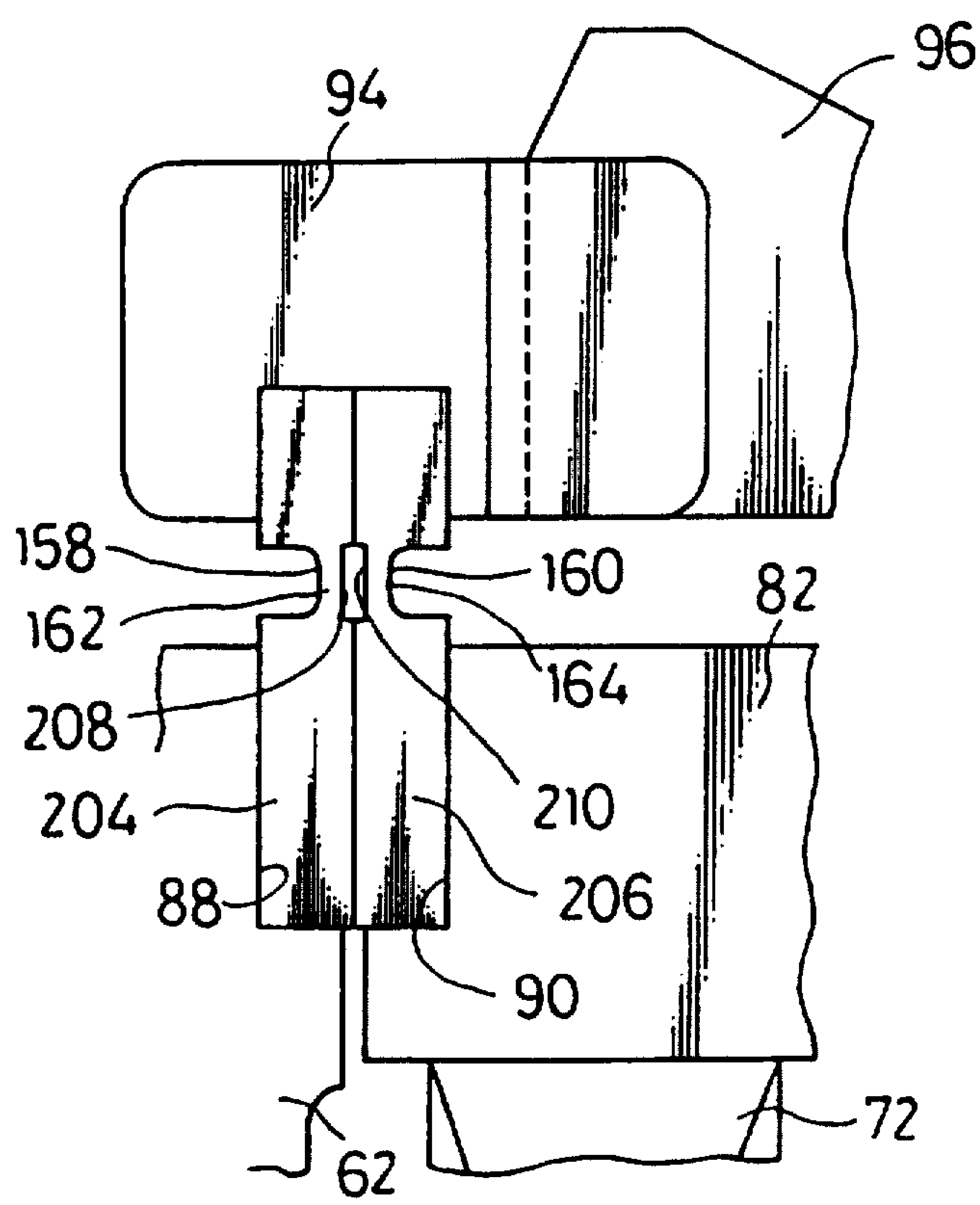

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FIG.19

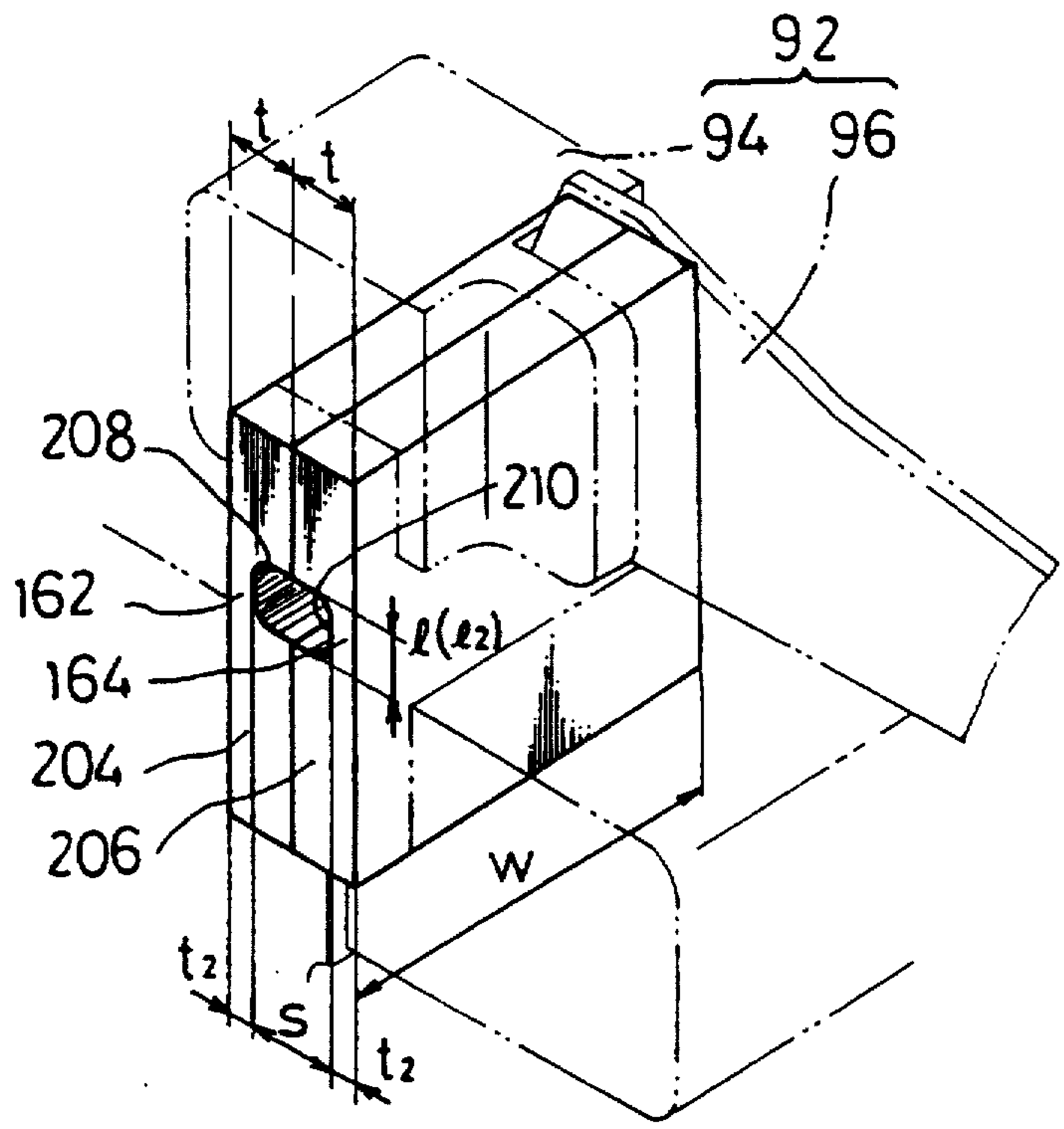
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FIG.20

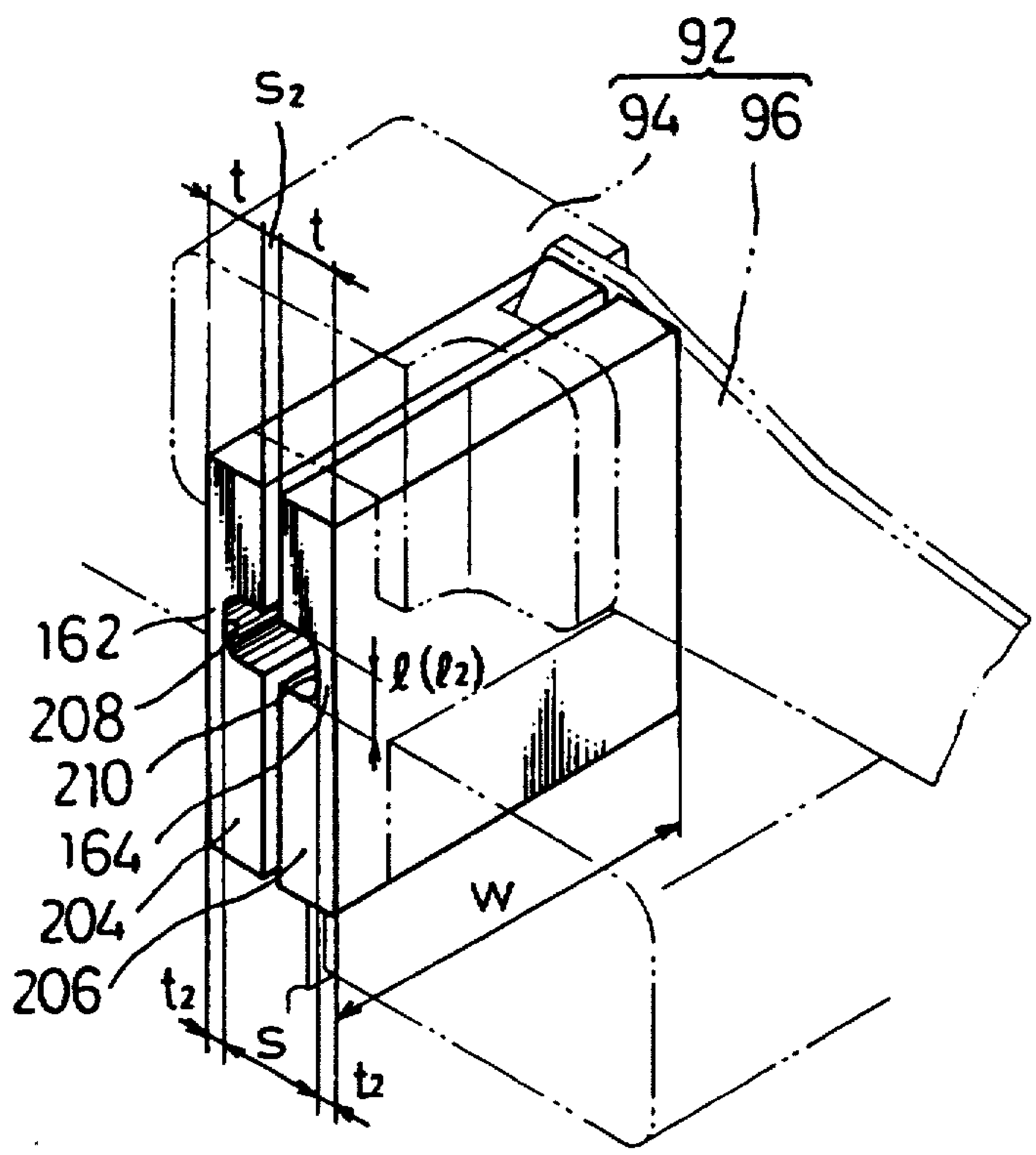
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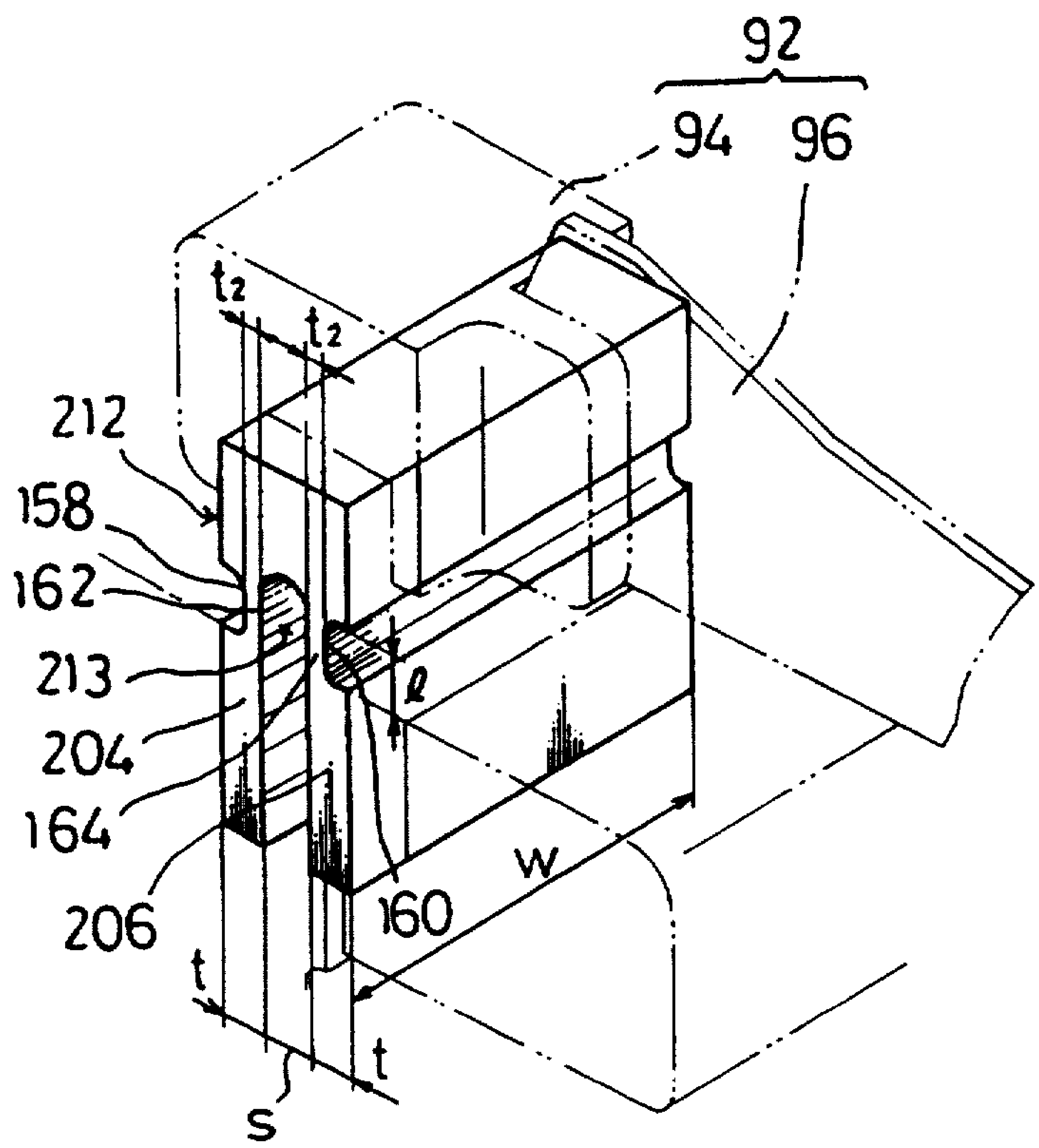
FIG.21



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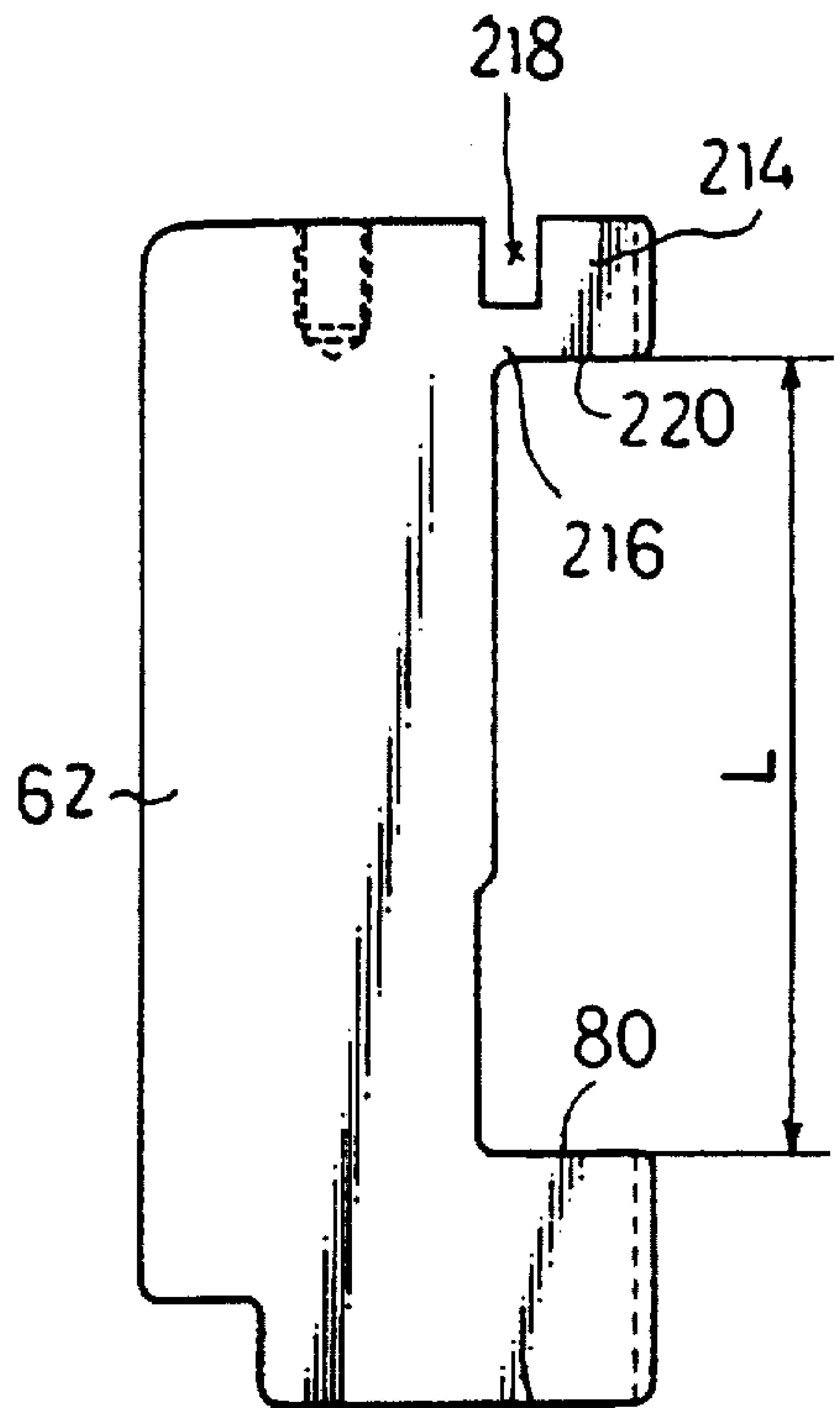

