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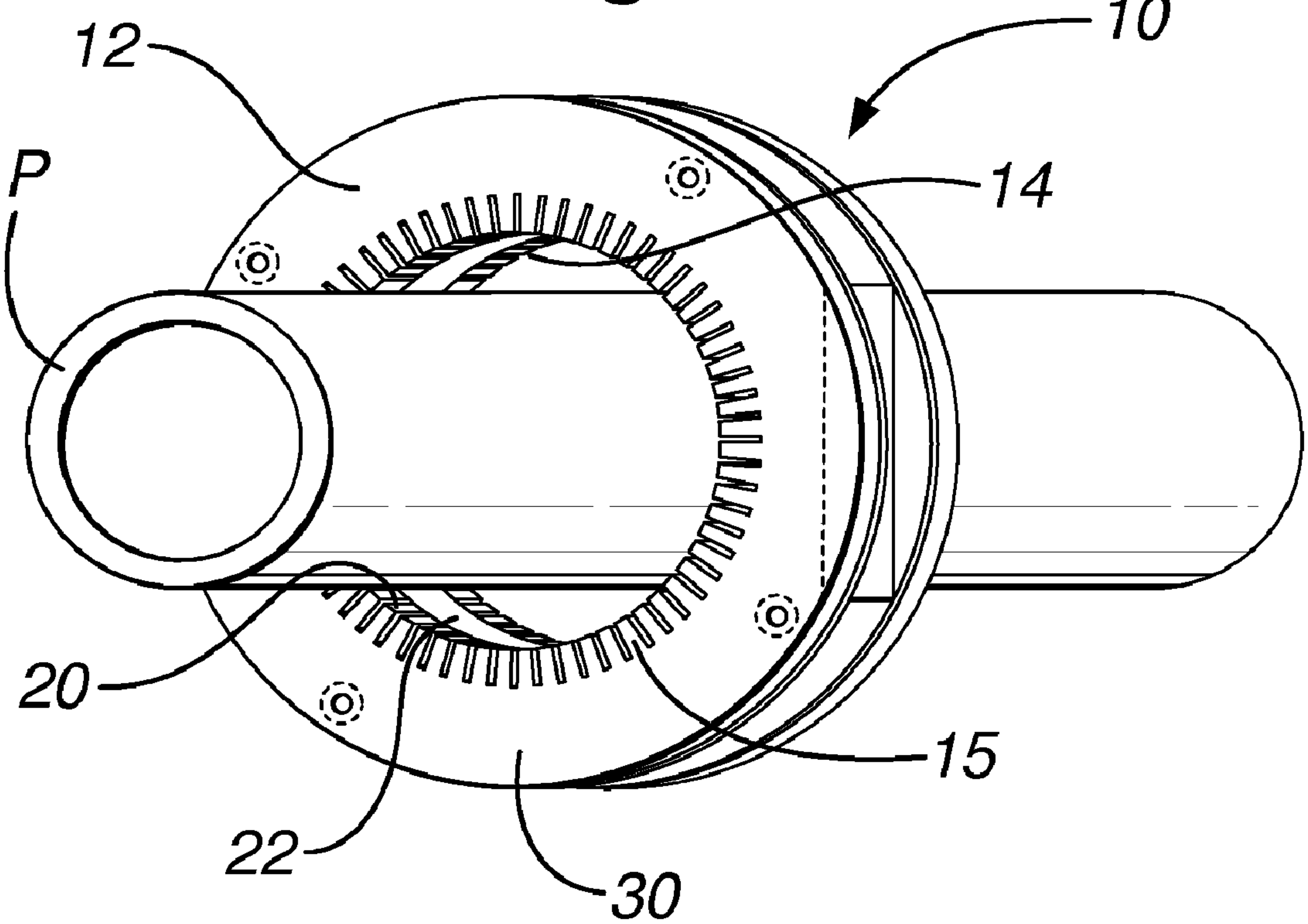
(54) Titre : APPAREIL ET PROCEDE D'INSPECTION D'UN ELEMENT TUBULAIRE
(54) Title: APPARATUS AND METHOD FOR INSPECTING A TUBULAR

Fig. 1A



(57) Abrégé/Abstract:
A shoe apparatus (10; 100) for inspecting a tubular (P), which shoe apparatus comprises: a body (12; 112); a film (22; 50; 51; 113) on saidbody(12; 112), said film comprising piezoelectric material, and a plurality of ultrasonic transducers(20; 110) on said film.

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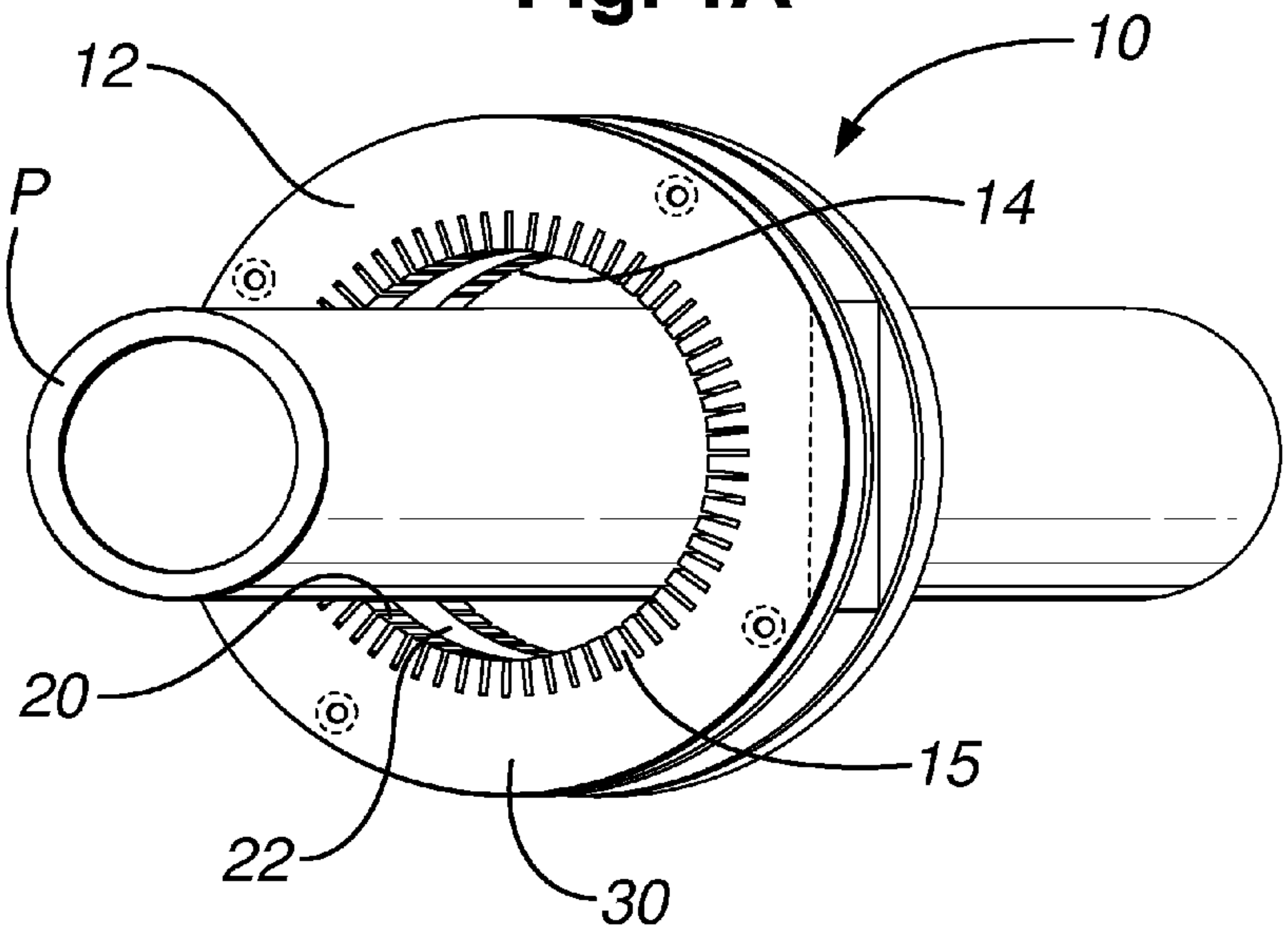
(54) Title: APPARATUS AND METHOD FOR INSPECTING A TUBULAR

Fig. 1A



(57) Abstract: A shoe apparatus (10; 100) for inspecting a tubular (P), which shoe apparatus comprises: a body (12; 112); a film (22; 50; 51; 113) on saidbody(12; 112), said film comprising piezoelectric material, and a plurality of ultrasonic transducers(20; 110) on said film.