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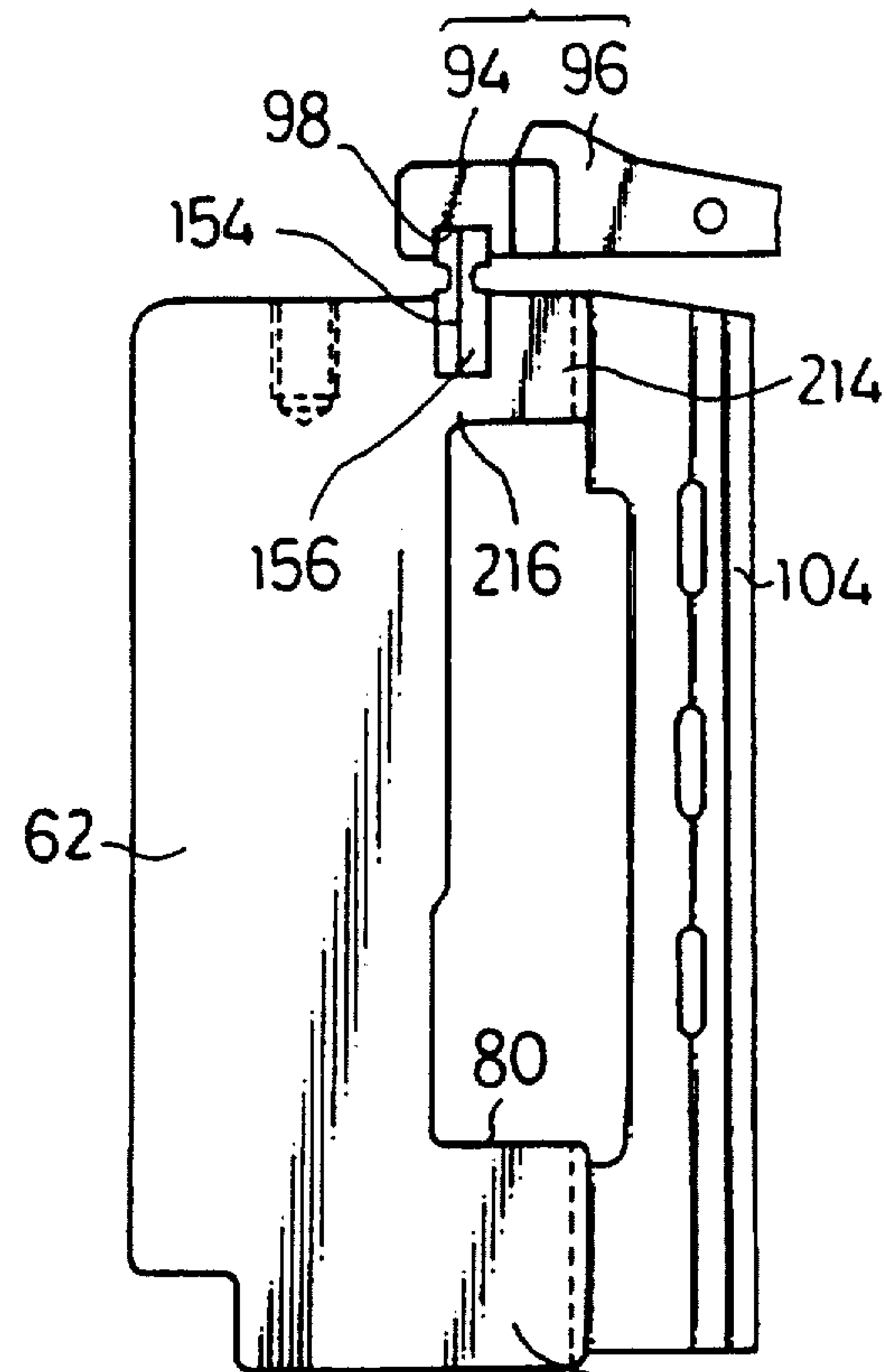

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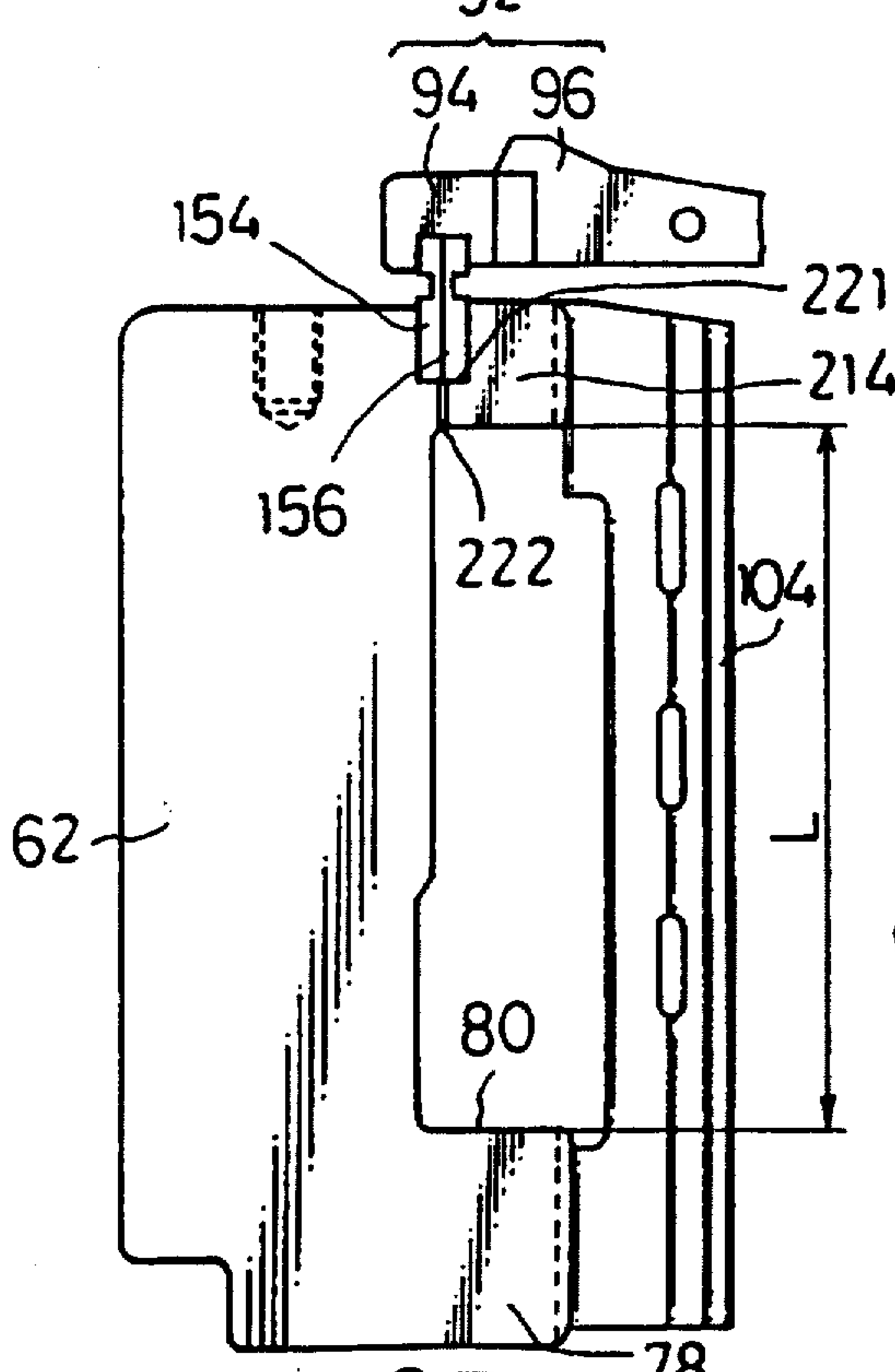

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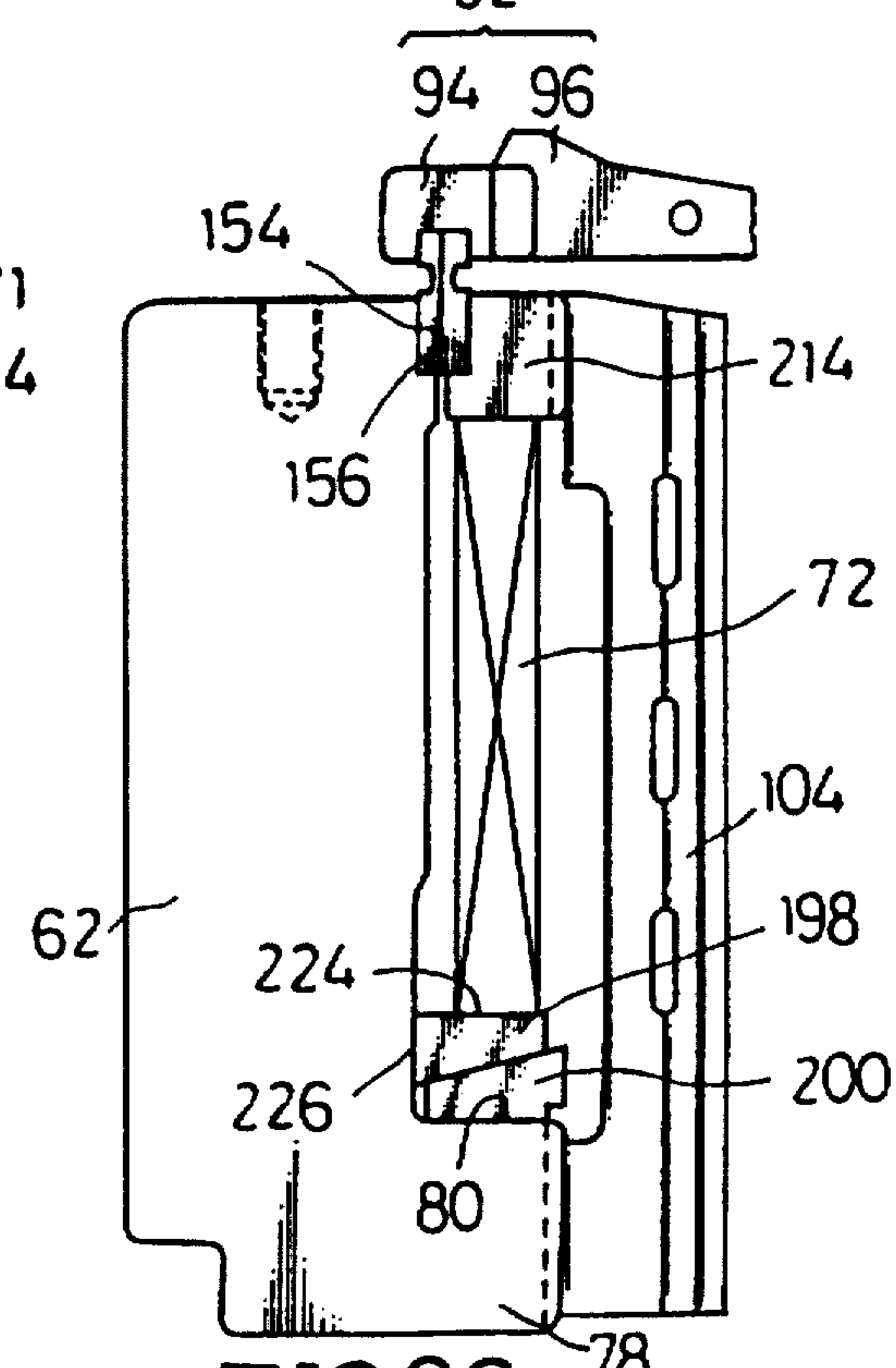

FIG.26

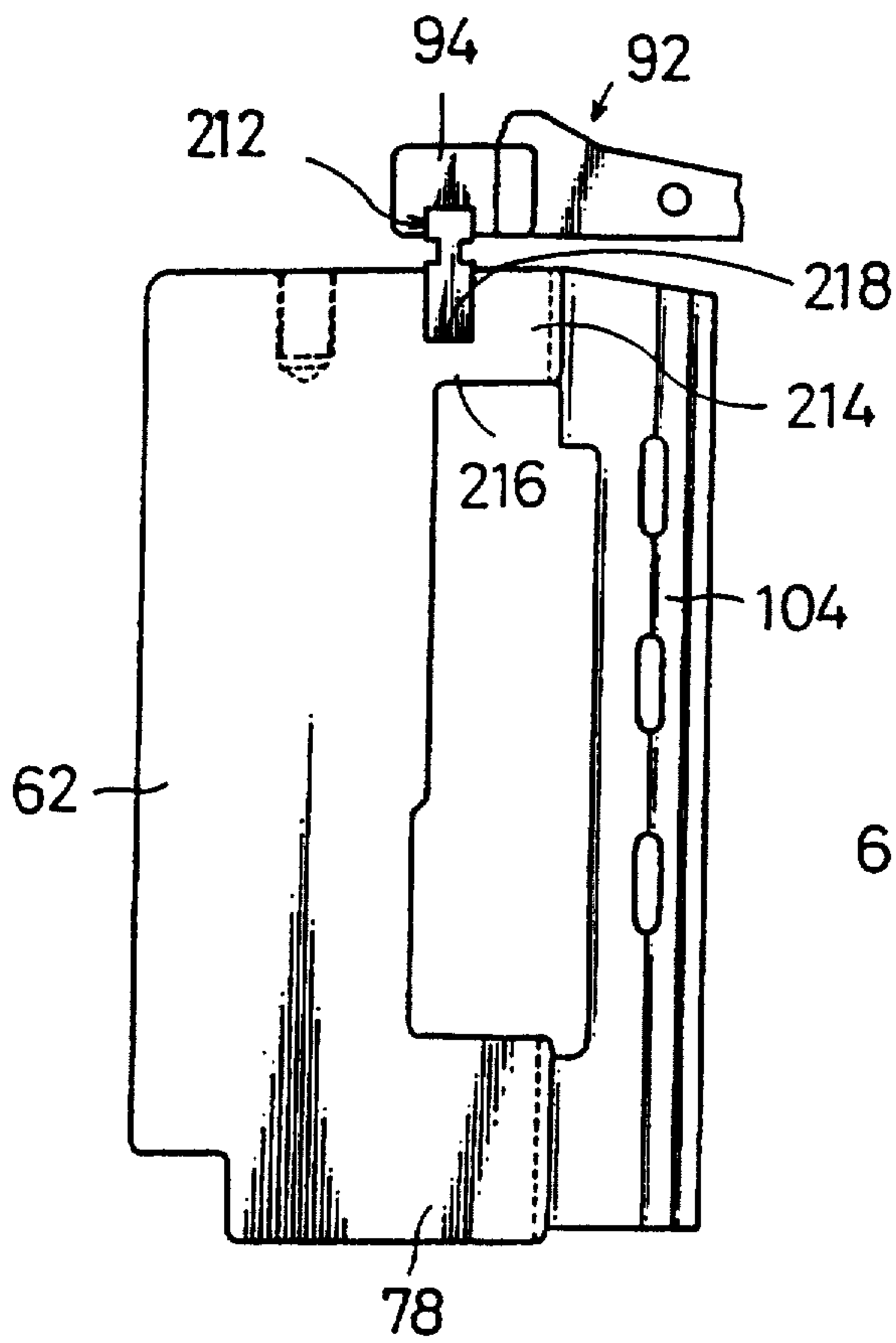
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FIG.27

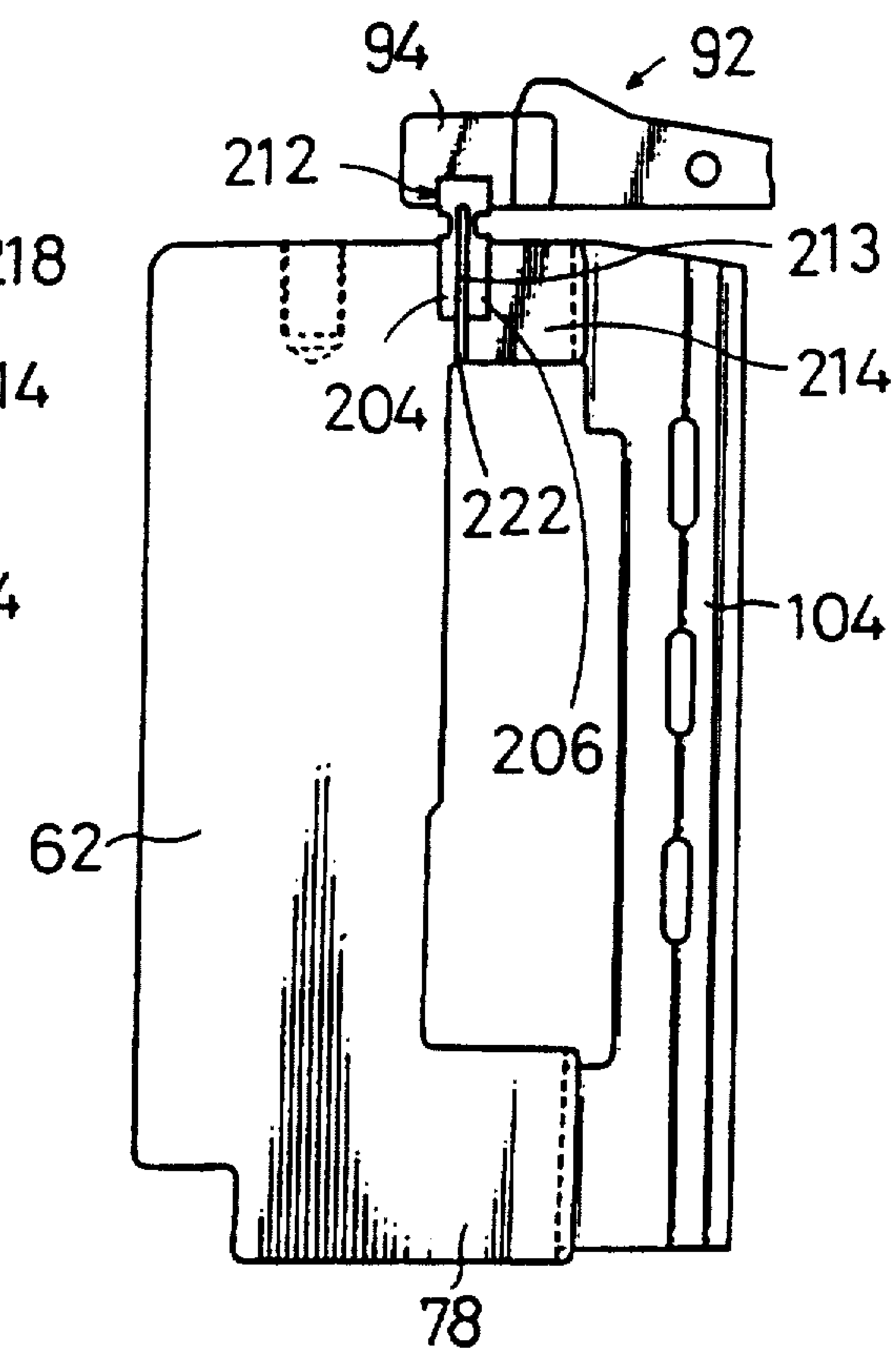
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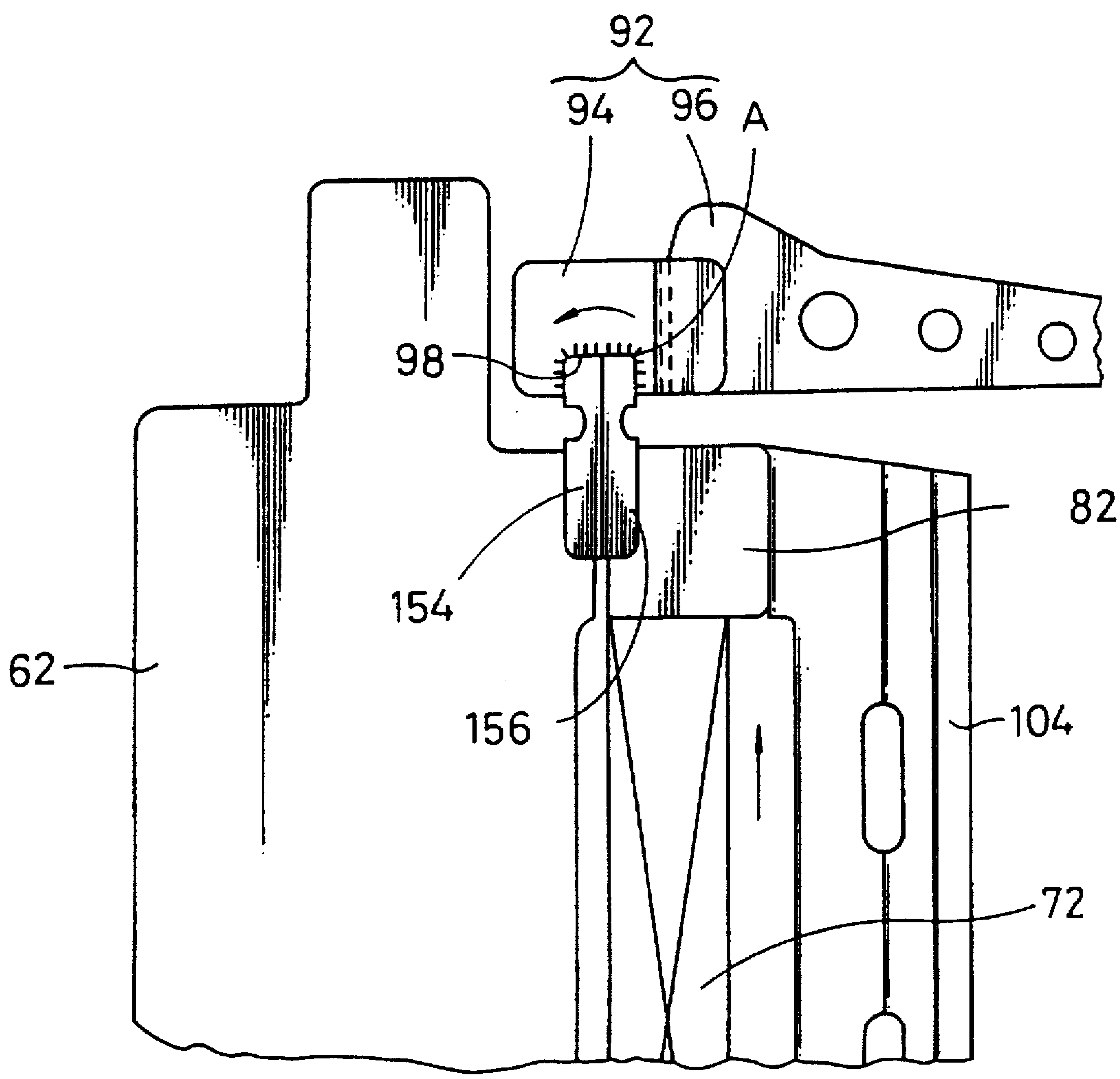
FIG.28