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Apparatus and Method for Inspecting a Tubular

The present invention relates to a shoe apparatus for inspecting a tubular, to an apparatus comprising the shoe apparatus and to a method of inspecting tubulars.

In certain aspects the present invention is directed to the non-destructive testing of tubulars and, in certain particular aspects, to systems and methods for such testing which employ ultrasonic transducers comprising a polyvinylidenefluoride piezoelectric film.

Non-destructive testing of tubulars can indicate flaws in the tubular. The prior art includes a wide variety of systems and methods for the non-destructive testing of tubulars; e.g., but not limited to, the systems and methods disclosed in U.S. Patents 5,063,776; 5,616,009; 5,975,129; 7,055,623; 5,715,861; 4,638,978; and in U.S. Application Ser. No. 11/098,166 filed 04/04/2005 (co-owned with the present invention), all patents and the application listed incorporated fully herein for all purposes.

In certain prior art methods ultrasonic beams generated by transducers cannot cover the full body of a tubular under test; and in other prior methods in which the ultrasonic beams generated by all the transducers can cover the full body of the tubular under test, mechanical rotation of either the scanning head or the tubular has to be facilitated, or a high number of individually packaged transducers is used, which can lead to complicated system design, high cost, and difficulty of operation.

According to the present invention there is provided a shoe apparatus for inspecting a tubular, which shoe apparatus comprises:

a body;

a film on said body, said film comprising piezoelectric material, and a plurality of ultrasonic transducers comprising said film. In some embodiments the film comprises an electroactive polymer, for example a ferroelectric polymer such as PVDF or a copolymer thereof. One advantage of using an electroactive polymer is that the shoe apparatus is more reliable and can be made at relatively low-cost compared to using piezo-ceramic transducers. Another advantage is that the shoe apparatus can be designed so that no rotation is required of the pipe or any shoe in order to effect inspection of the whole tubular.

Further features are set out in claims 2 to 22 to which reference is made.

According to another aspect of the present invention there is provided an apparatus for inspecting a tubular, which apparatus comprises one or more shoe apparatus as set out above, said one or more shoe apparatus arranged so that, in use, substantially the entire tubular may be inspected without relative rotation between the tubular and said one or more shoe apparatus.

According to yet another aspect of the present invention there is provided a method for inspecting a tubular, the method comprising:

(1) introducing the tubular into an apparatus as set out above; and

(2) activating said ultrasonic transducers using a control system to generate ultrasonic waves directed to the tubular to inspect the tubular.

Further steps of the method are set out in claims 24 to 29 to which reference is made.

The present invention, in at least certain embodiments, discloses systems and methods which employ a plurality of spaced-apart ultrasonic transducers made with polyvinylidenefluoride ("PVDF") (and its copolymers) piezoelectric films for measuring tubular wall thickness and/or detecting flaws.

In certain aspects of inspection systems according to the present invention with such transducers a tubular passing through an inspection system is not rotated and the transducers are not rotated.

When a mechanical stress, e.g. a stress due to an ultrasonic wave, is applied to an electroactive film, such as a PVDF film, which has two electrodes, each on a different surface of the film, the film that receives the wave generates a measurable electric voltage between electrodes on two surfaces. When an electric voltage is applied to the film through the electrodes, a mechanical strain is generated resulting in the generation of an ultrasonic wave. These two effects are combined in a PVDF ultrasonic transmitter-receiver ("transducer") useful in systems and methods according to the present invention. PVDF films with electrodes and ultrasonic transducers with PVDF films are commercially available.

In certain particular aspects, the present invention provides systems and methods for measuring tubular wall thickness and for detecting defects with a plurality of PVDF ultrasonic transducers attached to and spaced apart around a body (e.g. a hollow cylindrical body or a hollow conical body, e.g. with at least one, two, three or more PVDF films) through which a tubular is movable (e.g., but not limited to oilfield tubulars; e.g., but not limited to risers, casing, tubing, pipe, drill pipe, mechanical tubing, boiler tubing, and drill collars) whose wall thickness along its entire length is to be measured or whose entire body is to be scanned for defects. Each separate PVDF ultrasonic transducer is electrically connected to a computerized control system with control electronics or a circuit board which is in communication with such a control system.

In certain aspects, between the PVDF transducers and an outer tubular surface is a coupler, e.g. an ultrasonic coupling agent, e.g. water. The PVDF transducers are excited by high voltage pulses produced by the control system to generate ultrasonic waves that propagate to the tubular through the coupling agent. In the case of a hollow cylindrical body, the propagation direction of the ultrasonic waves is perpendicular to the outer and inner surfaces of the tubular. The ultrasonic waves are reflected by both surfaces and go back to the PVDF transducers. The reflection from the outer surface is commonly called interface echo. The reflection from the inner surface is commonly called back wall echo. Inside the tubular wall, the ultrasonic waves can also be reflected back and forth numerous times before their energy dies down, giving rise to multiple back wall echoes. The interface echo and the back wall echo or echoes are used to measure the tubular wall thickness since the time between two adjacent echoes is proportional to the thickness. In the case of a hollow conical body, the propagation direction of the ultrasonic waves is in an angle with the normal of the outer and inner surfaces of the tubular. The ultrasonic waves are reflected back to the PVDF transducers by defects, such as cracks, in the tubular wall. The returned waves are used to detect such defects. The control system communicates with (control, activates or excites; and/or detects return signals) the transducers.

The body, e.g. a hollow cylindrical or conical body, is a whole integral piece or it is two or more separate pieces. There can be one or more PVDF ultrasonic transducer on each PVDF film. In certain particular aspects of systems according to the present invention, multiple PVDF ultrasonic transducers positioned adjacent to each other are communicated with via a control system and excited at the same time, or each is communicated with and excited in order with a well defined delay pattern to form a composite wave, equivalent to one produced by a single PVDF transducer occupying the same area by the multiple transducers. The composite wave is used to obtain wall thickness measurements. Then a next group of transducers, i.e., one or more transducers from above and one or more transducers next to them, are excited in the same way to form another second composite wave that is partially overlapping with the first composite wave and the second composite wave is used to measure the tubular wall again. Multiple composite waves can also be formed at different circumferential locations of the tubular at the same time. By forming composite waves around the tubular, the system obtains wall thickness measurements and flaw detection for the entire surface of the tubular without any gaps and without mechanically rotating either the tubular or the transducers.

The present invention, therefore, provides in at least certain embodiments, a shoe apparatus for tubular inspection, the shoe apparatus including: a body; a film on the body, the film made of piezoelectric material; and a plurality of ultrasonic transducers on the film. Such a shoe apparatus may have one or some (in any possible combination) of the following: wherein the body is generally cylindrical and has a channel therethrough through which a tubular to be inspected is passable; a control system, each ultrasonic transducer in communication with the control system; wherein the control system controls any individual ultrasonic transducer, a series of adjacent ultrasonic transducers, or a plurality of series of adjacent ultrasonic transducers; a coupler for propagating ultrasonic waves from the ultrasonic transducers to a tubular to be inspected, the coupler adjacent the body for interposition between the body and a tubular to be inspected; the shoe is a plurality of individual shoes which are movable together to form a channel through which a tubular to be inspected is passable; movement apparatus for moving each individual shoe segment; each individual shoe segment overlaps an adjacent shoe segment; wherein the plurality of ultrasonic transducers are spaced-apart around the channel; a circuit board attached to the body, and each ultrasonic transducer connected to the circuit board; wherein the body is generally cylindrical and the plurality of ultrasonic transducers are spaced-apart around the generally cylindrical body; wherein each ultrasonic transducer includes a portion of the film with a top surface, a bottom surface, a top electrode on the top surface, a bottom electrode on the bottom surface, each electrode connected to the circuit board; and/or a control system, each ultrasonic transducer in communication with the control system via the circuit board.

The present invention, therefore, provides in at least certain embodiments, a method for inspecting a tubular, the method including introducing the tubular into a shoe apparatus for inspecting tubulars, the shoe apparatus as any disclosed herein according to the present invention, controlling the ultrasonic transducers with a control system of the shoe apparatus, and activating ultrasonic transducers of the shoe apparatus using the control system to generate ultrasonic waves directed to the tubular to inspect the tubular. Such a method may have one or some (in any possible combination) of the following: wherein a body of the shoe apparatus is generally cylindrical and has a channel therethrough through which the tubular passes and wherein there is a plurality of ultrasonic transducers spaced-apart around the generally cylindrical body, the method further including with the control system, communicating with individual ultrasonic transducers to inspect the tubular; wherein the body is generally cylindrical and has a channel therethrough through which the tubular passes and wherein the plurality of ultrasonic transducers are spaced-apart around the generally cylindrical body, the method further including with the control system, communicating with a plurality of ultrasonic transducers to form a composite wave to inspect the tubular; wherein each of the plurality of ultrasonic transducers is used simultaneously; wherein each of the plurality of ultrasonic transducers is used in order according to a defined delay pattern; wherein the tubular has a circumference and a generally cylindrical body and has a channel through the body for tubular passage, and wherein the plurality of ultrasonic transducers are spaced-apart around the generally cylindrical body, the method further including activating pluralities of adjacent ultrasonic transducers to form a plurality of multiple composite waves around the tubular's circumference to inspect the entire tubular; and/or inspecting the tubular with the shoe apparatus without rotating the tubular and/or without rotating the ultrasonic transducers.

For a better understanding of the present invention reference will now be made by way of example only to the accompanying drawings in which:

Fig. 1A is a schematic perspective view of a first embodiment of an apparatus according to the present invention in use;

Fig. 1B is a schematic front view of part of the apparatus of Fig. 1A;

Fig. 1C is a schematic cross-section view through the apparatus of Fig. 1A;

Fig. 2A is a schematic perspective view of a first embodiment of a PVDF film for use in the apparatus of Fig. 1A;

Fig. 2B is a schematic end view of part of the film of Fig. 2A, the film in a flattened state;

Fig. 2C is an enlargement in schematic plan view of a corner part of the film of Fig. 2A;

Fig. 2D is schematic perspective view of a second embodiment of a PVDF film for use in the system of Fig. 1A;

Fig. 2E is a schematic end view of part of the apparatus of Fig. 1A;

Fig. 2F is an enlarged view of part of Fig. 2E;

Fig. 2G is schematic diagram showing the connection of the part of the apparatus shown in Fig. 2E to a control system;

Fig. 3A is a schematic perspective view of a second embodiment of an apparatus according to the present invention in use;

Fig. 3B is a schematic perspective view of part of the apparatus of Fig. 3A;

Fig. 3C is a schematic side view of the part shown in Fig. 3B in use;

Fig. 3D is a schematic perspective view of the apparatus of Fig. 3A mounted to a frame; and

Fig. 3E is a schematic end view of the system of Fig. 3D.

Fig. 1A shows a system 10 according to the present invention which has a generally cylindrical body 12 (or "shoe") with a channel 14 through which a pipe P to be tested is movable. A plurality of PVDF ultrasonic transducers 20 are spaced-apart around the circumference of the channel 14. PVDF film 22 covers the interior of the channel 14 and each transducer 20 includes a strip or finger of this film. The PVDF film 22 can be one or more pieces, each of which has patterned electrodes on its top and bottom surfaces to form multiple transducers. For example, but not limited to, the pattern can be an array of rectangular electrodes with small gaps between them. The area where the top electrode and the bottom electrode fully overlap defines an active area of each transducer 20. The 'top' electrodes can be used as the ground electrodes and then the 'bottom' electrodes are the signal electrodes, or vice versa. A coupler (not shown) adjacent the body 12 and interposed between the transducers and a tubular to be inspected provides coupling for the transducers and maintains stand off between the tubular and the transducers as the tubular moves through the body 12.

Each transducer 20 corresponds to a portion 15 of the body 12 and is connected directly to control electronics or, e.g. as shown connected to a printed circuit board ("PCB") 30. In certain aspects each transducer has a width of about 0.25″ (~6mm) around the circumference of the body and this has been found to work well. A ground electrode of each transducer is connected to a ground plane of the PCB 30, and its signal electrode is connected to a signal trace on the PCB 30 (see traces 15, Figs. 2E, 2F, and traces 115, Fig. 3B). "Traces" are formed on a circuit board by depositing or "printing" a thin layer of conductive material on the board's surface to connect individual electronic components. Metal plates 40 outside each board 30 are bolted together with bolts 42 that pass through the body 12. In one aspect the plates 40 are made of aluminium (but may be made of e.g. steel or copper or any non-conducting material). The body 12 is made, e.g., of LUCITE (trademark) material or any suitable plastic, metal, rubber, or polyester.

Fig. 2A shows a PVDF piezoelectric film 50 which has a base 52 made of PVDF; a top layer 54 of spaced-apart rows 55 of electrodes; and a bottom layer 56 of spaced-apart rows 57 of electrodes (see Fig. 2B). The top electrodes 55 and the bottom electrodes 57 overlap partially. The overlapped area (e.g. the area OA, Fig. 2B) defines the active area of a transducer, and the non-overlapped areas (e.g. at the ends of each electrode) are used for electrical connection that can be achieved by, e.g., but not limited to, mechanically pressing the non-overlapped ends of the film 50 onto the PCB 30 so that the electrodes are in direct contact with the traces of the PCB (see traces 15, Figs. 2E, 2F, and traces 115, Fig. 3B) or directly attaching connectors or wires to the non-overlapped ends of the film 50. Typical thicknesses of commercially available PVDF films include 9 µm, 25 µm, 52 µm, and 110 µm, though other thicknesses can be used. In certain aspects, electrodes are made of conductive inks, paints, tapes, or vacuum deposited metals.

As shown in Fig. 2C, the film 50 is cut (lines 53) between the rows 55, 57 (either from end to end or only at the ends) to form strips or fingers 58 that are folded over the spaced-apart traces of the boards 30 to achieve electrical connections (see also Fig. 2E). In the arrangement shown, traces 15 on the PCB 30 are connected to the 'bottom' electrodes 54 (i.e. those on the outside surface of the film 50 in Fig. 2D) on one side of the body 12. When the 'top' electrodes 54 (i.e. those on the inside surface of the film 50 in Fig. 2D) are folded outwards onto the body 12 the electrodes do not make contact with anything. When the metal plate 40 (see Fig. 1C) is bolted to the end of the body 12, the exposed part of these electrodes comes into contact with that plate. The metal plate 40 is then connected to the ground plane of the PCB 30 thereby connecting the top electrodes to ground. One advantage of connecting the top and bottom electrodes this way round is that the signal electrodes (i.e. the bottom electrodes) are better shielded from outside electromagnetic interference. However, it is possible for the electrodes to be connected the opposite way round i.e. for the top electrodes to be connected to the traces 15 and the bottom electrodes to be connected to the ground plane of the circuit board.

Fig. 2D shows a piece of PVDF piezoelectric film 51 (not to scale) with strips 58a formed into a cylinder for insertion into a channel like the channel 14 and attachment to the wall of the channel using an adhesive. The cutting lines 53 are parallel to the axis of the cylinder. Each strip 58a is a PVDF ultrasonic transducer 20 whose top ground electrode is connected to the ground plane of the PCB 30 and whose bottom signal electrode is connected to a signal trace of the PCB 30. The test body 12 behind the film 51 acts as a backing material for the transducer. The top of the film 51 can be coated with acrylics, adhesives, synthetic rubber resins, epoxies and/or cyano-acrylates, etc., to prevent corrosion and oxidation of the electrodes.

As shown in Fig. 2E, the film 51 is positioned within a test body 12 so that when the ends of the strips 58a are folded over on the PCB 30 they line up with the signal traces 15 of the PCB 30. As shown in Fig. 2F, a strip 58a is folded over a signal trace 15 of the PCB 30.

Fig. 2G illustrates a primary connection 70 connecting the PCB board 30 to a control system 72. All the signal traces 15 on the PCB 30 are connected to the primary connection 70 and, thus, all the ultrasonic transducers, defined by the strips 58a, are connected to the control system 72. The control system 72 can excite one transducer by generating and delivering high voltage pulses to it and take wall or flaw measurement from the signal received by it subsequently, then move to the next transducer. In one aspect this leaves a gap between two successive measurements because there is a gap between the ultrasonic beams produced by two adjacent transducers. The control system can also excite multiple adjacent transducers at the same time or with a well defined delay pattern to form a composite wave, equivalent to one produced by a single PVDF transducer occupying the same area by the multiple transducers, and take wall or flaw measurements from the summed signal received by the same group of the transducers, then move to a next group of adjacent transducers to form a new composite wave that is partially overlapped with the previous composite wave. This eliminates the gaps caused by exciting a single transducer at a time, resulting in a full coverage of the entire circumference and area of the pipe.