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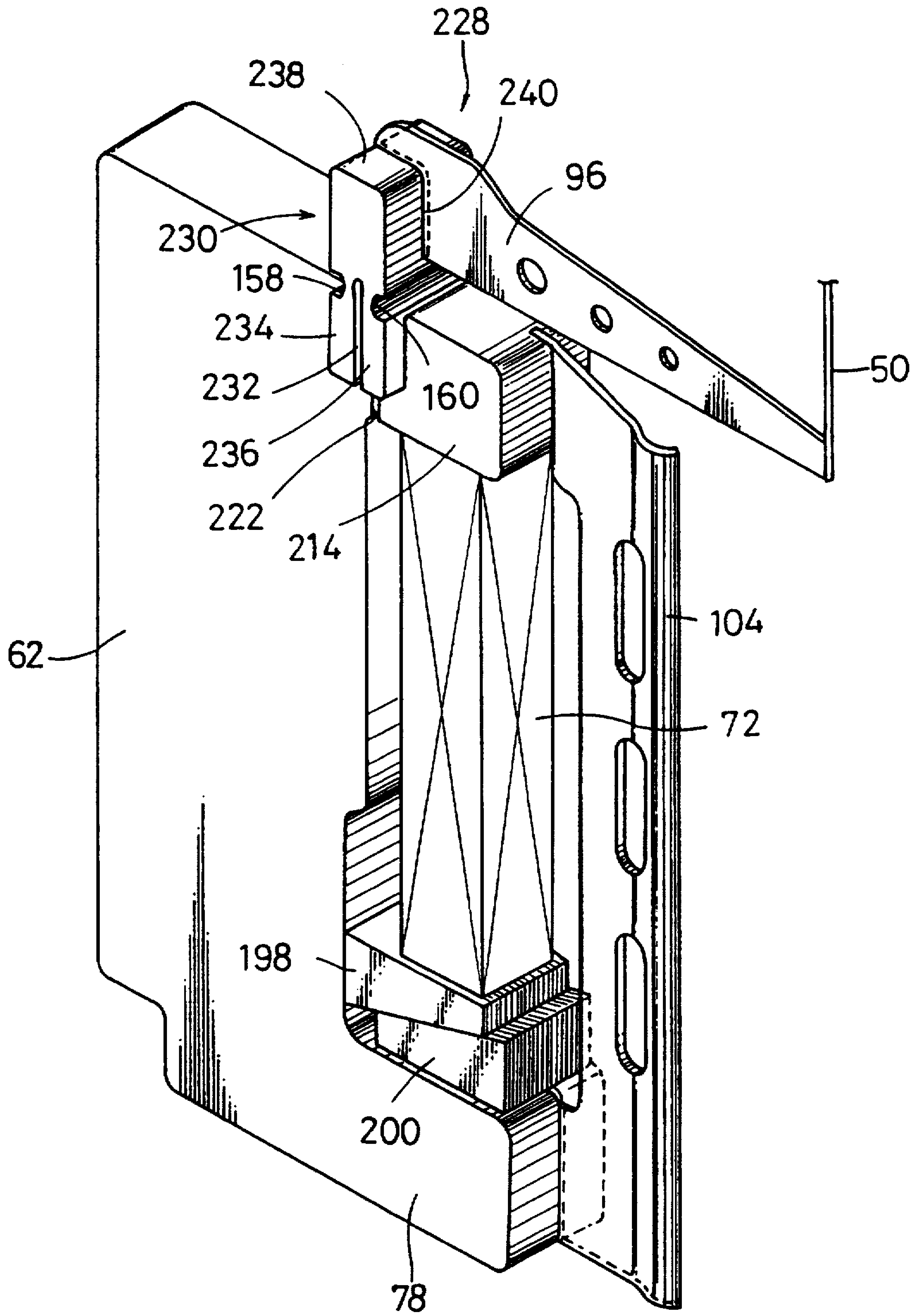
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FIG.30

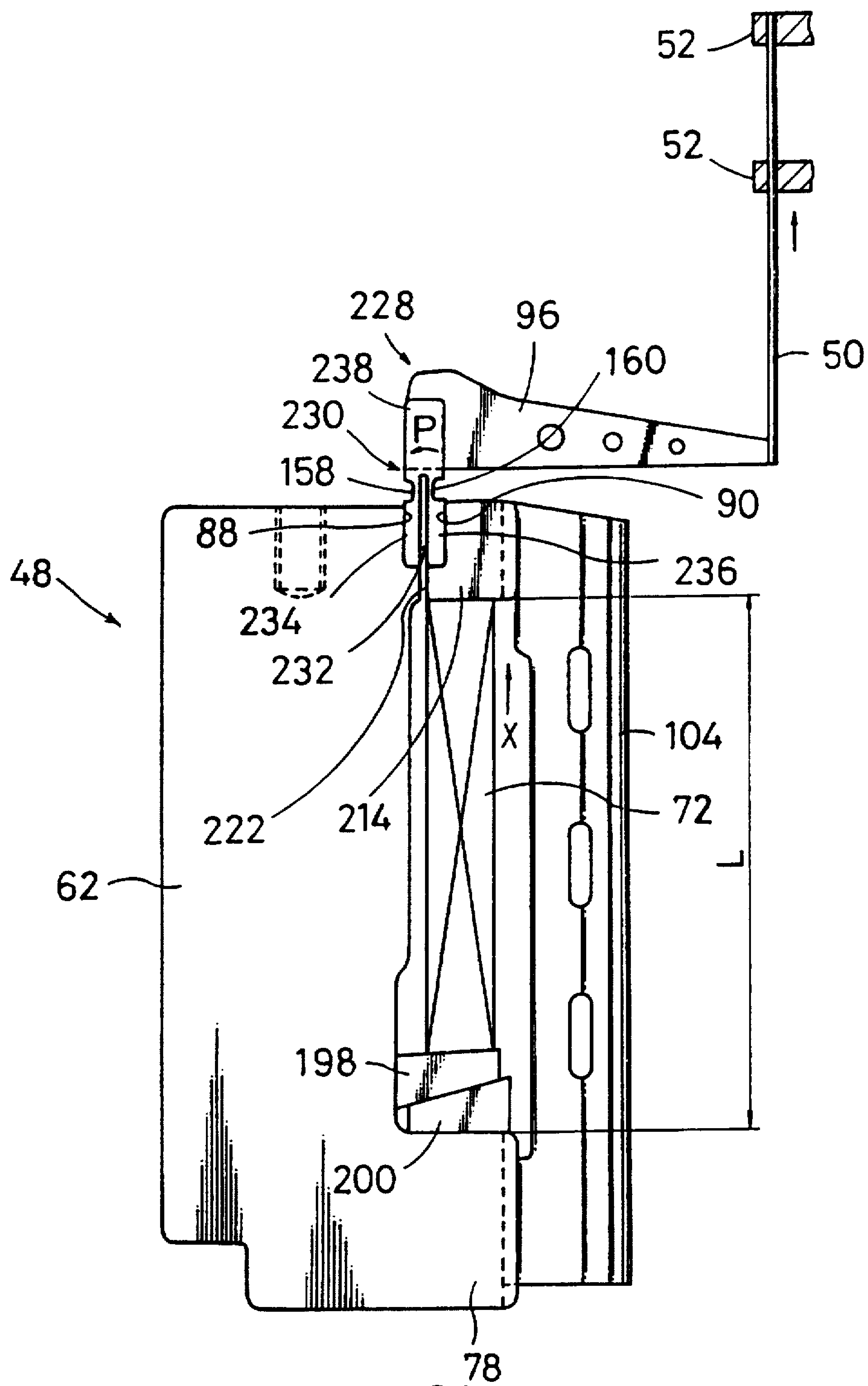
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FIG.31

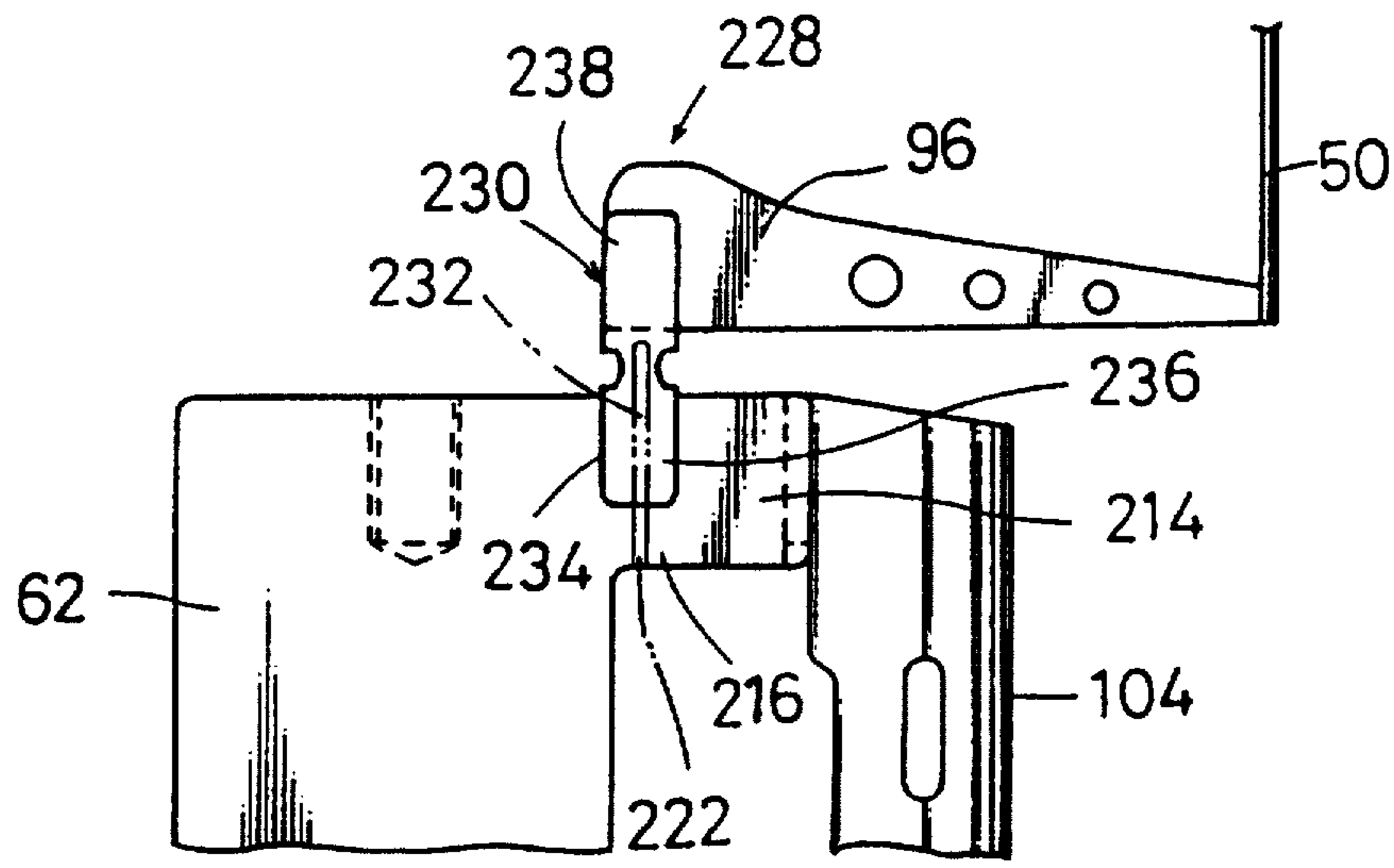

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FIG.32

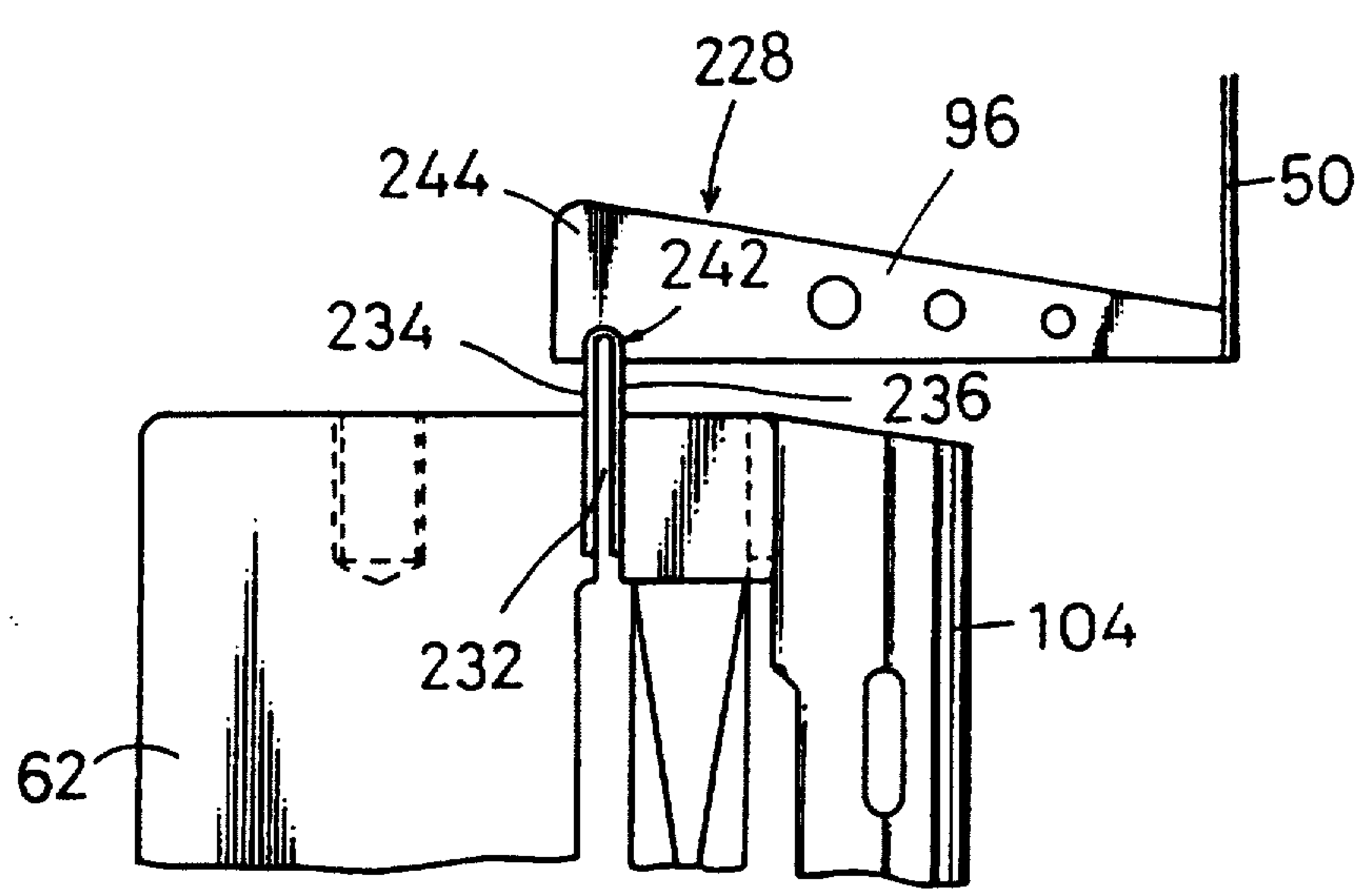

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FIG.33

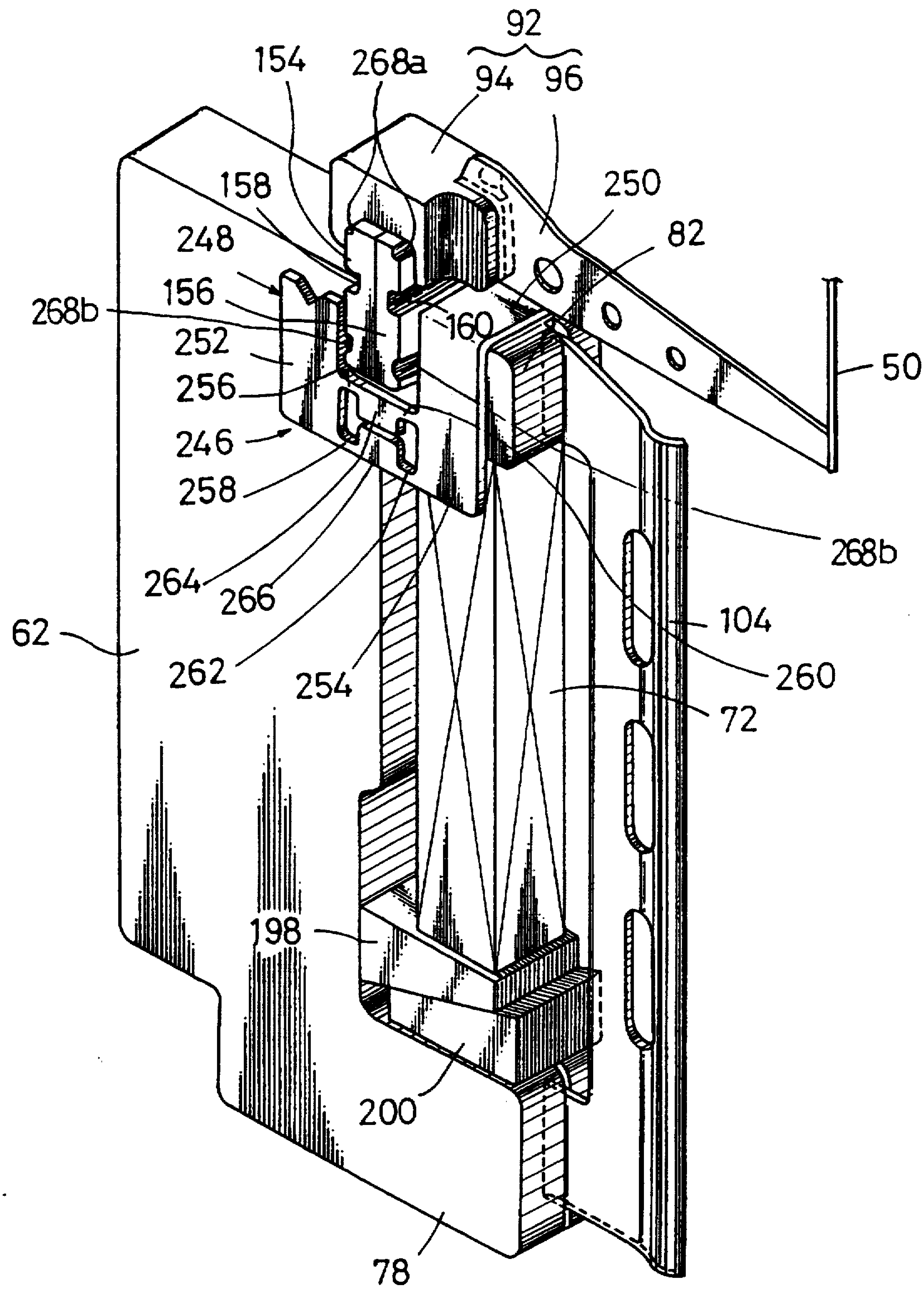
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FIG.34

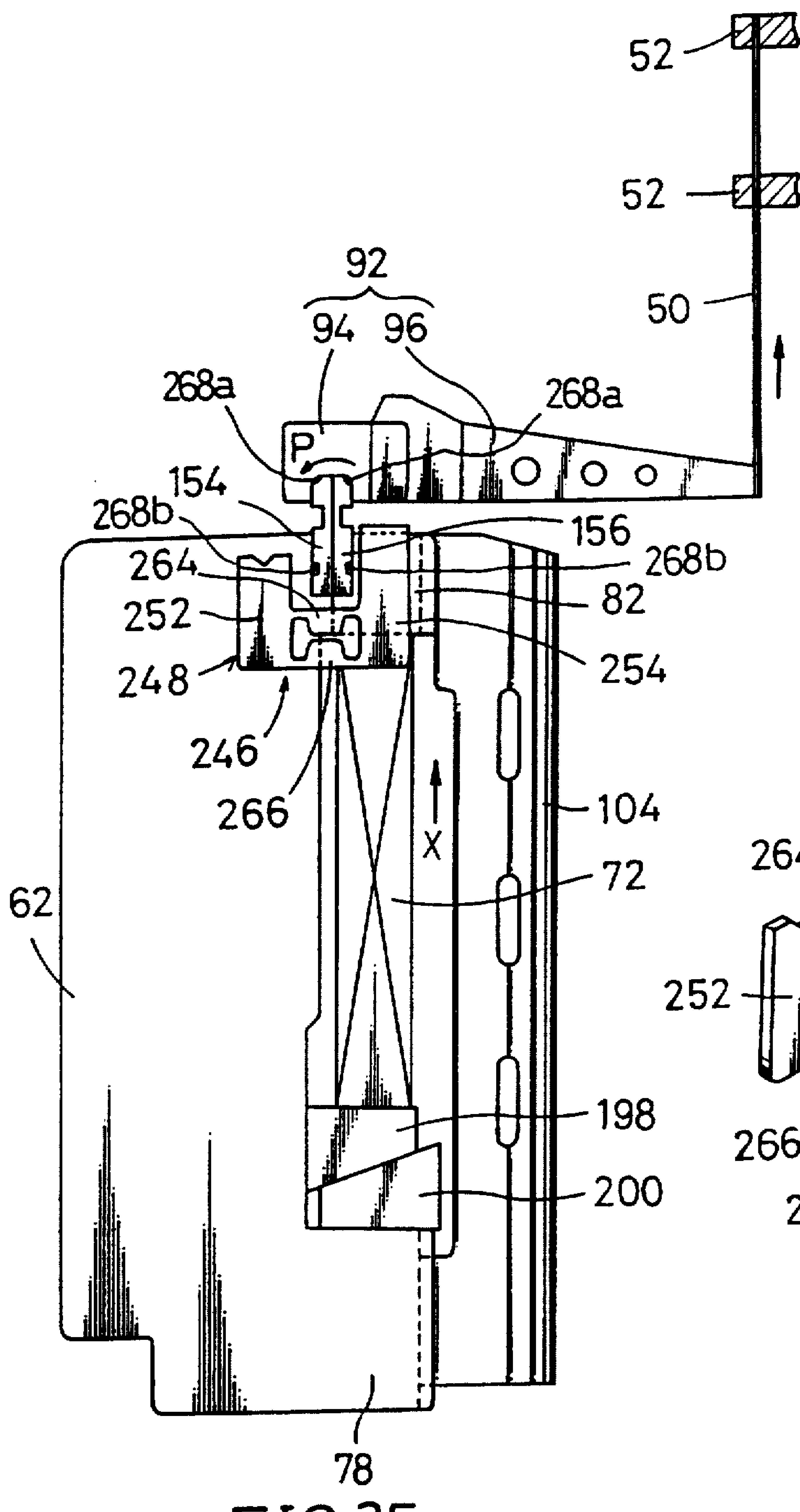
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FIG.35

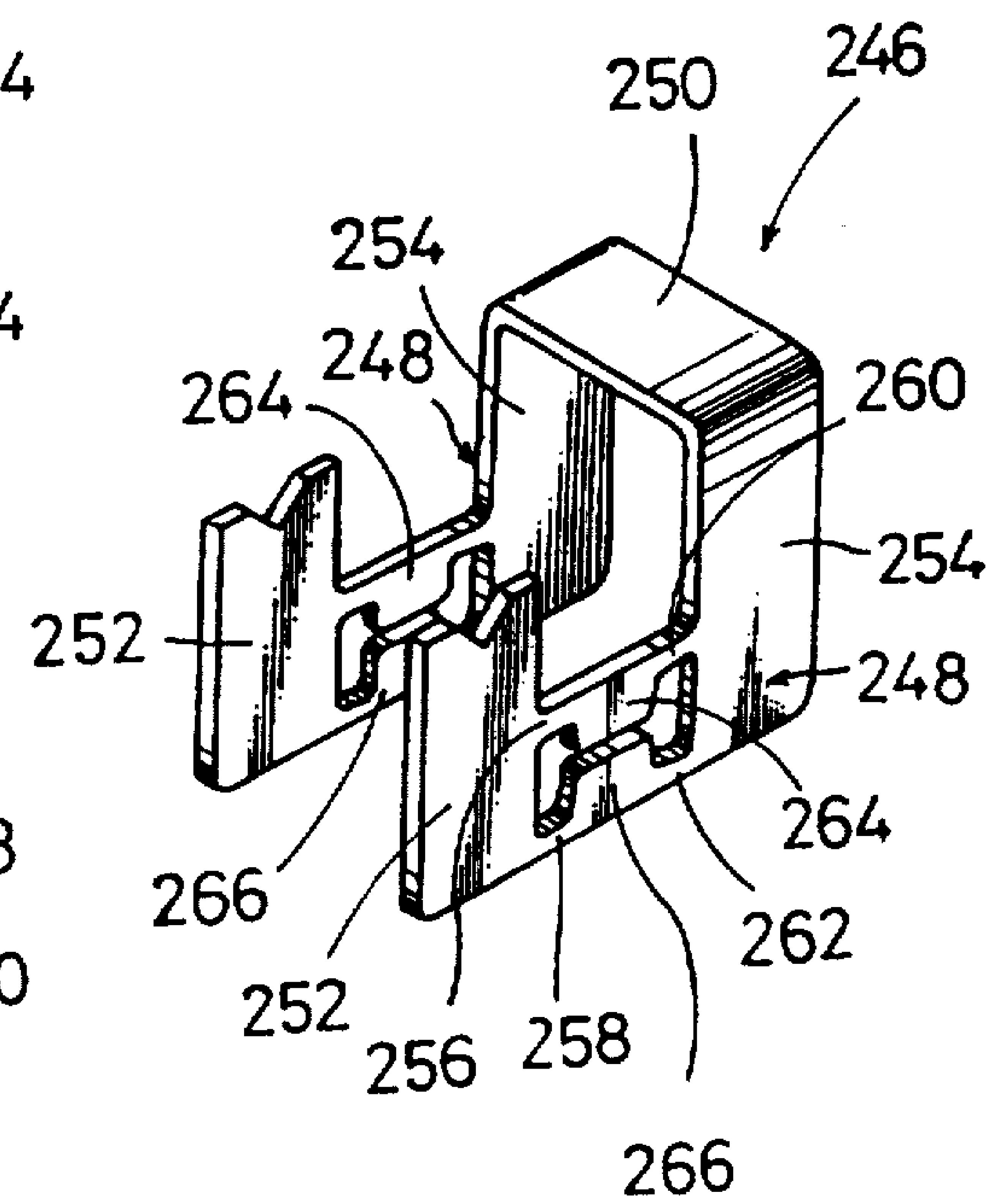
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FIG.36

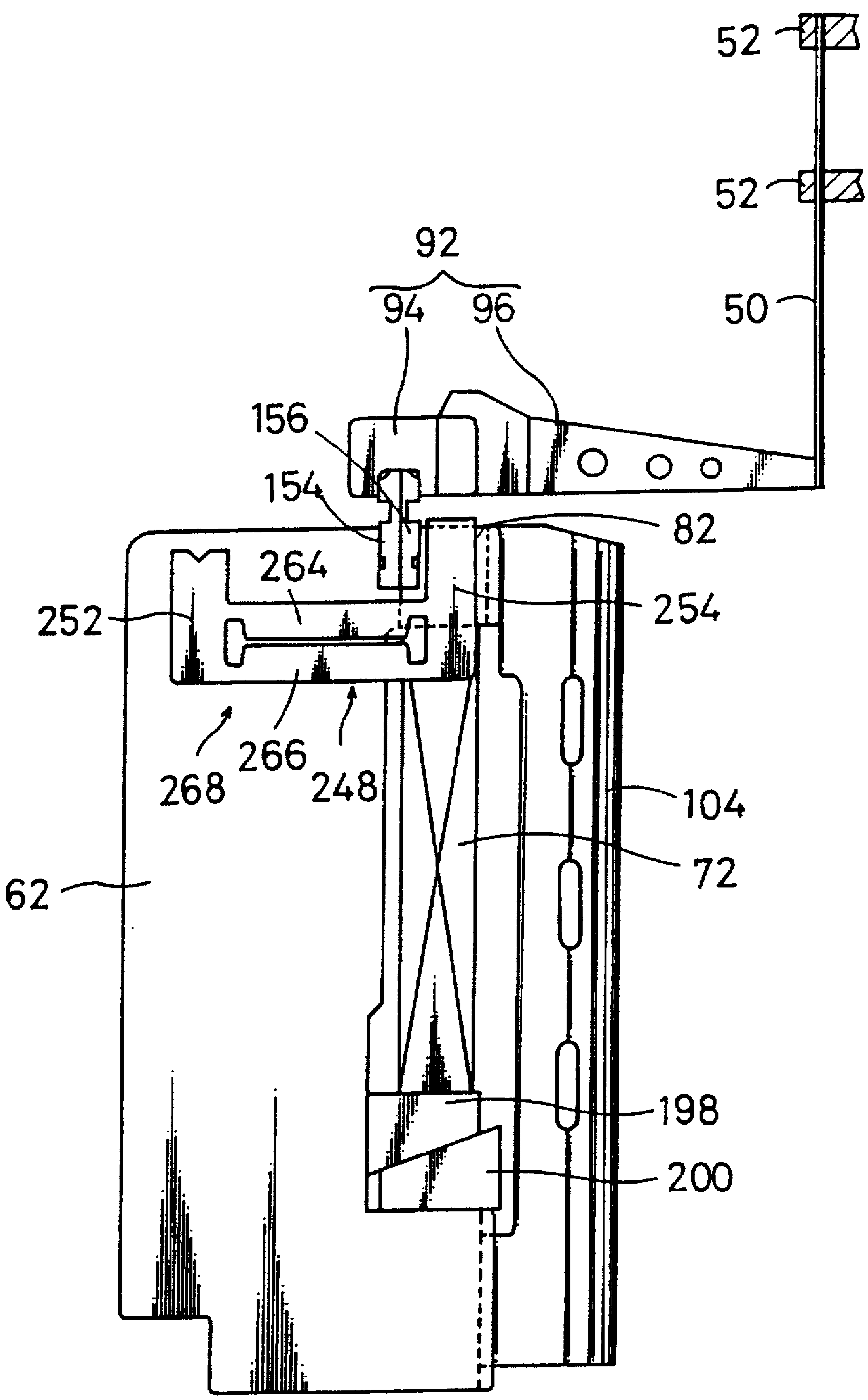
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FIG.37

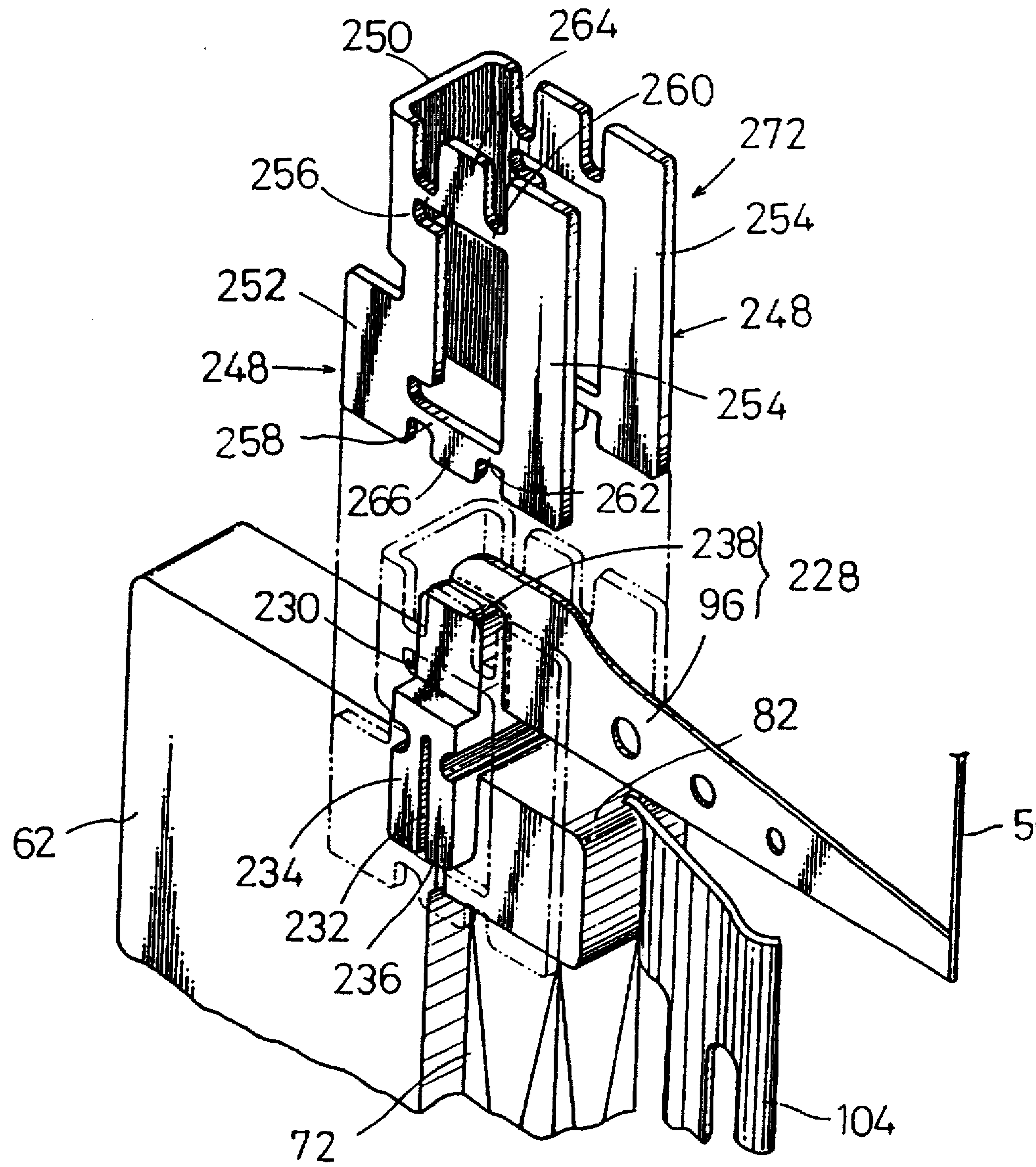
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FIG.38