Fig. 3A shows a system 100 according to the present invention like the system 10, but with a plurality of distinct offset test shoes 102 (or "shoe segments"). The test shoes 102 are partially overlapped (e.g. overlap as indicated by dotted lines in Fig. 3E) to fully cover the entire circumference of the pipe P being tested. Fig. 3B shows internal components of a test shoe 102. A PVDF film 113 is attached to the inner cylindrical surface of a backing material 112 by an adhesive. The PVDF film 113 has a plurality of ultrasonic transducers 110 on it. Each

PVDF film 113 and its ultrasonic transducers 110 are made as shown in Fig. 2A. The end strips 114 of each ultrasonic transducer 110 are cut and folded over the signal traces 115 on a PCB 118 that is mounted to the side of the backing material 112. The end strips 114 and the signal traces 115 are electrically connected. The signal traces 115 are connected to a connector 117 mounted on the PCB 118. The shoes 102 are electrically connected to a control system (like the control system of Fig. 2G) through the connectors 117 via cables C. Like the system 10, the control system can excite one transducer or a group of adjacent transducers to form a single wave or a composite wave and take wall measurement, then move to the next transducer or a next group of transducers.

Fig. 3C shows a side view of a test shoe 102 with its inside exposed, in the axial direction of a test pipe E below it. Although the figure shows the test shoe 102 in direct contact with the pipe E, it could be spaced-apart from the pipe. With the test shoe 102 in direct contact with the pipe E, it sits on and conforms to the outer surface of the pipe E. Immediately below the PVDF film is a water compartment 116. The water compartment 116 is open from the bottom or sealed by an acoustically transparent membrane 119. The water compartment 116 provides water coupling for the ultrasonic transducers and maintains stand off between the transducers and the pipe when the pipe moves through the system in the axial direction. If the water compartment 116 is open, it is filled continuously with running water. If the water compartment 116 is sealed, only the gap 111 between the membrane 119 and the outer surface of the pipe E is filled continuously with running water.

Fig. 3D shows a plurality of test shoes 102 mounted to a frame 120 through movable arms 121 and an actuating mechanism 122 (e.g., but not limited to, air cylinders). The arms 121 bring the shoes down to the pipe or move them off a pipe R. For example, when the pipe R is moved into the system in the axial direction, the actuated arms 121 bring the shoes toward the pipe to start testing and hold the shoes around the pipe while testing is in progress. When the pipe is about to leave the system, the actuated arms move the shoes away from the pipe. Fig. 3E is an end view of the system in Fig. 3D.

One particular advantage of the present invention is that tubulars can be inspected without the need to rotate an inspection head around the tubular, or to rotate the tubular relative to the inspection head. This greatly simplifies the construction and maintenance of the inspection apparatus, and in some circumstances may allow tubulars to be inspected at a faster rate than inspection methods that rely on rotation. Furthermore the invention provides a multi-channel inspection head at relatively low cost (compared to using traditional piezo-ceramic transducers for example).

Claims: -

1. A shoe apparatus for inspecting a tubular, which shoe apparatus comprises:

a body;

a film on said body, said film comprising piezoelectric material, and

a plurality of ultrasonic transducers on said film.

2. A shoe apparatus as claimed in claim 1, further comprising a control system, each of said plurality of ultrasonic transducers in communication with said control system.

3. A shoe apparatus as claimed in claim 2, wherein in use said control system controls any individual ultrasonic transducer, a series of adjacent ultrasonic transducers, or a plurality of series of adjacent ultrasonic transducers.

4. A shoe apparatus as claimed in claim 1, 2 or 3, further comprising a coupler for propagating ultrasonic waves from the ultrasonic transducers to a tubular to be inspected, said coupler adapted to fit between said body and a tubular to be inspected.

5. A shoe apparatus as claimed in any of claims 1 to 4, wherein said body is generally cylindrical and comprises a channel therethrough through which a tubular to be inspected is passable.

6. A shoe apparatus as claimed in any of claims 1 to 4, further comprising a plurality of separate bodies that in use form channel through which a tubular to be inspected is passable.

7. A shoe apparatus as claimed in claim 6, further comprising movement apparatus for moving each separate body toward and away from a position in which said channel is formed.

8. A shoe apparatus as claimed in claim 6 or 7, wherein

each body provides a portion of circumferential coverage on a tubular to be inspected, and wherein said plurality of separate bodies are arranged such that adjacent portions of circumferential coverage are overlapping.

9. A shoe apparatus as claimed in any preceding claim, wherein said plurality of ultrasonic transducers is spaced apart along the or each body.

10. A shoe apparatus as claimed in any preceding claim, further comprising a circuit board attached to said body, and each ultrasonic transducer connected to said circuit board.

11. A shoe apparatus as claimed in claim 10, wherein the body is generally cylindrical and the plurality of ultrasonic transducers is spaced-apart around the generally cylindrical body.

12. A shoe apparatus as claimed in claim 10 or 11, wherein each ultrasonic transducer comprises a portion of said film with a top surface, a bottom surface, a top electrode on the top surface, a bottom electrode on the bottom surface, each electrode connected to said circuit board.

13. A shoe apparatus as claimed in claim 12, further comprising a first circuit board to which one set of said top or bottom electrodes is connected, and a second circuit board to which the other of said top or bottom electrodes is connected.

14. A shoe apparatus as claimed in claim 10, 11, 12 or 13, wherein said film is attached to an inspection part of said body that, in use, faces a tubular being inspected, said film having ends exposed outside said inspection part, ends exposed on one side of said body connectable to signal traces on said circuit board and ends exposed on the other side of said body connectable to a ground plane of said circuit board.

15. A shoe apparatus as claimed in claim 14, wherein

said exposed ends are folded over an edge on either side of said body.

16. A shoe apparatus as claimed in claim 14, wherein said film comprises a top electrode nearest side tubular in use, and a bottom electrode in use further from said tubular than said top electrode, said exposed end with said top electrode being folded against a trace on said circuit board on one side of said body, and on the other side of said body said exposed end with said bottom electrode is folded against said body and said bottom electrode is connected to a ground plane of said circuit board via a conductive plate.

17. A shoe apparatus as claimed in any of claims 10 to 16, further comprising a control system, each ultrasonic transducer in communication with said control system via said circuit board.

18. A shoe apparatus as claimed in any preceding claim, wherein said film comprises an electroactive polymer.

19. A shoe apparatus as claimed in claim 17, wherein said electroactive polymer comprises polyvinylidenefluoride or a co-polymer thereof.

20. A shoe apparatus as claimed in any preceding claim, wherein said film has a thickness between about 9µm and 110µm.

21. A shoe apparatus as claimed in any preceding claim, wherein each transducer has a width corresponding to a circumferential dimension of a tubular to be inspected, said width being about 6mm.

22. An apparatus for inspecting a tubular, which apparatus comprises one or more shoe apparatus as claimed in any of claims 1 to 21, said one or more shoe apparatus arranged so that, in use, substantially the entire tubular may be inspected without relative rotation between the tubular and said one or more shoe apparatus.

23. A method for inspecting a tubular, the method

comprising:

(1) introducing the tubular into an apparatus as claimed in claim 22; and

(2) activating said ultrasonic transducers using a control system to generate ultrasonic waves directed to the tubular to inspect the tubular.

24. A method according to claim 23, the method further comprising the step of said control system communicating with individual ultrasonic transducers to inspect the tubular.

25. A method according to claim 23, further comprising the step of said control system communicating with a plurality of ultrasonic transducers to form a composite wave to inspect the tubular.

26. A method according to claim 25, further comprising the step of activating each of the plurality of ultrasonic transducers substantially simultaneously.

27. A method according to claim 25, further comprising the step of activating each of said plurality of ultrasonic transducers in order according to a defined delay pattern.

28. A method according to any of claims 25 to 27, further comprising the step of activating pluralities of adjacent ultrasonic transducers to form a plurality of multiple composite waves around the tubular's circumference to inspect the entire tubular.

29. A method according to any of claims 23 to 28, further comprising the step of inspecting substantially the entire tubular without rotating said tubular or said shoe apparatus with respect to one another.

Fig. 1A

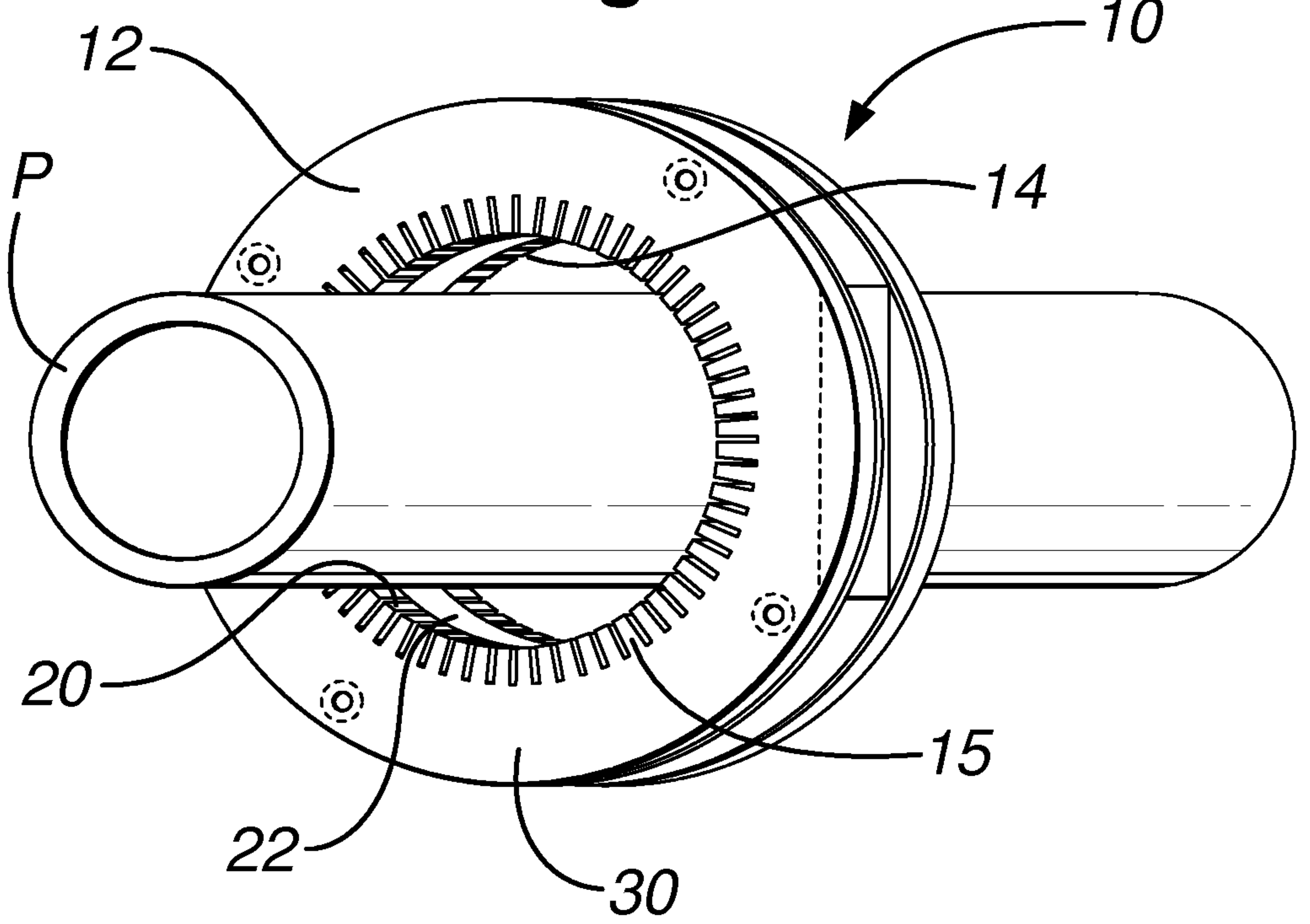

Fig. 1B

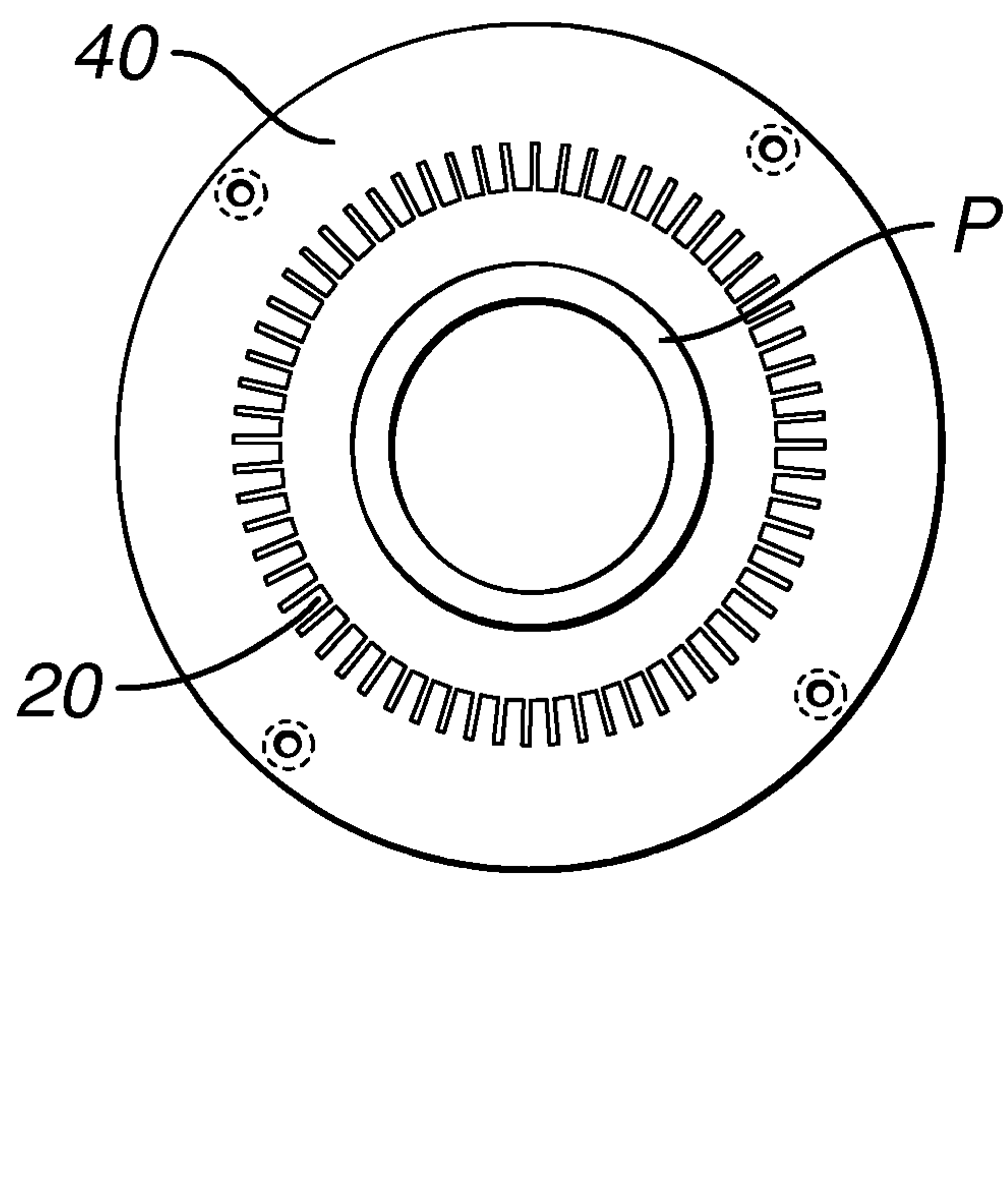

Fig. 1C