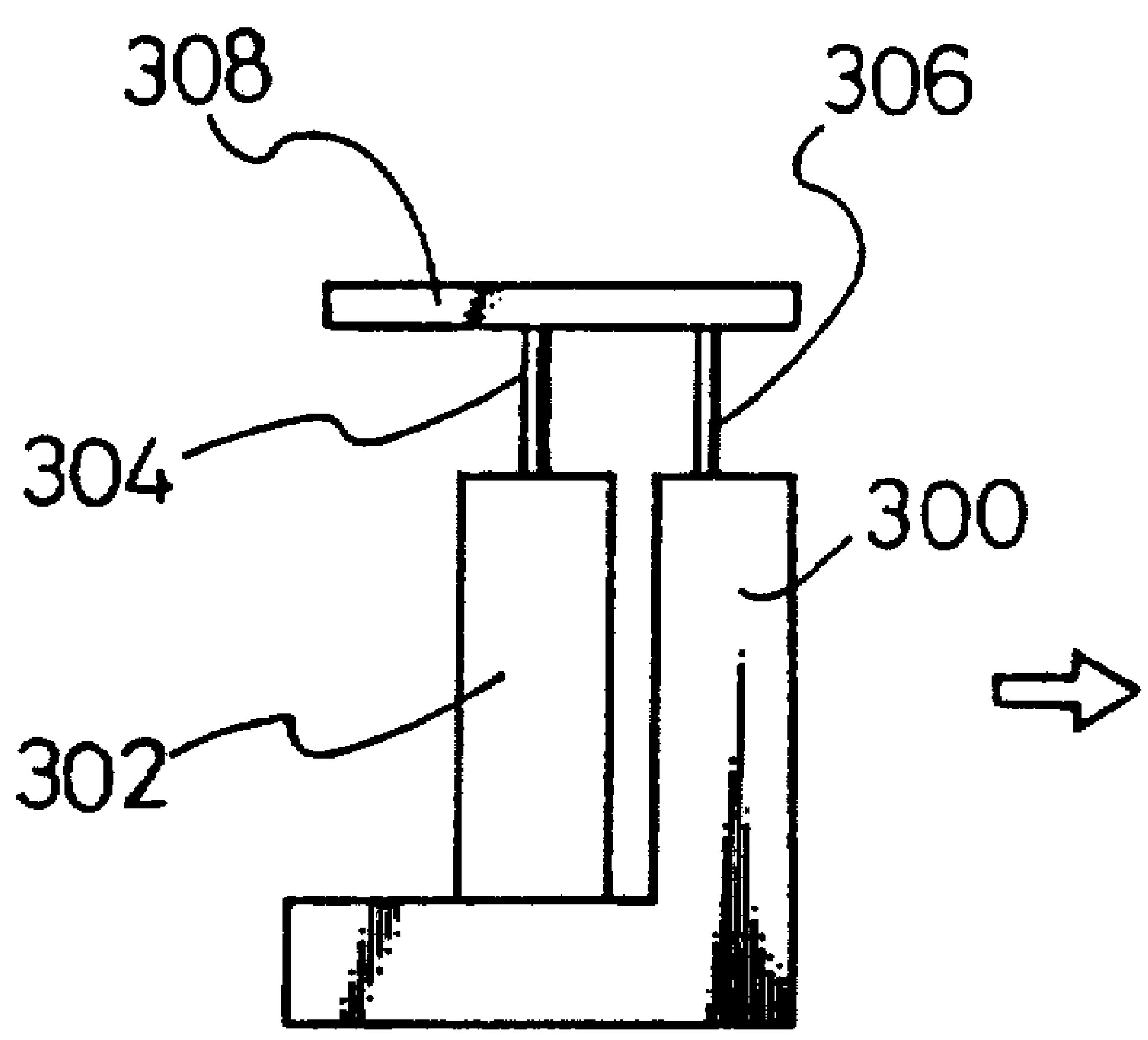

FIG.39(A)
PRIOR ART

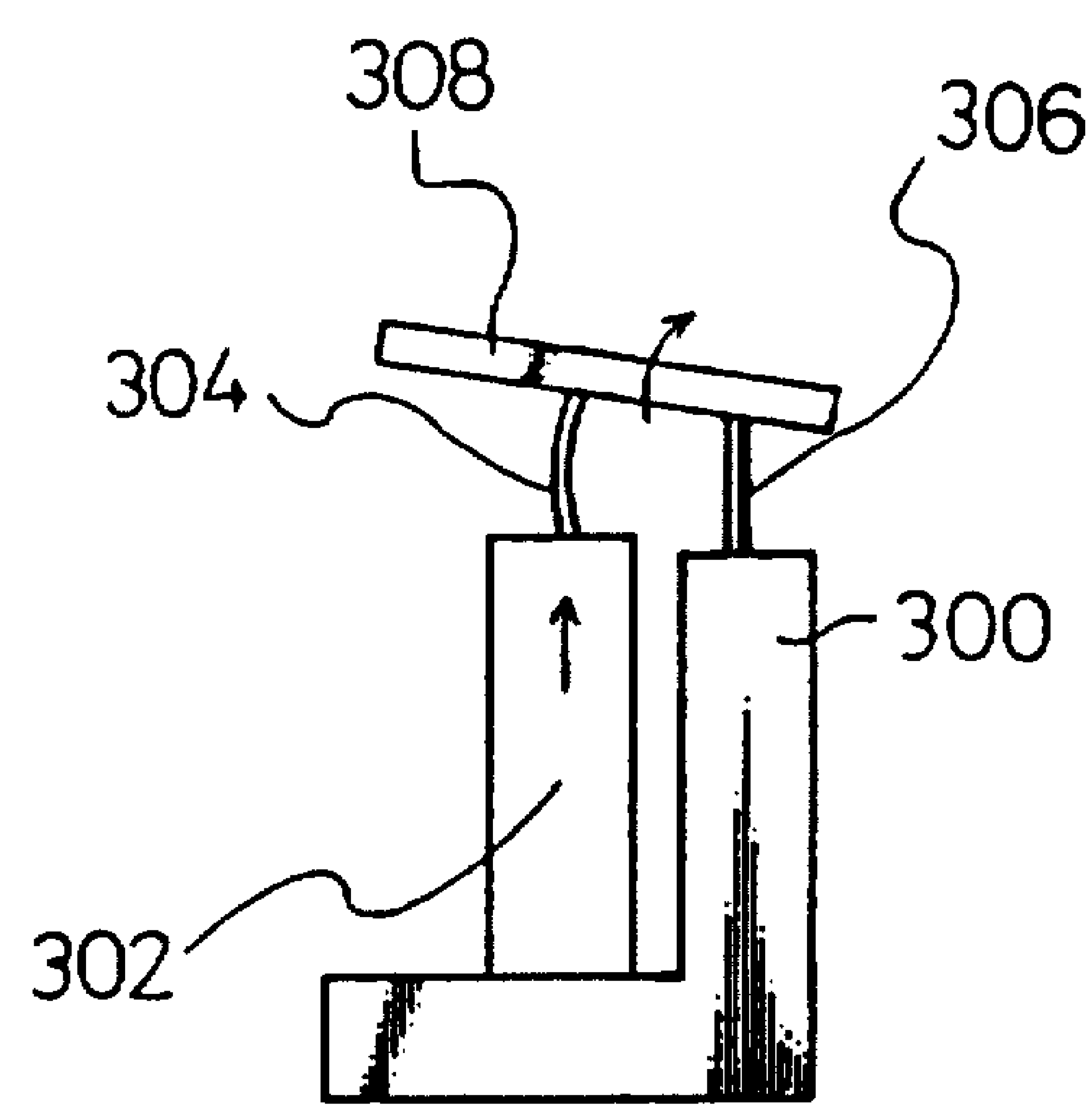

FIG.39(B)
PRIOR ART

DEVICE FOR MAGNIFYING DISPLACEMENT OF PIEZOELECTRIC ELEMENT OR THE LIKE AND METHOD OF PRODUCING SAME

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

The present invention relates to an actuator for driving a printing wire or the like in a printing head, for example, and more particularly to a device for magnifying displacement of a piezoelectric element or the like as a driving source wherein expansion and contraction of the piezoelectric element is magnified through a rolling motion of a rolling member into a relatively large movement of the printing wire to carry out a printing operation of the printing wire. The present invention also relates to a method of producing such a device as mentioned above.

There are various known devices as mentioned above. For example, there is disclosed in Japanese Patent Laid-Open Publication No. 57-187980 a device for magnifying displacement of a piezoelectric element as shown in FIGS. 39(A) and 39(B). Referring to FIGS. 39(A) and 39(B) which show a rest condition and an operative condition of the device, respectively, a piezoelectric element **302** is fixed to a frame **300**, and a rolling member **308** is connected through a pair of leaf springs **304** and **306** spaced a given distance from each other to the piezoelectric element **302** and the frame **300**. As shown in FIG. 39(B), when the piezoelectric element **302** is expanded, the rolling member **308** is rolled about a connecting portion between the same and the leaf spring **306** by the moment generated at a connecting portion of the rolling member **308** and the leaf spring **304**. Thus, the displacement of the piezoelectric element **302** is converted into a rolling motion of the rolling member **308**.

However, such a conventional displacement magnifying device cannot exhibit a large magnification rate of displacement of the piezoelectric element **302** which is to be magnified and transmitted to the rolling member **308**. Accordingly, in the case of driving a printing wire, it is necessary to lengthen the rolling member **308**, so as to obtain a sufficient stroke of the printing wire. Such a large size and an increased mass of the rolling member **308** cause a problem in high-speed operation of the printing wire.

In the case that the displacement magnifying device as shown in FIGS. 39(A) and 39(B) is utilized in a printing head for a wire dot printer (not shown), for example, a printing wire is connected directly to one end of the rolling member **308** or indirectly such as through another member to the one end of the rolling member **308**, thus constructing a printing unit. A plurality of a printing units of the number equal to that of the printing wires are installed in the printing head. Each printing unit includes the piezoelectric element **302**, and lead wires extending from both electrodes of the piezoelectric element **302** are guided to a certain wiring board, and are connected to feeder lines formed on the wiring board by soldering or the like. However, in the connection of the lead wires, they tend to be tangled with each other, making the connecting operation difficult. Further, **[i]** *it* is also difficult to recognize the polarity of the lead wires.

Furthermore, the plurality of printing units are usually located between two parallel base plates, and the frame **300** of each printing unit is fixed to the base plates by a suitable fixing means such as bolts directed parallel to a direction of displacement of the piezoelectric element **302**. However, in fixing the frame **300** to the base plates, the frame **300** is expanded parallel to the direction of displacement of the piezoelectric element **302**. Further, a fixed position of the frame **300** with respect to the direction parallel to the direction of displacement is slipped.

SUMMARY OF THE INVENTION

It is a first object of the present invention to provide a device for magnifying displacement of a piezoelectric element, including a pair of leaf springs displaceable in receipt of displacement of the piezoelectric element, which device may improve a magnification rate of the displacement of the piezoelectric element.

It is a second object of the present invention to provide a device for magnifying displacement of a piezoelectric element, including a pair of leaf springs displaceable in receipt of displacement of the piezoelectric element, which device may reduce friction between the leaf springs and thereby smoothen the displacement of one of the leaf springs relative to the other leaf spring.

It is a third object of the present invention to provide a device for magnifying displacement of a piezoelectric element, including a pair of leaf springs displaceable in receipt of displacement of the piezoelectric element and a rolling member fixed to the leaf springs, which device may reduce stress at a fixed portion between the leaf springs and the rolling member and thereby improve the durability of the fixed portion.

It is a fourth object of the present invention to provide a device for magnifying displacement of a piezoelectric element, including a pair of leaf springs displaceable in receipt of displacement of the piezoelectric element and a rolling member fixed to the leaf springs, which device may improve the durability of a fixed portion between the leaf springs and the rolling member and reduce the number of parts.

It is a fifth object of the present invention to provide a device for magnifying displacement of a piezoelectric element, including a pair of leaf springs displaceable in receipt of displacement of the piezoelectric element and a movable member provided at an end of the piezoelectric element for displacing one of the leaf springs relative to the other leaf spring, which device may prevent inclination of the movable member due to a reaction force from the leaf spring displaced to thereby prevent a reduction in magnification rate of the displacement.

It is a sixth object of the present invention to provide a method of producing a device for magnifying displacement of a piezoelectric element, including a frame, a movable member, a rolling member and a pair of leaf springs assembled with the movable member and the rolling member, which method may improve the accuracy of distance and parallelism between the movable member and a base portion of the frame in installation of the piezoelectric element therebetween.

It is a seventh object of the present invention to provide a device for magnifying displacement of piezoelectric elements to be electrically connected through lead wires to feeder lines, which device may make easy the connection between the lead wires and the feeder lines and prevent the lead wires from being tangled.

It is an eighth object of the present invention to provide an impact dot printing head adapted to be driven by a plurality of printing units including piezoelectric elements and frames which units are fixedly supported between two base plates, which printing head may prevent expansion of the frame in fixing the printing units to the base plates and also prevent slippage of fixed positions of the frames.

According to a first aspect of the present invention, there is provided a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element and mounting the piezoelectric element thereon, a movable member fixed to one end of the piezoelectric element with respect to the direction of displacement, a first mount surface formed on the frame and extending substantially parallel to the direction of displacement, a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, said second mount surface being opposed to the first mount surface, a first leaf spring mounted at its one end portion on the first mount surface and extending substantially parallel to the direction of displacement, a second leaf spring mounted at its one end portion on the second mount surface and extending substantially parallel to the direction of displacement, and a rolling member fixed to the other end portions of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member.

According to a second aspect of the present invention, there is provided a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element and mounting the piezoelectric element thereon, a movable member fixed to one end of the piezoelectric element with respect to the direction of displacement, a first mount surface formed on the frame and extending substantially parallel to the direction of displacement, a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, said second mount surface being opposed to the first mount surface, a first leaf spring mounted at its one end portion on the first mount surface and extending substantially parallel to the direction of displacement, a second leaf spring mounted at its one end portion on the second mount surface and extending substantially parallel to the direction of displacement, and a rolling member fixed to the other end portions of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member, and wherein the first and second leaf springs include respective deformable portions facing to each other, and the deformable portions are formed at their facing surfaces with respective non-contact portions for inhibiting contact between the deformable portions.

According to a third aspect of the present invention, there is provided in a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending along the piezoelectric element and having a base portion for supporting one end of the piezoelectric element with respect to a direction of displacement, a movable member fixed to the other end of the piezoelectric element, a pair of first and second leaf springs each fixed at one end portion to the frame and the movable member, and a rolling member fixed to the other end portion of each of the leaf springs, wherein when the piezoelectric element is displaced, the leaf springs are deformed to roll the rolling member. The leaf springs are formed from a single spring member to define a split groove therein extending from one end of the spring member toward the other end thereof, and the rolling member is integrally connected to the other end of the spring member.

According to a fourth aspect of the present invention, there is provided in a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending along the piezoelectric element and having a base portion for supporting one end of the piezoelectric element with respect to a direction of displacement, a movable member fixed to the other end of the piezoelectric element, a pair of first and second leaf springs each fixed at one end portion to the frame and the movable member, and a rolling member fixed to the other end portion of each of the leaf springs, wherein when the piezoelectric element is displaced, the leaf springs are deformed to roll the rolling member. The first and second leaf springs are formed with a small sectional area portion at a portion except the fixed ends of the leaf springs, said small sectional area portion having a small sectional area in a direction substantially perpendicular to the direction of displacement of the piezoelectric element smaller than a sectional area of the fixed ends.

According to a fifth aspect of the present invention, there is provided a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element and mounting the piezoelectric element on a base portion thereof, a movable member fixed to one end of the piezoelectric element with respect to the direction of displacement, a first mount surface formed on the frame and extending substantially parallel to the direction of displacement, a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, said second mount surface being opposed to the first mount surface, a first leaf spring mounted at one end portion on the first mount surface and extending substantially parallel to the direction of displacement, a second leaf spring mounted at one end portion on the second mount surface and extending substantially parallel to the direction of displacement, and a rolling member fixed to the other end portion of each of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member, said device further comprising an elastically deformable connecting member extending along the piezoelectric element on an opposite side of the frame with respect to the movable member and connecting the movable member with a base portion of the frame, wherein when the piezoelectric element is displaced, the movable member is displaced substantially parallel to the direction of displacement against the elasticity of the connecting member to curve the second leaf spring relative to the first leaf spring and thereby roll the rolling member.

According to a sixth aspect of the present invention, there is provided a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element and mounting the piezoelectric element on a base portion thereof, a movable member fixed to one end of the piezoelectric element with respect to the direction of displacement, a first mount surface formed on the frame and extending substantially parallel to the direction of displacement, a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, said second mount surface being opposed to the first mount surface, a first leaf spring mounted at one end portion on the first mount surface and extending substantially parallel to the direction of displacement, a second leaf spring mounted at one end portion on the second mount surface and extending substantially parallel to the direction of displacement, and a rolling member fixed to the other end portion of each of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member, said device further comprising a four-hinged parallel link mechanism provided between the frame and the movable member for maintaining the parallelism of the movable member to the direction of displacement of the piezoelectric element.

According to a seventh aspect of the present invention, there is provided a method of producing a device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a frame extending substantially parallel to a direction of displacement of the piezoelectric element and mounting the piezoelectric element thereon, a movable member fixed to one end of the piezoelectric element with respect to the direction of displacement, a first mount surface formed on the frame and extending substantially parallel to the direction of displacement, a second mount surface formed on the movable member and extending substantially parallel to the direction of displacement, said second mount surface being opposed to the first mount surface, a first leaf spring mounted at one end portion on the first mount surface and extending substantially parallel to the direction of displacement, a second leaf spring mounted at one end portion on the second mount surface and extending substantially parallel to the direction of displacement, and a rolling member fixed to the other end portion of each of the first and second leaf springs, wherein when the piezoelectric element is displaced, the second leaf spring is displaced along the first leaf spring through the movable member to roll the rolling member, said method comprising a first step of forming the movable member integrally with the frame, through a connecting portion in such a manner as to define a space for inserting therein the piezoelectric element between the movable member and a base portion of the frame, a second step of fixing the leaf springs to the frame and the movable member, and a third step of forming a separation groove in the connecting portion to separate the movable member from the frame.

According to an eighth aspect of the present invention, there is provided an impact dot printing head of a type to be driven by a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a plurality of printing units each having a printing wire for printing dots onto a printing medium, a displacement transmitting mechanism for transmitting displacement of the piezoelectric element to the printing wire, and a frame for supporting the piezoelectric element and the displacement transmitting mechanism, said frame extending in a direction of displacement of the piezoelectric element; a first base plate for fixedly supporting one end of the frame with respect to the direction of displacement of the piezoelectric element; a second base plate for fixedly supporting the other end of the frame with respect to the direction of displacement of the piezoelectric element, said second base plate having a nose portion for supporting the printing wire; a first fixing means for fixing the first base plate to the frame; and a second fixing means for fixing the second base plate to the frame, wherein at least one of the first and second fixing means is so arranged as to intersect the direction of displacement of the piezoelectric element.

According to a ninth aspect of the present invention, there is provided an impact dot printing head of a type to be driven by a piezoelectric element adapted to be displaced by application of voltage thereto, comprising a displacement transmitting mechanism for transmitting displacement of the piezoelectric element to a printing wire for printing dots onto a printing medium; a base plate for supporting the piezoelectric element; a wiring board fixed to the base plate for supporting a feeder line to be electrically connected to a lead wire connected to the piezoelectric element; and a holder having a cylindrical portion to be engaged with an outer periphery of the piezoelectric element and a leg portion extending from one end of the cylindrical portion toward the wiring board, said leg portion having a throughhole for inserting the lead wire.

The invention will be more fully understood from the following detailed description and appended claims when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view of a preferred embodiment of the printing head according to the present invention;

FIG. 2 is a side view as viewed from the arrow II in FIG. 1.

FIG. 3 is a perspective view of a printing unit installed in the printing head shown in FIG. 1;

FIG. 4 is an elevational view in partial section of the printing unit shown in FIG. 3;

FIG. 5 is a plan view of FIG. 3;

FIG. 6 is a perspective view of a modification of the printing unit;

FIG. 7 is an enlarged elevational view of the essential part of the printing unit shown in FIG. 3;

FIG. 8 is a perspective view of one of the leaf springs shown in FIG. 7;

FIG. 9 is a perspective view of a modification of the printing unit;

FIG. 10 is an elevational view of FIG. 9;

FIG. 11 is a perspective view of the leaf springs shown in FIG. 9;

FIG. 12 is an elevational view of FIG. 11;

FIG. 13 is an elevational view of a modification of FIG. 12;

FIG. 14 is an elevational view of another modification of FIG. 12;

FIG. 15 is an exploded perspective view of a further modification of FIG. 12;

FIG. 16 is a perspective view of a modification of the printing unit;

FIG. 17 is an elevational view of FIG. 16;

FIG. 18 is a perspective view of the leaf springs shown in FIG. 16;

FIG. 19 is an elevational view of FIG. 18;

FIG. 20 is a perspective view of a modification of FIG. 18;

FIG. 21 is a perspective view of another modification of FIG. 18;

FIG. 22 is a perspective view of a further modification of FIG. 18;

FIGS. 23 to 26 are elevational views of the printing unit, illustrating each step of the producing method according to the present invention;

FIGS. 27 and 28 are elevational views similar to FIGS. 23 to 26, illustrating each step of a modification of the producing method according to the present invention;

FIG. 29 is a partial elevational view of the essential part of FIG. 10;

FIG. 30 is a perspective view of a modification of the printing unit;

FIG. 31 is an elevational view of FIG. 30;

FIG. 32 is a partial elevational view of FIG. 31;

FIG. 33 is a partial elevational view of a modification of FIG. 31;

FIG. 34 is a perspective view of a modification of the printing unit;

FIG. 35 is an elevational view of FIG. 34;

FIG. 36 is a perspective view of the parallel link mechanism shown in FIG. 34;

FIG. 37 is an elevational view of a modification of FIG. 34;

FIG. 38 is an exploded perspective view of the essential part of another modification of FIG. 34;

FIG. 39(A) is a schematic elevational view of the conventional device for magnifying displacement of a piezoelectric element, illustrating an inoperative condition; and

FIG. 39(B) is a view similar to FIG. 39(A), illustrating an operative condition.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

There will now be described some preferred embodiments of the present invention with reference to the drawings.

Referring to FIGS. 1 and 2 which show a printing head in vertical section and side, respectively, a head body 40 primarily consists of first and second substantially rectangular base plates 42 and 44 opposed to each other at a predetermined distance, and four posts 46 connecting the base plates 42 and 44 at the four corners thereof.

A plurality of (twenty four, for example) printing units 48 are provided between the first and second base plates 42 and 44 in such a manner as to be arranged on a circle concentric with a common center line of both the base plates 42 and 44.

The second base plate 44 is formed with a substantially circular plate portion 49 disposed along the printing units 48, and with a hollow nose portion 54 extending outward from the plate portion 49. The nose portion 54 includes a plurality of guide plates 52 for guiding the movement of each printing wire 50 connected to each printing unit 48. A support member 56 is provided on the inner surface of the second base plate 44 to position and support each printing unit 48. The support member 56 primarily consists of a circular support plate 58 disposed along the inner surface of the second base plate 44 and a plurality of partition walls 60 radially extending inward from the support plate 58 in such a manner that each partition wall 60 is interposed between the adjacent printing units 48. The partition walls 60 are integrally formed with a support ring 64 for supporting the outer surface of each frame 62 of the printing units 48. The support plate 58 is formed at its central portion with a central hole 66 which communicated with the axial hole of the nose portion 54. A plurality of guide pins 70 project from the inner surface of the support plate 58 in such a manner as to be arranged around the central hole 66, for guiding each wire driving arm 96 of the printing units 48.

Referring to FIGS. 3, 4 and 5, each printing unit 48 includes a piezoelectric element 72, *one type of electro-distortion element,* adapted to be expanded and contracted by the application of voltage thereto and a displacement transmitting mechanism 74 adapted to magnify the expansion and contraction of the piezoelectric element 72 and transmit such a magnified displacement to the printing wire 50. The piezoelectric element 72 and the displacement transmitting mechanism 74 are supported by the frame 62.

The frame 62 is formed of a metal plate having a predetermined thickness and an elongated shape in such a manner as to extend substantially parallel to the displacement direction of the piezoelectric element 72. The frame 62 is formed at its lower end with a laterally extending base portion 78 for supporting one end of the piezoelectric element 72 through a temperature compensation member 76.

The piezoelectric element 72 is formed by a stack of piezoelectric ceramics adapted to be expanded and contracted in the direction of the stack (in the longitudinal direction of the piezoelectric element 72). The temperature compensation member 76 is fixed to one end surface of the piezoelectric element 72 by an adhesive or the like. The piezoelectric element 72 is supported through the temperature compensation member 76 on a support surface 80 of the support portion 78.