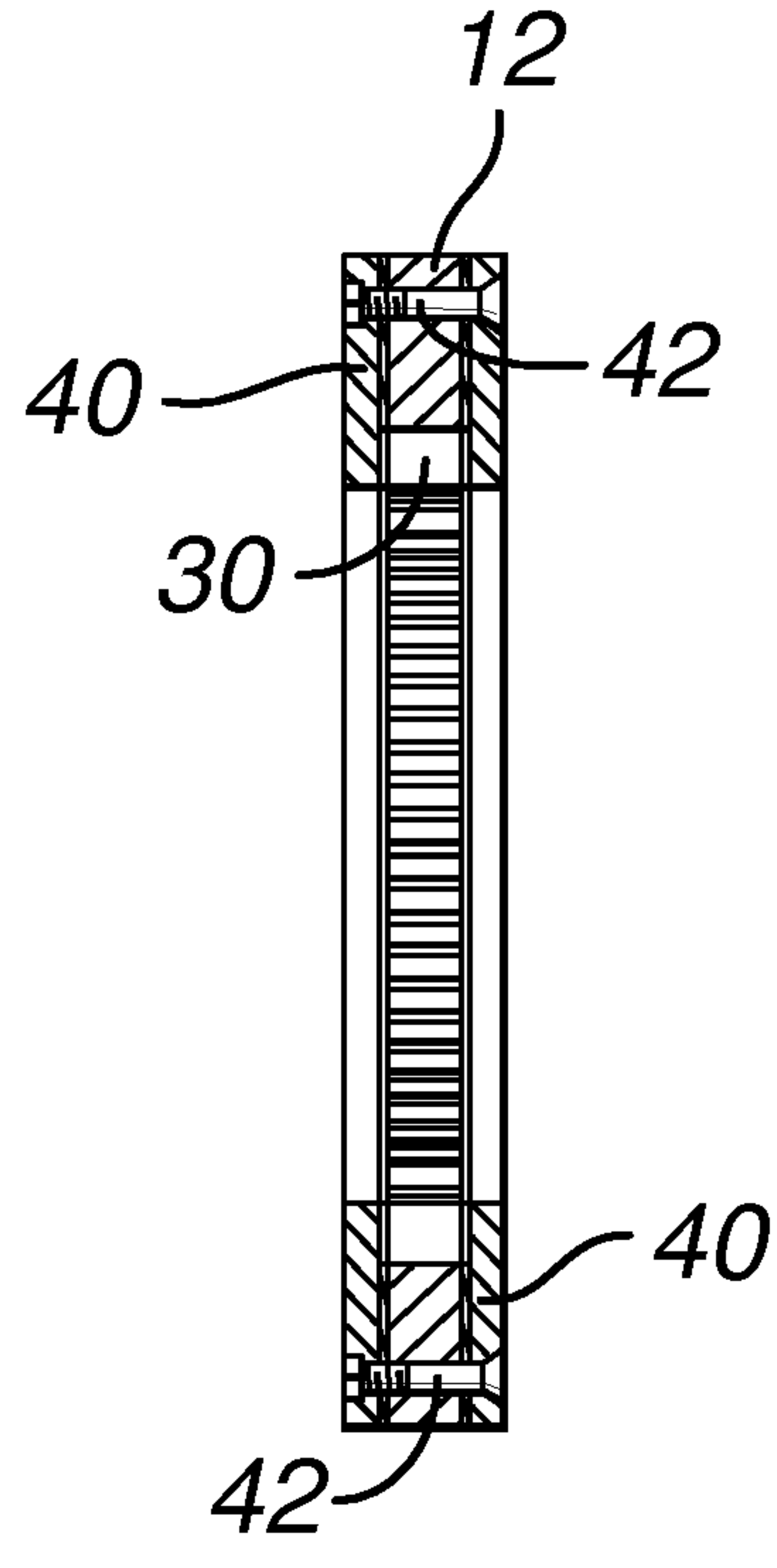

Fig. 2A

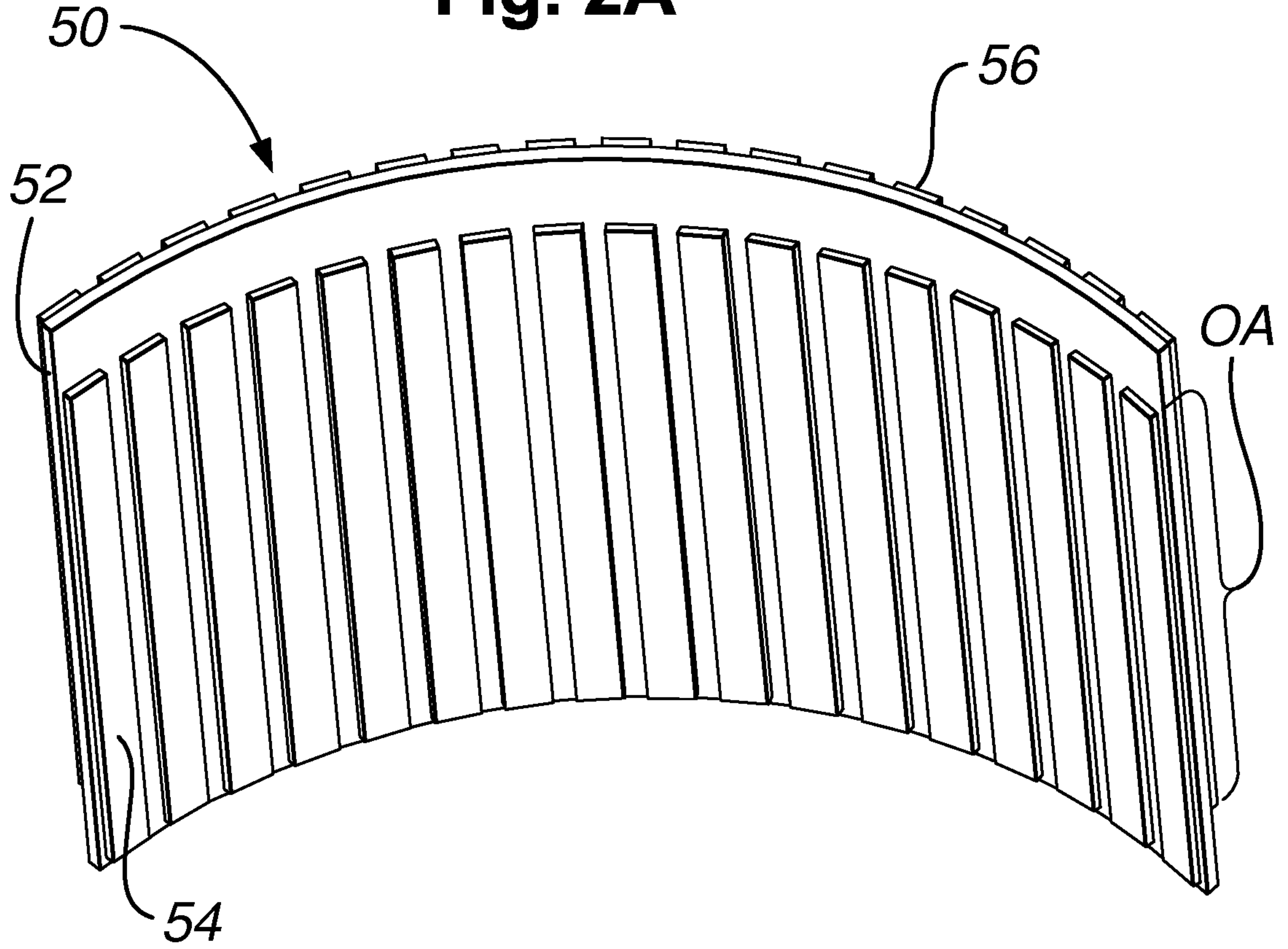

Fig. 2B

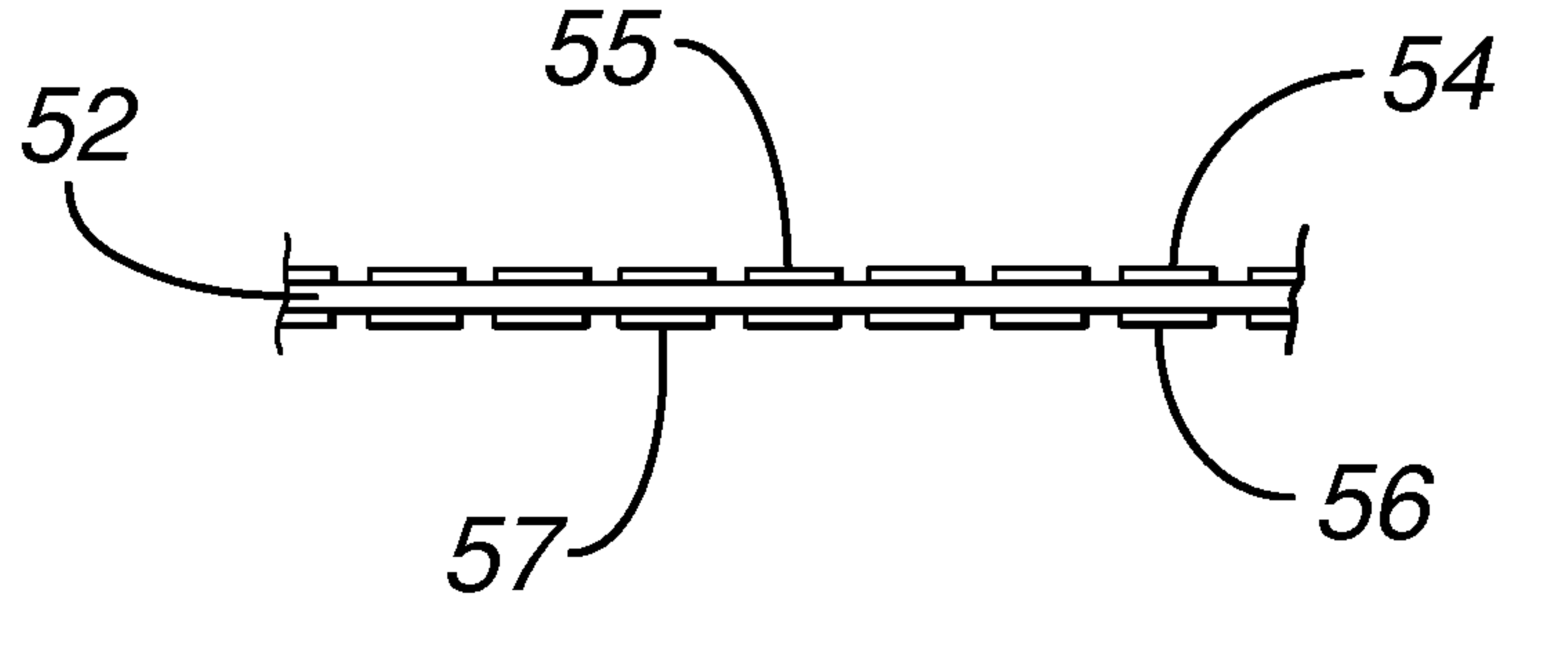

Fig. 2C

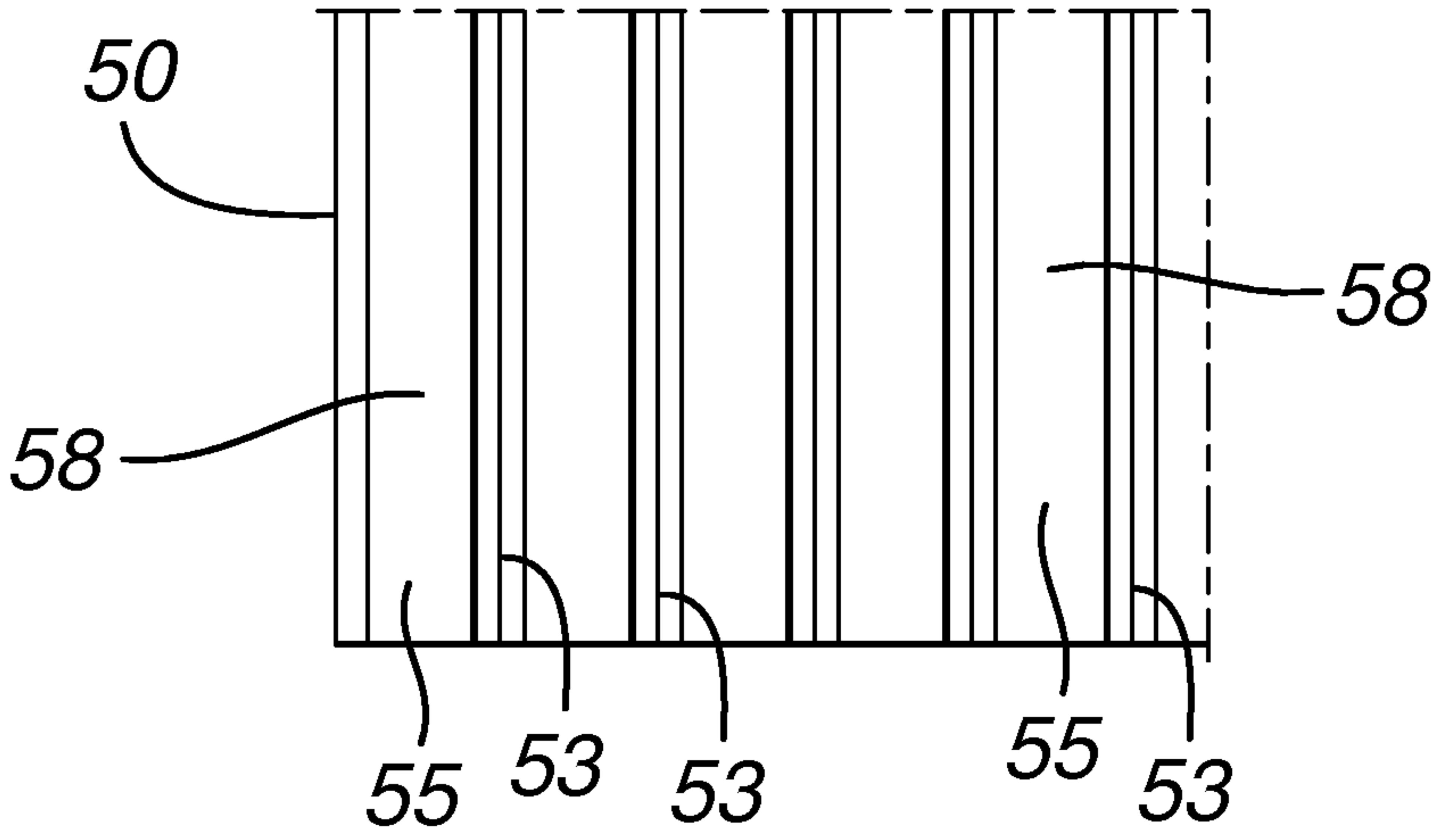

Fig. 2D

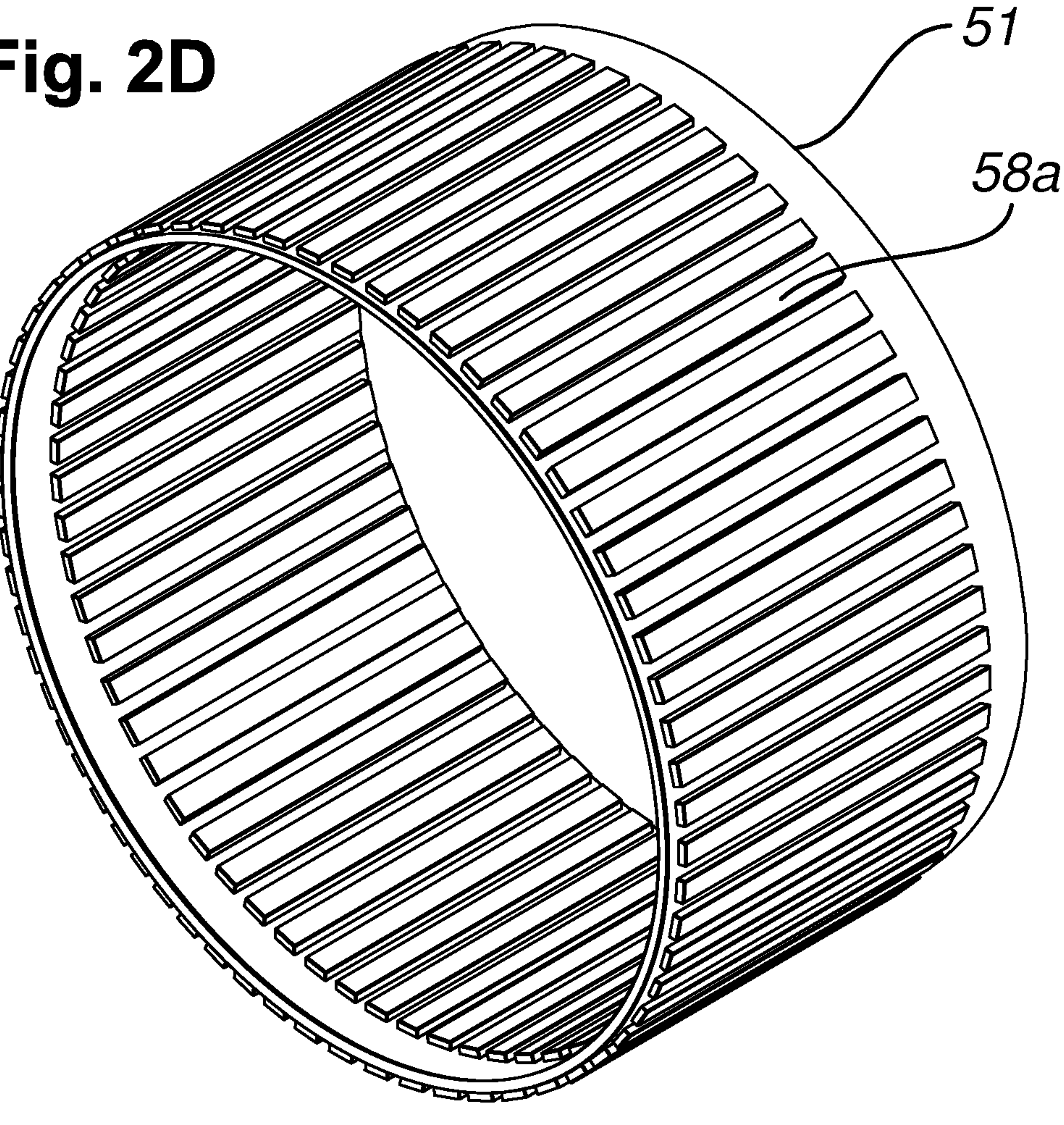