A rectangular movable member 82 is fixed to the other end surface of the piezoelectric element 72 by an adhesive or the like. The movable member 82 has a side surface opposed to an upper side surface of the frame 62 with a given spacing defined therebetween. The given spacing is filled with a pair of first and second leaf springs 84 and 86, *which are elastic, resilient members,* to be fixed to spring mounting surfaces 88 and 90 of the frame 62 and the movable member 82, respectively. The spring mounting surfaces 88 and 90 are flat surfaces extending substantially parallel to the displacement direction of the piezoelectric element 72. The spring mount surface 90 of the movable member 82 is located at an end surface of the movable member 82 offset from a center line of the piezoelectric element 72 to the frame 62.

The first leaf spring 84 has a side surface *or connecting portion* entirely fixed by brazing or the like to the spring mounting surface 88 of the frame 62, while the second leaf spring **86** has a side surface *or connecting portion* entirely fixed by brazing or the like to the spring mounting surface **90** of the movable member **82**. The second leaf spring **86** is movable relative to the first leaf spring **84** under the condition where the opposed surfaces of both the leaf springs **84** and **86** are in contact.

The first and second leaf springs **84** and **86** extend upward by a given length from the upper ends of the spring mounting surfaces **88** and **90** along the displacement direction of the piezoelectric element **72**. A rolling member **92** is fixed to the upper ends of the first and second leaf springs **84** and **86**. The rolling member **92** primarily consists of a base member **94** having a high rigidity and a lightweight wire driving arm **96** connected to the base member **94**.

The base member **94** of the rolling member **92** is formed at its lower surface with a horizontal recess **98** for receiving the upper ends of the first and second leaf springs **84** and **86**. The surfaces (back surfaces) opposite the facing surfaces of the leaf springs **84** and **86** are fixed by brazing to the inner surface of the recess **98**. The base member **94** is further formed at its front surface with a vertical recess **100** for receiving the base portion of the wire driving arm **96**. The base portion is fixed in the vertical recess **100** by brazing. The printing wire **50** is fixed at its one end to the front end of the wire driving arm **96** by brazing.

In order to move the movable member **82** parallel to the displacement direction of the piezoelectric element **72**, there is provided an elastically deformable *restricting or* connection member **104** between the frame **62** and the movable member **82**. The connection member **104** extends vertically along the displacement direction of the piezoelectric element **72** on the opposite side of the frame **62** with respect to the piezoelectric element **72**. A lower end portion of the connection member **104** is fixed to an end surface of the base portion **78** of the frame **62** *which functions as a connection part*, while an upper end portion of the connection member **104** is fixed to a front end surface of the movable member **82** *or connection part* on the opposite side of the second leaf spring **86**.

The connection member **104** is formed of a thin-walled planar material having a width in a plane parallel to the side surface of the frame **62**. This arrangement [,] of the connection member **104** contributes to ensuring a high rigidity of the connection member **104** in a rolling direction of the movable member **82** rolled by a reaction force of the leaf spring **86**. Further, an elastic force of the connecting member **104** is set so that the moving force of the movable member **82** due to the expansion of the piezoelectric element **72** may be applied substantially uniformly to the leaf spring **86** and the connection member **104**. That is, the elastic force of the connection member **104** is set to be smaller than that of the leaf spring **86**. For example, the ratio of the elastic forces of the connection member **104** and the leaf spring **86** is set to be about 1:1.5 under the unoperational condition of the piezoelectric element **72**. This is due to the fact that when the leaf spring **86** is curved by the upward movement of the movable member **82**, a substantially vertical component (a component in the displacement direction of the piezoelectric element **72**) of the elastic force of the leaf spring **86** is required to be equal to the elastic force of the connection member **104** under the operational condition. Therefore, the elastic force of the connection member **104** is set to be smaller than that of the leaf spring **86**. If the elastic force of the connection member **104** is greater than that of the leaf spring **86** under the operational condition of the piezoelectric element **72**, the movable member generates a clockwise moment to hinder smooth vertical motion of the movable member **82** and also badly affect smooth expansion of the piezoelectric element **72**. Thus, the provision of the connection member **104** contributes to substantially prevent the inclination of the movable member **82**.

A back stopper **106** formed of low elastic rubber is fixed at an upper end of the connection member **104**, so that when the rolling member **92** is rolled and returned, the lower edge of the wire driving arm **96** abuts against the upper surface of the back stopper **106**. The back stopper **106** is formed with a recess **108** for receiving the upper end portion of the connection member **104**, and is further formed with a side hole **110** for filling an adhesive therethrough into the recess **108**. Thus, the back stopper **106** is fixed to the connection member **104** by the adhesive.

The temperature compensation member **76** bonded to the lower surface of the piezoelectric element **72** functions to compensate the expansion or contraction of the piezoelectric element **72** due to a peripheral temperature change and thereby maintain constant the height from the support surface **80** of the base portion **78** of the frame **62** to the upper end of the piezoelectric element **72**.

A thrust pin **112** is fitted into the base portion **78** for supporting the lower surface of the temperature compensation member **76**, and is then fixed integrally with the base portion **78** by means of beam welding. The thrust pin **112** operates to slightly upwardly thrust the lower surface of the temperature compensation member **76** on the support surface **80**, thereby applying the spring forces of the connection member **104** and the second leaf spring **86** to the piezoelectric element **72** at all times.

Lead wires **114** and **116** each connected at respective ends to both electrodes of the piezoelectric element **72** of each printing unit **48**, and are welded at their respective opposite ends to by welding feeder lines **122** by welding. The feeder lines **122** are supported on a wiring plate **120** formed of an electrical insulator material. The wiring plate **120** is fixed to the outer surface of the first base plate **42**. The lead wires **114** and **116** are supported on a holder **118** formed of an electrical insulator material.

Each holder **118** is primarily composed of a rectangular cylindrical portion **124** surroundingly engaged with the outer periphery of the piezoelectric element **72** and a leg portion **128** extending from one side of the cylindrical portion **124** through a hole **126** formed through the first base plate **42** to the inner surface of the wiring plate **120**. The leg portion **128** of the holder **118** is formed on one side surface with a pair of guide channels **130** and **132** for guiding and supporting the lead wires **114** and **116** led out from both the electrodes of the piezoelectric element **72** toward the wiring plate **120**. The leg portion **128** is further formed at its lower end with a projection **134** projecting from the one side surface of the leg portion **128**. The projection **134** has a pair of guide holes **136** and **138** coaxially [communication] *communicating* with the guide channels **130** and **132**. The wiring plate **120** also has a pair of guide holes **140** and **142** coaxially communicating with the guide holes **136** and **138** of the projection **134**. Thus, the lead wires **114** and **116** guided by the guide channels **130** and **132** pass through the guide holes **136** and **138** of the projection 134 and the guide holes 140 and 142 of the wiring plate 120. Then, the lead wires 114 and 116 from the guide holes 140 and 142 are connected by soldering to the feeder lines 122.

The rectangular cylindrical portion 124 is formed at its lower end on the opposite side of the leg portion 128 with a downward projection 143 bonded at its lower end to the temperature compensation member 76, so as to support the cylindrical portion 124. The cylindrical portion 124 is loosely fitted around the piezoelectric element 72 so as not to hinder the expansion and contraction of the piezoelectric element 72. The feeder lines 122 on the wiring plate 120 are supplied with a signal corresponding to print data from a control circuit.

Referring back to FIG. 1, the inner surface of the first base plate 42 is defined as a reference surface F, and one end surface of the frame 62 of each printing unit 48 is brought into abutment against the reference surface F. Then, a tightening screw 144 is threadly inserted from the outer surface of the first base plate 42 in a direction parallel to the displacement direction of the piezoelectric element 72 into one end portion of the frame 62, thus fixing the one end portion of the frame 62 to the first base plate 42.

The circular plate portion 49 of the second base plate 44 is formed at its outer periphery on the inner surface thereof with a plurality of mounting projections 148 projecting inwardly perpendicularly therefrom. Each projection 148 has a hole 150 elongated in a direction parallel to the displacement direction of the piezoelectric element 72. A tightening screw 146 is inserted through each hole 150 of the projection 148 in a direction instersecting the displacement direction, preferably in a direction perpendicular thereto, and is threaded into a mounting projection 152 projecting outwardly from the other end surface of the frame 62, thus fixing the other end portion of the first base plate 44.

In this preferred embodiment, the support posts 46 of the head body 40, the frames 62 and the connection members 104 of the printing units 48 are formed of a material having the same coefficient of linear thermal expansion, so as to cope with a temperature change.

In operation, when a print data signal is outputted from the control circuit to each printing unit 48 to apply voltage across both the electrodes of the piezoelectric element 72, the piezoelectric element 72 is expanded by a fixed length in the direction of stack of the ceramics, namely, in the direction of arrow X shown in FIG. 4 to thereby lift the movable member 82. As a result, the second leaf spring 86 receives the moving force of the movable member 82, and is accordingly lifted along the first leaf spring 84. At this moment, the second leaf spring 86 is elastically deformed to be curved between the movable member 82 and the base portion 94 of the rolling member 92. Such an elastic deformation of the second leaf spring 86 generates a moment in the direction of arrow P shown in FIG. 4. As a result, the first leaf spring 84 is slightly elastically deformed, and simultaneously the rolling member 92 is rolled, so that the printing wire 50 connected at the tip of the rolling member 92 is driven to advance as being guided by the guide plates 52. Accordingly, an end of the printing wire 50 is forced against a printing ribbon (not shown), thus carrying out printing. In this preferred embodiment, the opposed surfaces of the first and second leaf springs 84 and 86 contact with each other. As compared with the case that the first and second leaf springs 84 and 86 were spaced a certain distance from each other, the preferred embodiment can provide a greater magnification of expansion of the piezoelectric element 72 owing to the above arrangement of the leaf springs 84 and 86. Accordingly, a requisite stroke of the printing wire 50 can be sufficiently provided.

When the voltage applied to the piezoelectric element 72 is cut off, the piezoelectric element 72 under the expanded condition is returned to its original condition. Then, the movable member 82, the leaf springs 84 and 86 and the rolling member 92 are all returned to their original condition, thus retracting the printing wire 50 to its original position.

As mentioned above, the flat surfaces of the first and second leaf springs 84 and 86 are fixed by brazing or the like to the flat spring mounting surfaces 88 and 90 of the frame 62 and the movable member 82. Therefore, large fixing areas between the frame 62 and the first leaf spring 84 and between the movable member 82 and the second leaf spring 86 may be provided to thereby ensure a strong and stable fixed condition. Furthermore, as the volumes of the frame 62 and the movable member 82 are large, these members may be of large rigidity.

Further, the base portion 94 of the rolling member 92 as fixed to the respective end portions of the first and second leaf springs 84 and 86 has a width substantially the same as that of the leaf springs 84 and 86, and has a large volume, so that the base portion 94 may also be of large rigidity. Owing to the large rigidity of the frame 62, the movable member 82 and the base portion 94 of the rolling member 92, the leaf springs 84 and 86 are deformed at a limited portion among the frame 62, the movable member 82 and the base portion 94, thereby suppressing a reduction in displacement magnification rate. Moreover, excess vibration of the leaf springs 84 and 86, the frame 62, the movable member 82 and the base portion 94 may be eliminated to thereby reduce the time until stoppage of the rolling member 92 including the wire supporting arm 96, that is, to increase a natural frequency of the whole movable element including the rolling member 92, the leaf springs 84 and 86, etc. As a result, a high-speed operation of the rolling member 92 may be achieved.

Furthermore, in this preferred embodiment, as the end surface of the base portion 78 of the frame 62 and the end surface of the movable member 82 opposite the second leaf spring 86 are connected to each other by means of the elastically deformable connection member 104, the moving force of the movable member 82 generated by the expansion of the piezoelectric element 72 is substantially uniformly received by the second leaf spring 86 and the connection member 104. Accordingly, the movable member 82 may be moved in a direction parallel to the displacement direction of the piezoelectric element 72, thereby preventing the generation of a bending moment in the piezoelectric element 72. Therefore, in spite of the fact that the piezoelectric element 72 is formed of piezoelectric ceramics which are less resistant against a bending stress, the piezoelectric element 72 may be prevented from being damaged to thereby improve the durability.

In installing each printing unit 48 into the head body 40, the printing unit 48 is first inserted into the adjacent partition walls 60 of the supporting member 56 on the second base plate 44, and is then temporarily mounted at one end to the second base plate 44 by means of the tightening screw 146. Then, the first base plate 42 is mounted to the printing unit 48 in such a manner that the other end of the frame 62 abuts against the reference surface F of the first base plate **42**, and is fixed to the printing unit **48** by tightening the screw **144** in a direction parallel to the displacement direction of the piezoelectric element **72**. Thereafter, the screw **146** is tightened in a direction perpendicular to the displacement direction of the piezoelectric element **72** to fix the frame **62** at the mounting portion **152** to the second base plate **44**. Thus, the frame **62** of each printing unit **48** is fixed at both ends to the first and second base plates **42** and **44**. As compared with devices in which tightening means (bolts or screws) are tightened in a direction parallel to the displacement direction of the piezoelectric element **72** to fix the frame **62** to the first and second base plates **42** and **44**, this preferred embodiment may reduce the dispersion in mounting position of the frame **62** with respect to the displacement direction of the piezoelectric element **72**. Further, the tightening forces of the screws **144** and **146** do not operate to expand the frame **62** in the displacement direction of the piezoelectric element **72**, thereby preventing the expansion of the frame **62** upon tightening of the screws **144** and **146**.

As mentioned above with reference to FIGS. **3** and **4**, the lead wires **114** and **116** connected to both the electrodes of each piezoelectric element **72** are guided through the guide channels **130** and **132** of the leg portion **128** of the holder **118**, and are inserted through the holes **136** and **138** of the leg portion **128** and through the holes **140** and **142** of the wiring plate **120**. Then, each end of the lead wires **114** and **116** is connected by soldering to the feeder lines **122** on the wiring plate **120**. With this arrangement, it is possible to prevent interference or entanglement between the lead wires **114** and **116** and make the soldering work easy. Further, it is also possible to prevent the lead wires **114** and **116** from being erroneously soldered to the electrodes of the piezoelectric element **72**.

In this embodiment, the frame **62**, the connection member **104** and the movable member **82** are formed independently, and are then integrally fixed together by brazing or the like. Therefore, the supporting surface **80** of the base portion **78** of the frame **62** and the fixing surface of the movable member **82** to the piezoelectric element **72** may be easily finished with a high accuracy. Accordingly, the displacement of the piezoelectric element **72** upon application of voltage thereto may be reliably transmitted to the movable member **82** and the second leaf spring **86**. Alternatively, the frame **62**, the connection member **104** and the movable member **82** may be integrally formed from a single metal plate.

Further, the first base plate **42** may be formed at its outer periphery on the inner surface with a perpendicular projection for threadedly inserting thereinto the tightening screw **144** in a direction perpendicular to the displacement direction of the piezoelectric element **72**. As to the tightening screw **146** on the second base plate **44** side, the screw **146** may be tightened in a direction either perpendicular or parallel to the displacement direction of the piezoelectric element **72**.

As shown in FIG. **6**, the holder **118** shown in FIG. **3** may be removed. In this case, the lead wires **114** and **116** are directly led to the feeder lines **122** on the wiring plate **120**.

Although it is preferable to contact the leaf springs **84** and **86** for the purpose of increasing the displacement magnifying rate to the maximum as associated with the expansion of the piezoelectric element **72**, the leaf springs **84** and **86** may be spaced a small distance.

FIG. **8** shows an expanded perspective view of the leaf spring **84(86)**. Both the leaf springs **84** and **86** are formed from a rectangular elastic plate having uniform thickness and width. As shown in FIG. **7**, upon application of voltage to the piezoelectric element **72**, the leaf spring **86** fixed to the movable member **82** is upwardly displaced in parallel to the leaf spring **84** fixed to the frame **62**. At the same time, both the leaf springs **84** and **86** are elastically deformed to generate a stress therein. The stress tends to be concentrated at an fixed edge of the leaf springs **84** and **86**, e.g., near the point **0** shown in FIG. **7**.

Referring next to FIGS. **9** to **12** which show a second preferred embodiment intending to reduce such a stress concentration in the first preferred embodiment and improve the durability of the leaf springs. In the second preferred embodiment, the same or like parts as in the first preferred embodiment are designated by the same reference numerals, and the related explanation will be omitted.

As shown in FIGS. **9** and **10**, a second leaf spring **156** fixed to the movable member **82** is adapted to be displaced in parallel to a first leaf spring **154** fixed to the frame **62** upon expansion of the piezoelectric element **72**, resulting in rolling of the rolling member **92**. The leaf springs **154** and **156** are constructed in such a manner that a sectional area in a direction perpendicular to the displacement direction is reduced at an intermediate position of the displacement direction. That is, as clearly shown in FIGS. **11** and **12**, the first and second leaf springs **154** and **156** are formed on their side surfaces opposite to the facing surfaces with sectional U-shaped grooves **158** and **160** extending across the width W of the leaf springs, respectively. As a result, there are formed thin-walled portions **162** and **164** at the positions of the grooves **158** and **160** of the first and second leaf springs **154** and **156**. In other words, the first leaf spring **154** has a large sectional area at the fixed portions fixed to the frame **62** and the rolling member **92**, but has a small sectional area at the thin-walled portion **162**, namely, at the elastically deformable portion. Similarly, the second leaf spring **156** also has a large sectional area at the fixed portions fixed to the movable member **82** and the rolling member **92**, but has a small sectional area at the thin-walled portion **164**.

When the second leaf spring **156** is displaced in a direction substantially parallel to the first leaf spring **154** upon expansion of the piezoelectric element **72**, and both the leaf springs **154** and **156** are elastically deformed, the stress is primarily applied to the thin-walled portions **162** and **164** having a small sectional area, thereby greatly reducing the stress to be applied to the upper and lower fixed (brazed) edges of the leaf springs **154** and **156**, e.g., at the point **0** shown in FIG. **12**. Accordingly, it is possible to prevent the generation of cracking at the fixed edges due to repeated elastic deformation of the leaf springs **154** and **156** and thereby improve the durability.

In accordance with CAEDS (tradename of structure analysis software produced by International Business Machines Corporation), the present inventors have investigated to calculate the stresses to be applied at the points **0**, P and Q of the leaf springs **154** and **156** shown in FIG. **12** and the stresses to be applied at the points O, P and Q of the leaf springs **84** and **86** shown in FIG. **7** as having the uniform width and thickness. The result of calculation is shown in Table 1.

TABLE 1

	Conditions				
	Rate of Magnification (%)	Natural Frequency (KHz)	Stress (kg/mm^2)		
			O	P	Q
Example of FIG. 12	230	2.5	7.6	54.9	56.2
Example of FIG. 7	230	2.5	14.4	50.6	51.2

The dimensions of the leaf springs **154** and **156** shown in FIG. **12** and the leaf springs **84** and **86** shown in FIG. **7** are shown in Table 2.

TABLE 2

	W(mm)	t(mm)	L(mm)	D(mm)	E(mm)	F(mm)
Example of FIG. 12	4.0	0.8	1.2	0.8	0.52	0.28
Example of FIG. 7	4.0	0.28	0.8	—	—	—

Where the characters, W, t, L, D, E and F stand for a width of each leaf spring, a thickness of each leaf spring, a vertical distance of the unfixed portion of each leaf spring, a width of the U-shaped groove, a depth of the U-shaped groove and a thickness of the thin-walled portion, respectively.

As is apparent from Table 1, the stress at the point **0** in Example of FIG. **12** is made substantially half the stress at the point **0** in Example of FIG. **7**.

Referring to FIG. **13** which shows a modification of the embodiment shown in FIGS. **9** to **12**, the first leaf spring **154** is formed on its outer side surface with three U-shaped grooves **166, 168** and **170** extending across the width of the leaf spring **154** and arranged in uniformly spaced relationship from each other in the displacement direction of the leaf spring **154**. The central groove **168** has a depth greater than the other grooves **166** and **170**. Similarly, the second leaf spring **156** is formed on its side surface opposite to the outer side surface of the first leaf spring **154** with three U-shaped grooves **172, 174** and **176** similar to the U-shaped grooves **166, 168** and **170**. With this arrangement, the stress is prevented from being concentrated at the thin-walled portions corresponding to the central deep grooves **168** and **174**, and may be dispersed to the other thin-walled portions corresponding to the shallow grooves **166, 170, 172** and **176**.

Referring to FIG. **14** which shows another modification of the embodiment shown in FIGS. **9** to **12**, the first leaf spring **154** is formed on its outer side surface with a pair of U-shaped grooves **178** and **180** extending across the width of the leaf spring **154** and arranged in given spaced relationship from each other in the displacement direction of the leaf spring **154**. The grooves **178** and **180** have the same width and depth. Similarly, the second leaf spring **156** is formed on its side surface opposite to the outer side surface of the first leaf spring **154** with a pair of U-shaped grooves **182** and **184** similar to the grooves **178** and **180**. With this arrangement, the stress is substantially uniformly dispersed to the thin-walled portions formed between the grooves **178, 182** and **180, 184**.

Referring to FIG. **15** which shows a further modification, the first and second leaf springs **154** and **156** have a uniform thickness, but have a reduced width at their intermediate portions **186**. Further, each leaf spring **154(156)** is formed at its upper and lower fixed ends with recesses **188** and **190** to be engaged with projections **194** of the base portion **94** of the rolling member **92** and projections **192** and **196** of the frame **62** and the movable member **82**, respectively. With this arrangement, the first and second leaf springs **154** and **156** are positioned at their fixed end portions adjacent to the groove **98** of the rolling member **92**, the mounting surface **88** of the frame **62** and the mounting surface **90** of the movable member **82**, and are fixed by brazing thereto. Further, as each leaf spring has intermediate small-width portions **186**, the stress may be prevented from being concentrated at the fixed edge of each leaf spring.

In the first and second preferred embodiments as mentioned above, the first and second leaf springs **84** and **86** or **154** and **156** are so arranged as to extend in parallel to the displacement direction of the piezoelectric element **72** under the condition where the facing surfaces of each leaf spring are in contact with each other. Upon expansion of the piezoelectric element **72**, the movable member **82** is displaced to upwardly move the leaf spring **86(156)** fixed to the movable member **82** in such a manner as to slidingly contact the leaf spring **84(154)** fixed to the frame **62**. At the same time, both the leaf springs **84** and **86 (154** and **156)** are elastically deformed. In such a structure, the leaf springs **84** and **86 (154** and **156)** are installed into the groove **98** of the base portion **94** of the rolling member **92** in such a manner that the lower ends of the leaf springs tend to be curved outwardly. Further, the leaf spring **86(156)** is fixed to one side surface of the movable member **82**. As a result, it was realized in the experiment that the deformable portions of the leaf springs are wavingly slid with a large frictional force, causing a possibility of wear or seizure of the leaf springs.

FIGS. **16** to **22** show a third preferred embodiment intended to reduce such large friction at the deformable portions of the leaf springs contacting with each other and thereby prevent the wear or seizure of the leaf springs.

Referring to FIGS. **16** to **19** which show a third preferred embodiment, a pair of upper and lower wedge members **198** and **200** are interposed between the lower end surface of the piezoelectric element **72** and the upper end surface of the base portion **78** of the frame **62**. Both the wedge members **198** and **200** are formed of a material such as zinc having a linear expansion characteristic contrary to that of the piezoelectric element **72**, so that the expansion and contraction of the piezoelectric element **72** due to a temperature change may be compensated by the contraction and expansion of the wedge members **198** and **200** to thereby maintain constant the height of the piezoelectric element **72** from the upper end surface of the base portion **78** of the frame **62**.

Similar to the previous preferred embodiments, the first and second leaf springs **204** and **206** contacting with each other are formed with U-shaped grooves **158** and **160** to form thin-walled portions (deformable portions) **162** and **164**, respectively. The thin-walled portions **162** and **164** are readily deformable.

The opposed surfaces of the deformable portions **162** and **164** of the leaf springs **204** and **206** are formed with recessed portions **208** ad **210** for hindering contact between the deformable portions **162** and **164**. The recessed portions **208** and **210** extend across the width of the leaf springs **204** and **206** on the opposite side of the grooves **158** and **160**, thus defining a rectangular cavity between the deformable portions **162** and **164**.

When the second leaf spring 206 fixed to the movable member 82 is upwardly moved along the first leaf spring 204 fixed to the frame 62, and the deformable portions of the leaf springs 204 and 206 are elastically deformed, the frictional force to be generated between the deformable portions is reduced by the provision of the recessed portions 208 and 210. Accordingly, it is possible to prevent the generation of wear or seizure between the deformable portions 162 and 164 and well transmit the displacement of the movable member 82 in receipt of the expansion of the piezoelectric element 72. As a result, both the leaf springs 204 and 206 are deformed duly by a given quantity at the deformable portions 162 and 164, respectively. Accordingly, the rolling member 92 is rolled by a given angle to thereby greatly magnify the expansion of the piezoelectric element 72 and transmit the magnified expansion to the printing wire 50.

The inventors have investigated to compare the natural frequencies of the movable portion consisting of the leaf springs 154 and 156 and the rolling member 92 shown in FIG. 12 and the movable portion consisting of the leaf springs 204 and 206 and the rolling member 92 shown in FIG. 19, and also compare the strokes of the printing wire 50 between FIG. 12 and FIG. 19. The results of comparison is shown in Table 3.

TABLE 3

	W (mm)	t (mm)	l (mm)	t2 (mm)	S (mm)	l2 (mm)	N (KHz)	P (μm)
Example of FIG. 19	4.0	0.8	1.0	0.2	0.2	1.2	2.1	380
Example of FIG. 12	4.0	0.8	1.0	0.27	—	—	2.7	227

Where W and t stand for a width and a thickness of the leaf spring, respectively; l and t2 stand for a length and a wall thickness of the deformable portion, respectively; S and l2 stand for a spacing and a length of the cavity defined by the recessed portion; and N and P stand for the natural frequency and the stroke of the wire 50. The leaf springs 154 and 156 were used in the test under an initial condition where seizure and wear have not yet been generated.

As is apparent from Table 3, since the deformable portions 162 and 164 of the leaf springs 204 and 206 shown in FIG. 19 are formed with the recessed portions 208 and 210 defining a cavity with a spacing of 0.2 mm, a frictional force between the facing surfaces of the deformable portions 162 and 164 may be greatly reduced to thereby increase the displacement magnification rate (a percentage of the stroke of the printing wire 50 relative to the expansion quantity of the piezoelectric element 72). As a result, the seizure and wear generated between the facing surfaces of the deformable portions 162 and 164 may be prevented to maintain the increased magnification rate for a long period of time.

It is noted that each dimension shown in Table 3 is merely exemplary, and may be modified as shown in Table 4 corresponding to the following Examples 1 to 4.

In Example 1, the spacing S of the cavity defined by the deformable portions 208 and 210 was set to 0.6 mm, and the length of the cavity was set to 1.0 mm. The other dimensions were identical with those of the embodiment shown in FIG. 19.

In Example 2 shown in FIG. 20, the deformable portions 162 and 164 of the leaf springs 204 and 206 have no grooves on opposite side surfaces thereof so as to increase the spacing S of the cavity defined by the recessed portions 208 and 210.

In Example 3 shown in FIG. 21, the structure is similar to that of Example 2 except that a small spacing S2 is defined between the facing surfaces of the leaf springs 204 and 206.

In Example 4 shown in FIG. 22, a single leaf spring 212 is provided to be formed with a vertically extending U-shaped groove 213 at a laterally central portion thereof to result in the formation of a pair of leaf spring portions 204 and 206. The U-shaped groove 213 functions as the cavity mentioned in the previous Examples 1 to 3. Table 4 shows the comparison among the above Examples 1 to 4.

TABLE 4

	W (mm)	t (mm)	l (mm)	t2 (mm)	S (mm)	l2 (mm)	S2 (mm)	N (KHz)	P (μm)
Example 1	4.0	0.8	1.0	0.2	0.6	1.0	—	2.4	330
Example 2	4.0	0.8	1.0	0.27	1.06	1.0	—	4.2	210
Example 3	4.0	0.6	1.0	0.2	1.0	1.0	0.2	3.5	250
Example 4	4.0	0.5	1.0	0.2	0.6	—	—	2.4	330

As apparent from Tables 3 and 4, the displacement magnification rate in the embodiment shown in FIG. 19, Example 1 and Example 4 is increased in comparison with that in the embodiment shown in FIG. 12.

In the embodiment shown in FIG. 12, the spacing S is reduced to be zero so as to increase the magnification rate in accordance with a principle of lever principles. However, a load to be applied to the piezoelectric element 72 is increased to suppress the expansion of the piezoelectric element 72, resulting in limitation of the stroke of the printing wire. To the contrary, in the embodiment shown in FIG. 19, Example 1 and Example 4, a distance between the center of the thickness of the deformable portion 162 and the center of the thickness of the deformable portion 164 is set to 0.4–0.8 mm, so that although the magnification rate is just reduced, the load to be applied to the piezoelectric element 72 is reduced. Accordingly, it is considered that a large stroke of the printing wire could be obtained.

However, the distance between the centers of the thickness is further increased as in Examples 2 and 3, the magnification rate is reduced, and the stroke tends to be suppressed.

As to the natural frequency, an increase in the natural frequency contributes to an increase in a return speed of the rolling member 92, resulting in an improvement in a printing speed of the printing head. Although the natural frequencies in Examples 1 and 4 are smaller than those in Examples 2 and 3, Examples 1 and 4 are preferred from the viewpoint of the stroke of the printing wire.

In the foregoing preferred embodiments, the frame **62** and the movable member **82** are formed independently. In mounting the piezoelectric element **72**, the movable member **82** is positioned through the leaf springs **84** and **86** (**154** and **156** or **204** and **206**) and the connecting member **104** relative to the frame **62**, and then the piezoelectric element **72** is fixedly interposed between the movable member **82** and the base portion **78** of the frame **62**. In connection with this, it is desirable to provide an accurate dimension and a high degree of parallelism between the movable member **82** and the base, portion **78** of the frame **62**. That is, less error during installation of the movable member **82** is desired.

FIGS. **23** to **26** show a method of producing the printing unit which improves the accuracy of dimension and the degree of parallelism between the movable member **82** and the base portion **78** of the frame **62** by way of an example in accordance with the present invention.

Referring to FIG. **23**, the frame **62** is formed from a rectangular metal plate having a given thickness extending in a direction substantially parallel to the piezoelectric element 72. The frame **62** is formed at its lower end portion with the laterally projecting base portion **78** for supporting the lower end of the piezoelectric element 72 through the pair of wedge members **198** and **200**. Further, the frame **62** is integrally formed at its upper end portion with a movable member **214** connected through a connecting portion **216**. Thus, the movable member **214** is spaced a distance L from the base portion **78** so as to insert the piezoelectric element 72 and the wedge members **198** and **200**. A recess **218** is defined between the frame **62** and the movable member **214** so as to insert the base portions of the leaf springs **154** and **156** by press working, for example.

The upper surface **80** of the base portion **78** of the frame **62** and the lower surface **220** of the movable member **214** are finished as required so as to further improve the accuracy of the distance L and the degree of parallelism.

After the frame **62** and the movable member **214** are formed as mentioned above, the upper end portions of the leaf springs **154** and **156** are inserted into the groove **98** of the base member **94** of the rolling member **92**, and are fixed by brazing thereto. Then, the base portions of the leaf springs **154** and **156** fixed to the base member **94** are inserted into the recess **218**, and are fixed by brazing to the inner wall surface of the recess **218**. Under this condition, the leaf springs **154** and **156** are elastically deformably contacted with each other.

Then, the connecting member **104** adapted to be elastically displaced in a direction parallel to the displacement direction of the piezoelectric element **72** is provided between the movable member **214** and the base portion **78** of the frame **62** in such a manner that the upper end portion of the connecting member **104** is fixed to the side surface of the movable member **214**, while the lower end portion is fixed to the side surface of the base portion **78**. In this embodiment, a sectional area at the end portions of the connecting member **104** to be fixed to the movable member **214** and the frame **62** are larger than a sectional area at an intermediate portion between the fixed end portions, by forming three elongated holes at the intermediate portion, so that the connecting member **104** may be more readily expanded and contracted in receipt of the displacement of the piezoelectric element **72**.

After the leaf springs **154** and **156** and the supporting member **104** are mounted as mentioned above, a separation slit **222** is formed into the connecting portion **220** from the underside to the bottom of the recess **218**, so as to separate the movable member **214** from the frame **62**.

Thereafter, the upper wedge member **198** is fixed to the lower end surface of the piezoelectric element **72** by an adhesive, and they are inserted between the movable member **214** and the base portion **78** of the frame **62** until a stopper surface **226** of the upper wedge member **198** abuts against the side surface of the frame **62**, and then the upper end surface of the piezoelectric element **72** abuts against the lower surface of the movable member **214**. At this time, the upper end surface of the piezoelectric element **72** is bonded by an adhesive to the lower surface of the movable member **214** as required.

Then, the lower wedge member **200** is inserted between the upper wedge member **198** and the base portion **78** of the frame **62**, and force is applied, thus completing the installation of the piezoelectric element **72**. At this time, the abutting surfaces among the lower wedge member **200**, the upper wedge member **198** and the base portion **78** of the frame **62** are coated with an adhesive as required.

In accordance with the above steps, the high accuracy of the distance L (shown in FIG. **25**) and the parallelism between the base portion **78** of the frame **62** and the movable member **214** may be ensured. Accordingly, the piezoelectric element **72** and the pair of wedge members **198** and **200** may be closely fitted between the base portion **78** of the frame **62** and the movable member **214**, and the movable member **214** may be displaced sufficiently in receipt of the displacement of the piezoelectric element **72**. Thus, both the leaf springs **154** and **156** are elastically deformed sufficiently in receipt of the displacement of the movable member **214** to accurately roll the rolling member **92** at a given angle, thereby ensuring good printing operation.

Referring to FIGS. **27** and **28** which show a modification of the preferred embodiment shown in FIGS. **23** to **26**, wherein a single thick leaf spring **212** is formed with a central split groove **213** extending from the separation groove **222** formed at the connecting portion **216**.

The printing unit in this case is manufactured in the following manner. That is, as shown in FIG. **27**, the movable member **214** is integrally formed at one end of the frame **62** through the connecting portion **216**. Then, the single thick leaf spring **212** fixed to the rolling member **92** is inserted into the recess **218** formed between the frame **62** and the movable member **214**, and is fixed by brazing to the recess **218**.

Thereafter, as shown in FIG. **28**, the separation groove **222** is formed in the connecting portion to separate the movable member **214** from the frame **62**. Further, the central split groove **213** is formed in the single leaf spring **212** in such a manner as to extend from the separation groove **222**, thereby forming a pair of leaf spring members **204** and **206**.

According to this example, the high accuracy of the distance and the parallelism between the movable member **214** and the base portion **78** of the frame **62** can be obtained. Moreover, since the single leaf spring **212** is used, the number of parts may be reduced.

In the foregoing preferred embodiments, the rolling member **92** is so fixed as to ride over the end portions of the pair of leaf springs. In such a structure as shown in

FIG. 29, the upper end portions of the leaf springs **154** and **156** are fixed in the recess **98** of the base member **94** of the rolling member **92**, and the lower end portions are fixed to the movable member **82** and the frame **62**. Upon displacement of the piezoelectric element **72**, the deformation of the leaf springs **154** and **156** on the base member **94** side is greater than that on the frame **62** and the movable member **82** side, and a brazed portion A on the inner surface of the recess **98** is subjected to a repeated tensile load and compression load. Thereafter, there is a possibility of cracks being generated at the brazed portion A. If the cracks were generated, the leaf springs **154** and **156** would be eventually separated from the base member **94** of the rolling member **92**.

The following preferred embodiment as shown in FIGS. **30** and **31** is intended to prevent the generation of cracks at the fixing portion between the leaf springs and the rolling member and thereby improve the durability, and also to reduce the number of parts and thereby simplify the structure.

Referring to FIGS. **30** and **31**, a single thick spring member **230** is formed with a central split groove **232** to thereby form a pair of leaf springs **234** and **236**. Further, a head portion connecting the leaf springs **234** and **236** functions as a rolling base member **238**. That is, the pair of split plate portions of the spring member **230** function as the leaf springs **234** and **236**, while the head portion of the spring member **230** functions as the rolling base member **238**. In other words, the leaf springs **234** and **236** are integrally formed with the rolling base member **238** with no fixed portions.

The leaf springs **234** and **236** are fixed by brazing to the spring mounting surfaces **88** and **90** of the frame **62** and the movable member **214**. Further, the leaf springs **234** and **236** are formed at their intermediate positions with opposite U-shaped grooves **158** and **160** at which portions the leaf springs are mainly elastically deformed. The head portion **238** is formed with a recess **240** for receiving the wire driving arm **96** of the rolling member **228**. Thus, the base end portion of the wire driving arm **96** is inserted into the recess **240**, and is fixed by brazing to the recess **240**. The printing wire **50** is also fixed by brazing to the tip of the wire driving arm **96**. In this embodiment, the frame **62** is formed independently of the movable member **214**. In this regard, FIG. **32** shows a modification of the preferred embodiment shown in FIGS. **30** and **31**. In the modification shown in FIG. **32**, the movable member **214** is integrally formed with the frame **62**, so that the high accuracy of the distance L and the parallelism between the base portion of the frame **62** and the movable member **214** may be readily attained. After the spring member **230** is installed at the connecting portion **216** between the movable member **214** and the frame **62**, the separation groove **222** is formed in the connecting portion **216** to separate the frame **62** and the movable member **214**. Further, the central split groove **232** is formed in the spring member **230** in such a manner as to extend from the separation groove **222**.

As mentioned above, since the pair of leaf springs **234** and **236** and the rolling base member **238** are integrally formed by the single spring member **230**, there is no necessity for fixing (brazing) both the members, resulting in no possibility of the generation of cracks at the brazed portion, thus improving the durability. In addition, the number of parts may be reduced.

Referring to FIG. **33** which shows a modification of the above preferred embodiments shown in FIGS. **30** to **32**, a spring member **242** is bent in the form of a U-shape to form the pair of leaf springs **234** and **236**. A bent portion or a head portion of the spring member **242** is fixed to a base portion **244** (corresponding to the rolling base member) of the rolling member **228** by welding or brazing.

In the displacement magnifying mechanism as mentioned in the foregoing preferred embodiments shown in FIGS. **1** through **33**, there is provided the elastically deformable *restricting or* connecting member **104** between the movable member **82** (as in FIG. **10**, for example) and the base portion **78** of the frame, so as to maintain parallel displacement of the movable member **82** in receipt of the displacement of the piezoelectric element **72** and thereby prevent lack of the rolling angle of the rolling member **92**. In this case, it is necessary to set the elastic force of the connecting member **104** so that it may be fully balanced with the elastic force of the leaf springs **154** and **156**. However, it is actually hard to precisely balance both the elastic forces under the dynamic condition of these members.

The following preferred embodiment as shown in FIGS. **34** through **38** is intended to prevent the inclination of the movable member **82** more reliably by providing a *restricting member or* parallel link mechanism between the movable member **82** and the frame **62**.

Referring first to FIGS. **34** to **36**, the construction of the printing unit is similar to the preferred embodiment shown in FIG. **9**, for example, except that a parallel link mechanism **246** is provided.

The parallel link mechanism **246** is provided between the frame **62** and the movable member **82** so as to guide the movable member **82** under the condition parallel to the displacement direction of the piezoelectric element **72**. As clearly seen in FIG. **36**, the parallel link mechanism **246** is formed from an elastically deformable single plate by punching and bending, thus forming a pair of parallel link plates **248** having the same shape and a connecting portion **250** connecting both the link plates **248**.

Each of the pair of link plates **248** includes a pair of parallel vertical link portions **252** and **254**, a pair of parallel horizontal link portions **264** and **266** and four elastically deformable hinge portions **256**, **258**, **260** and **262** connecting the vertical link portions **252** and **254** with the horizontal link portions **264** and **266**. Thus, the link plate **248** forms a quadri-hinged parallel link.

As shown in FIGS. **34** and **35**, the opposed inner surfaces of the left vertical link portions **252** of the link plates **248** are fixed by brazing to both the side surfaces of the frame **62**, while the opposed inner surfaces of the right vertical link portions **254** are fixed by brazing to both the side surfaces of the movable member **82** at its intermediate portion. Further, the inner surface of the connecting portion **250** of the link mechanism **246** is fixed to the upper surface of the movable member **82**.

In operation, when the piezoelectric element **72** is supplied with voltage, it is expanded by a predetermined length in the direction of the arrow X shown in FIG. **35** to displace the movable member **82** against the load of the connecting member **104**, the second leaf spring **156** and the parallel link mechanism **246**. Then, the second leaf spring **156** is lifted along the first leaf spring **154** by the displacement force of the movable member **82**. As a result, both the leaf springs **154** and **156** are curved like a bimetal to generate a moment in the direction of the arrow P shown in FIG. **35**. Accordingly, the rolling member **92** is rolled to advance the printing wire 50. To the contrary, when the voltage applied to the piezoelectric element 72 is removed, the piezoelectric element 72 is contracted to follow the displacement of the movable member 82 and thereby return the rolling member 92 and the printing wire 50 to their original position.

In driving the leaf spring 156 by the movable member 82, the inclination of the movable member 82 due to the load of the leaf spring 156 is suppressed by the connecting member 104 connected to the movable member 82, and it is further suppressed by the parallel link mechanism 246 fixed so as to ride over the movable member 82 and the frame 62. That is, the movement of the movable member 82 is restricted by the link plates 248, and is guided under the condition parallel to the displacement direction of the piezoelectric element 72. Accordingly, it is possible to eliminate lack of elastic deformation of the leaf springs 154 and 156 due to the inclination of the movable member 82, thereby providing a sufficient stroke of the printing wire 50.

The leaf springs 154 and 156 are formed with grooves 158 and 160 to form thin-walled deformable portions similar to the previous preferred embodiments. Additionally, the leaf springs 154 and 156 are formed with upper small grooves 268a and lower small grooves 268b, so as to ensure brazing. That is, upon brazing, rod-like brazing members are inserted into the small grooves 268a and 268b, and the same molten by application of heat is penetrated into a small gap between the contact surfaces among the leaf springs, the movable member and the frame. Then, the brazing material is hardened to complete the brazing.

Referring to FIG. 37 which shows a modification of the preferred embodiment shown in FIGS. 34 to 36, the horizontal link portions 264 and 266 have a length greater than that in the previous preferred embodiment shown in FIGS. 34 to 36, and the other construction is similar to the previous preferred embodiment. With this arrangement, the displacement of the movable member 82 may be made near a linear displacement in parallel to the displacement of the piezoelectric element 72.

Referring to FIG. 38 which shows a further modification, the pair of leaf springs 234 and 236 are formed from a single thick spring member 230 by defining the split groove 232, and the head portion of the spring member 230 forms the rolling base member 238 to be fixed to the wire driving arm 96. This construction is substantially the same as that shown in FIG. 30.

Reference numeral 272 designates a parallel link mechanism in this modification. The vertical link portions 252 and 254 extend a fixed length upward from the upper surfaces of the frame 62 and the movable member 82. The vertical link portions 252 are fixed at their lower portion to both the side surfaces of the frame 62, and are integrally connected at their upper portion with each other by a connecting portion 250. In contrast to the constructions of the preferred embodiments shown in FIGS. 34 and 37 wherein the parallel link mechanisms 246 and 268 are located on one side of the leaf springs 154 and 156, the parallel link mechanism 272 shown in FIG. 38 is located in such a manner that the horizontal link portions 264 and 266 ride over the leaf springs 234 and 236, and the distance between the horizontal link portions 264 and 266 is increased.

With this arrangement, the movable member 82 may be more stably displaced in parallel to the displacement direction of the piezoelectric element 72.

In the foregoing preferred embodiments shown in FIGS. 34 to 38, the connecting member 104 may be removed when suitably setting an elastic force of the hinge portions of the parallel link mechanism owing to the elasticity of the hinge portions. Thus, the quick return operation of the movable member 82 and the rolling member 92 may be ensured, and the parallel displacement of the movable member 82 in relation to the piezoelectric element 72 may be also ensured.

Having thus described the preferred embodiments of the invention, it should be understood that numerous structural modifications and adaptations may be made without departing from the spirit of the invention.

What is claimed is:

1. A device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising:

a frame extending substantially parallel to a direction of displacement of said piezoelectric element, said piezoelectric element being mounted on said frame;

a movable member fixed to one end of said piezoelectric element with respect to said direction of displacement and adapted to be displaced in a direction substantially parallel to said frame;

a first mount surface formed on said frame and extending substantially parallel to said direction of displacement;

a second mount surface formed on a surface of said movable member which faces said first mount surface and extending substantially parallel to said direction of displacement, said second mount surface facing said first mount surface;

a first leaf spring mounted at a first end portion thereof on said first mount surface and extending substantially parallel to said direction of displacement;

a second leaf spring mounted at a first end portion thereof on said second mount surface and extending substantially parallel to said direction of displacement, said second leaf spring being positioned adjacent to said first leaf spring; and

a rolling member fixed to second end portions of said first and second leaf springs, wherein when said piezoelectric element is displaced, said second leaf spring is displaced along said first leaf spring through said movable member to roll said rolling member.

2. The device as defined in claim 1, wherein respective surfaces of said first and second leaf springs are in contact with each other under an inoperative condition of said piezoelectric element.

3. The device as defined in claim 1, wherein said first mount surface is located at an end portion of an end surface of said frame, and said second mount surface is located on an end surface of said movable member offset from a center line of said piezoelectric element to said frame.

4. The device as defined in claim 3, wherein said frame has a substantially L-shaped configuration as viewed from a side thereof such that said substantially L-shaped configuration is comprised of a vertical portion extending substantially parallel to the direction of displacement of said piezoelectric element and a base portion projecting laterally from said vertical portion for supporting one end of said piezoelectric element with respect to the direction of displacement, and wherein said first leaf spring is fixed to an end surface of said vertical portion of said frame, and said second leaf

spring is fixed to the end surface of said movable member opposed to said end surface of said vertical portion.

5. The device as defined in claim **1**, wherein said first and second leaf springs include respective deformable portion facing each other, and said deformable portions are formed at their facing surfaces with respective non-contact portions for inhibiting contact between said deformable portions.

6. The devices as defined in claim **5**, wherein said deformable portions of said first and second leaf springs are formed with recesses on opposite surfaces to said facing surfaces.

7. The device as defined in claim **5**, wherein said first and second leaf springs are formed from a single spring member in which a split groove is formed which extends from a first end of said spring member toward a second end thereof, and said rolling member is integrally connected to said second end.

8. The device as defined in claim **7**, wherein said first leaf spring is fixed to an end surface of said frame extending substantially parallel to said piezoelectric element, and said second leaf spring is fixed to an end surface of said movable member opposed to said end surface of said frame and offset from a center line of said piezoelectric element to said frame.

9. The device as defined in claim **7**, wherein said split groove comprises a cutout formed from said first end of said spring member toward said second end thereof.

10. The device as defined in claim **7**, wherein a head portion of said spring member formed at said second end thereof without said split groove forms at least a part of said rolling member, thus integrally forming the leaf springs with said at least a part of said rolling member.

11. The device as defined in claim **7**, wherein said split groove comprises a space defined by bending said spring member into a U-shaped configuration.

12. The device as defined in claim **1**, wherein said first and second leaf springs are formed on their opposite surfaces with grooves to form thin-walled portions opposed to each other at positions of said grooves.

13. The device as defined in claim **12**, wherein said grooves are arranged at intervals in the direction of displacement of said piezoelectric element.

14. The device as defined in claim **1**, wherein said first and second leaf springs have narrow portions each having a width smaller than that of said fixed ends, respectively.

15. A device for magnifying displacement of a piezoelectric element adapted to be displaced [be] *by* application of voltage thereto, comprising:

- a frame extending substantially parallel to a direction of displacement of said piezoelectric element, said piezoelectric element being mounted on said frame;
- a movable member fixed to one end of said piezoelectric element with respect to said direction of displacement;
- a first mount [surfaced] *surface* formed on said frame and extending substantially parallel to said direction of displacement;
- a second mount surface formed on a surface of said movable member and extending substantially parallel to said direction of displacement, and second mount surface facing said first mount surface;
- a first leaf spring mounted at a first end portion thereof on said first mount surface and extending substantially parallel to said direction of displacement;
- a second leaf spring mounted at a first end portion thereof on said second mount surface and extending substantially parallel to said direction of displacement;
- a rolling member fixed to second end portions of said first and second leaf springs, wherein when said piezoelectric element is displaced, said second leaf spring is displaced along said first leaf spring through said movable member to roll said rolling member; and
- an elastically deformable connecting member extending along said piezoelectric element on an opposite side of said frame with respect to said movable member and connecting said movable member with a base portion of said frame, wherein when said piezoelectric element is displaced, said movable member is displaced substantially parallel to the direction of displacement against the elasticity of said connecting member to curve said second leaf spring relative to said first leaf spring and thereby roll said rolling member.

16. The device as defined in claim **15**, wherein said connecting member is formed independently of said frame and said movable member, and is fixed to said frame and said movable member.

17. The device as defined in claim **15**, wherein said connecting member is formed by a plate-like member having a width substantially parallel to a direction of thickness of said leaf springs and having a small sectional area in a direction perpendicular to the width of said leaf spring.

18. The device as defined in claim **17**, wherein a sectional area at end portions of said connecting member to be fixed to said movable member and said frame are larger than a sectional area at an intermediate portion between said fixed end portions.

19. The device as defined in claim **15**, wherein said connecting member normally applies a compression force to said piezoelectric element.

20. A device for magnifying displacement of a piezoelectric element adapted to be displaced by application of voltage thereto, comprising:

- a frame extending substantially parallel to a direction of displacement of said piezoelectric element, said piezoelectric element being mounted on said frame;
- a movable member fixed to one end of said piezoelectric element with respect to said direction of displacement;
- a first mount surface formed on said frame and extending substantially parallel to said direction of displacement;
- a second mount surface formed on a surface of said movable member and extending substantially parallel to said direction of displacement, said second mount surface facing said first mount surface;
- a first leaf spring mounted at a first end portion thereof on said first mount surface and extending substantially parallel to said direction of displacement;
- a second leaf spring mounted at a first end portion thereof on said second mount surface and extending substantially parallel to said direction of displacement;
- a rolling member fixed to second end portions of said first and second leaf springs, wherein when said piezoelectric element is displaced, said second leaf spring is displaced along said first leaf spring

through said movable member to roll said rolling member; and

a quadri-hinged parallel link mechanism provided between said frame and said movable member for maintaining parallelism of said movable member to the direction of displacement of said piezoelectric element.

21. The device as defined in claim **20**, wherein said quadri-hinged parallel link mechanism comprises a pair of first and second link plates each comprising a pair of vertical parallel link portions fixed to a side surface of said frame and a side surface of said movable member, a pair of horizontal parallel link portions extending between said vertical parallel link portions, and four elastically deformable hinge portions connecting said vertical parallel link portions with said horizontal parallel link portions.

22. The device as defined in claim **21** further comprising a connecting portion for connecting one of said vertical parallel link portions of said first link plate with *an* opposite [on] one of said vertical parallel link portions of said second link plate.

23. The device as defined in claim **15** further comprising a quadri-hinged parallel link mechanism provided between said frame and said movable member for maintaining parallelism of said movable member to the direction of displacement of said piezoelectric element.

24. The device as defined in claim **1**, wherein said rolling member comprises a base member fixed to second end positions of said first and second leaf springs; and an arm connected to said base member, said base member being formed with a recess for inserting a firm end of said arm.

25. The device as defined in claim **1**, wherein said rolling member is formed with a recess for inserting the second end portions of said first and second leaf springs.

26. The device as defined in claim **10**, wherein said rolling member comprises said head portion and an arm connected to said head portion, said head portion being formed with a recess for inserting a first end of said arm.

27. The device as defined in claim **12**, wherein a spacing between said rolling member and said frame and between said rolling member and said movable member is greater than a width of said grooves.

28. The device as defined in claim **27**, wherein said first leaf spring is fixed by brazing to said first mount surface of said frame, and said second leaf spring is fixed by brazing to said second mount surface of said movable member.

29. A displacement magnifying device comprising:

a frame;

an elastic member having first and second connection portions, said first connecting portion being secured to said frame;

an electro-distortion element having first and second opposite ends and responsive to selective application of an electrical voltage thereto to undergo displacement, said first end being connected to said frame, said second end being connected to said second connecting portion; and

an elastically deformable restricting member for restricting displacement of said electro-distortion element, said elastically deformable restricting member having first and second opposite restriction ends, said first restriction end being secured to a first connection part connecting said frame to said first end of said electro-distortion element, said second restriction end being secured to a second connection part connecting said second end of said electro-distortion element to said second connecting portion of said elastic member.

30. A displacement magnifying device comprising:

a frame;

a rolling member;

an electro-distortion element having a first end connected to said frame and responsive to selective application of an electrical voltage thereto to undergo longitudinal expansion and contraction;

a first resilient member having a first end connected to a second opposite end of said electro-distortion element and a second end connected to said rolling member;

a second resilient member disposed in a substantially parallel relationahip to said first resilient member and having a first end connected to said frame and a second end connected to said rolling member; and

a restricting member, having first and second portions, extending transversely to said first and second resilient members and fixedly connected at said first portion to said electro-distortion element and at said second portion to said frame, said restricting member restricting said electro-distortion element from displacement away from said frame in a direction substantially perpendicular to said first and second resilient members.

31. A printing head comprising a frame, a plurality of impact printing wires constituting a wire-dot matrix and a plurality of displacement magnifying devices respectively corresponding to, and for selectively driving, said respective impact printing wires, each of said displacement magnifying devices comprising:

a rolling member to which the respective one of said impact printing wires is connected;

an electro-distortion device having a first end connected to said frame and responsive to selective application of an electrical voltage thereto to undergo longitudinal expansion and contraction;

a first resilient member having a first end connected to the second end of said electro-distortion device and thereby to said frame and a second end connected to said rolling member;

a second resilient member disposed in substantially parallel relationship to said first resilient member and having a first end connected to said frame and a second end connected to said rolling member so that the extent of longitudinal expansion and contraction of said electro-distortion device in response to the selective application of an electrical voltage thereto is enlarged by said rolling member and transmitted thereby to said impact printing wire; and

a restricting member having first and second, opposite ends, extending transversely to said first and second resilient member and fixedly connected at the first end to said electro-distortion device and at the second, opposite end to said frame and thereby extending therebetween and restricting said electro-distortion device from displacement away from said frame in a direction substantially perpendicular to said first and second resilient members.

32. A printing head as set forth in claim 31, wherein said frame is substantially L-shaped having a base and a side wall extending substantially perpendicular to said base, said electro-distortion device has one end connected to said base and the other end connected to said resilient member, and said restricting member has one end connected to said side wall and the other end connected to said electro-distortion device in the vicinity of the other end thereof.

33. A printing head as set forth in claim 31, wherein said impact printing wire is connected to said rolling member at a first position thereof;

said second end of said first reislient member is connected to said rolling member at a second position thereof; and

said second end of said second resilient member is connected to said rolling member at a third position thereof, said first and third positions being disposed oppositely, relatively to said second position, so that the extent of longitudinal expansion and contraction of said electro-distortion device is enlarged by said rolling member and transmitted to said impact printing wire.

34. A printing head as set forth in claim 33, wherein a distance from said first position to said second position is larger than a distance from said second position to said third position.

35. A printing head comprising a frame, a plurality of impact printing wires constituting a wire-dot matrix and a plurality of displacement magnifying devices respectively corresponding to, and for selectively driving, said respective impact printing wires, each of said displacement magnifying devices comprising:

a rolling member to which the respective one of said impact printing wires is connected;

an electro-distortion device having a first end connected to said frame and responsive to selective application of an electrical voltage thereto to undergo longitudinal expansion and contraction;

a first resilient member having a first end connected to the second end of said electro-distortion device and thereby to said frame and a second end connected to said rolling member;

a second resilient member disposed in substantially parallel relationship to said first resilient member and having a first end connected to said frame and a second end connected to said rolling member so that the extent of longitudinal expansion and contraction of said electro-distortion device in response to the selective application of an electrical voltage thereto is enlarged by said rolling member and transmitted thereby to said impact printing wire; and

a restricting member connected between said electro-distortion device and said frame for restricting said electro-distortion device from displacement in a direction substantially perpendicular to said first and second resilient members.

36. A device for magnifying displacement of an electro-distortion element adapted to be displaced by application of voltage thereto, comprising:

a frame extending substantially parallel to a direction of displacement of said electro-distortion element, said electro-distortion element being mounted on said frame;

a movable member fixed to one end of said electro-distortion element with respect to said direction of displacement;

a first mount surface formed on said frame and extending substantially parallel to said direction of displacement;

a second mount surface formed on a surface of said movable member and extending substantially parallel to said direction of displacement, said second mount surface facing said first mount surface;

a first elastic member, mounted at a first end portion thereof on said first mount surface and extending substantially parallel to said direction of displacement;

a second elastic member mounted at a first end portion thereof on said second mount surface and extending substantially parallel to said direction of displacement;

a rolling member fixed to second end portions of said first and second elastic members, wherein when said electro-distortion element is displaced, said second elastic member is displaced along said first elastic member through said movable member to roll said rolling member; and

an elastically deformable connecting member connected between said electro-distortion element and said frame to maintain said movable member substantially parallel with said frame when said electro-distortion element is displaced, such that said movable member is displaced substantially parallel to the direction of displacement against the elasticity of said connecting member to move said second elastic member relative to said first elastic member and thereby roll said rolling member.

37. The device as defined in claim 36, wherein said connecting member is formed independently of said frame and said movable member, and is fixed to said frame and said movable member.

38. The device as defined in claim 36, wherein said connecting member is formed by an elongate member having a width substantially parallel to a direction of thickness of said elastic members and having a small sectional area in a direction perpendicular to the width of said elastic members.

39. The device as defined in claim 38, wherein a sectional area at end portions of said connecting member to be fixed to said movable member and said frame are larger than a sectional area at an intermediate portion between said fixed end portions.

40. The device as defined in claim 36, wherein said connecting member normally applies a compression force to said electro-distortion element.

41. A device as defined in claim 36, wherein said first and second elastic members are leaf springs.

42. A device as defined in claim 36, wherein said connecting member extends substantially parallel to said first and second elastic members.

43. A device as defined in claim 36, wherein said connecting member extends substantially perpendicular to said first and second elastic members.

44. A device for magnifying displacement of an electro-distortion element adapted to be displaced by application of voltage thereto, comprising:

a frame extending substantially parallel to a direction of displacement of said electro-distortion element, said electro-distortion element being mounted on said frame;

a movable member fixed to one end of said electro-distortion element with respect to said direction of displacement;

a first mount surface formed on said frame and extending substantially parallel to said direction of displacement;

a second mount surface formed on a surface of said movable member and extending substantially parallel to said direction of displacement, said second mount surface facing said first mount surface;

a first elastic member mounted at a first end portion thereof on said first mount surface and extending *substantially parallel to said direction of displacement;*

a second elastic member mounted at a first end portion thereof on said second mount surface and extending substantially parallel to said direction of displacement;

a rolling member fixed to second end portions of said first and second elastic members, wherein when said electro-distortion element is displaced, said second elastic member is displaced along said first elastic member through said movable member to roll said rolling member; and

an elastically deformable mechanism provided between said frame and said movable member for maintaining parallelism of said movable member to the direction of displacement of said electro-distortion element.

45. A device as defined in claim 44, wherein said first and second elastic members are leaf springs.

46. A device as defined in claim 44, wherein said deformable mechanism is an elongate member extending substantially parallel to said first and second elastic members.

47. A device as defined in claim 44, wherein said deformable mechanism is a quadri-hinged parallel link.

48. The device as defined in claim 47, wherein said quadri-hinged parallel link comprises a pair of first and second link plates each comprising a pair of vertical parallel link portions fixed to a side surface of said frame and a side surface of said movable member, a pair of horizontal parallel link portions extending between said vertical parallel link portions, and four elastic deformable hinge portions connecting said vertically parallel link portions with said horizontal parallel link portions.

49. The device as defined in claim 48, further comprising a connecting portion for connecting one of said vertical parallel link portions of said first link plate with an opposite one of said vertical parallel link portions of said second link plate.

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