Fig. 2E

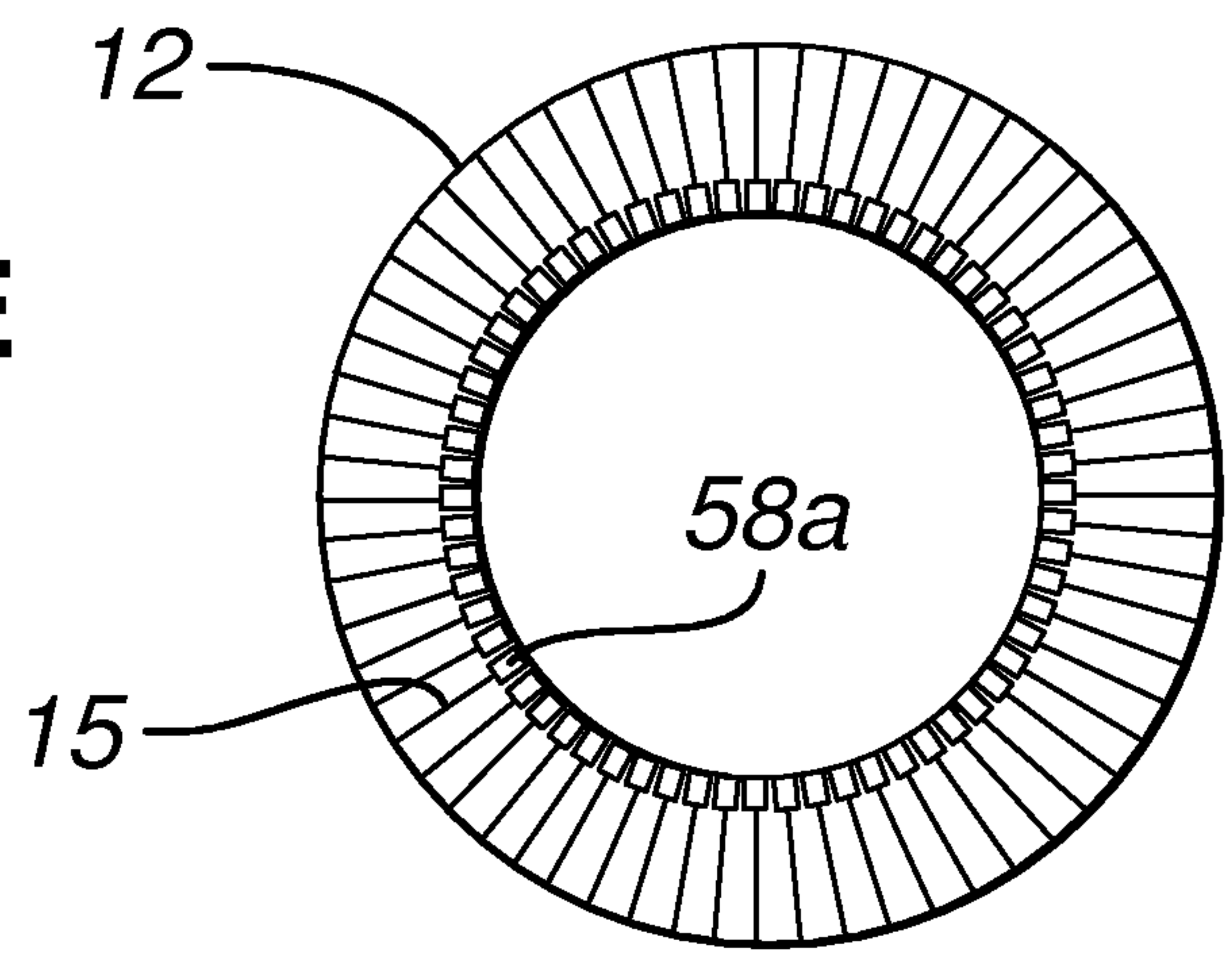

Fig. 2F

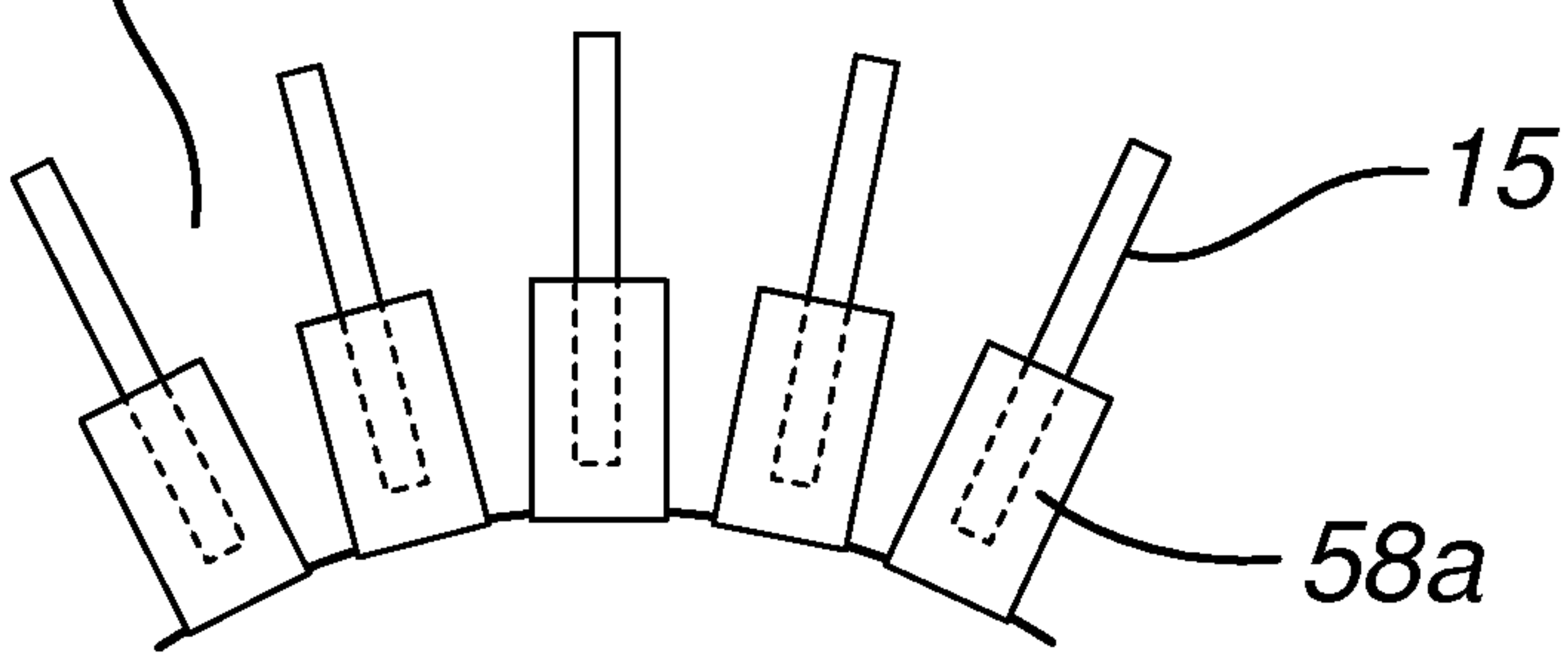

Fig. 2G

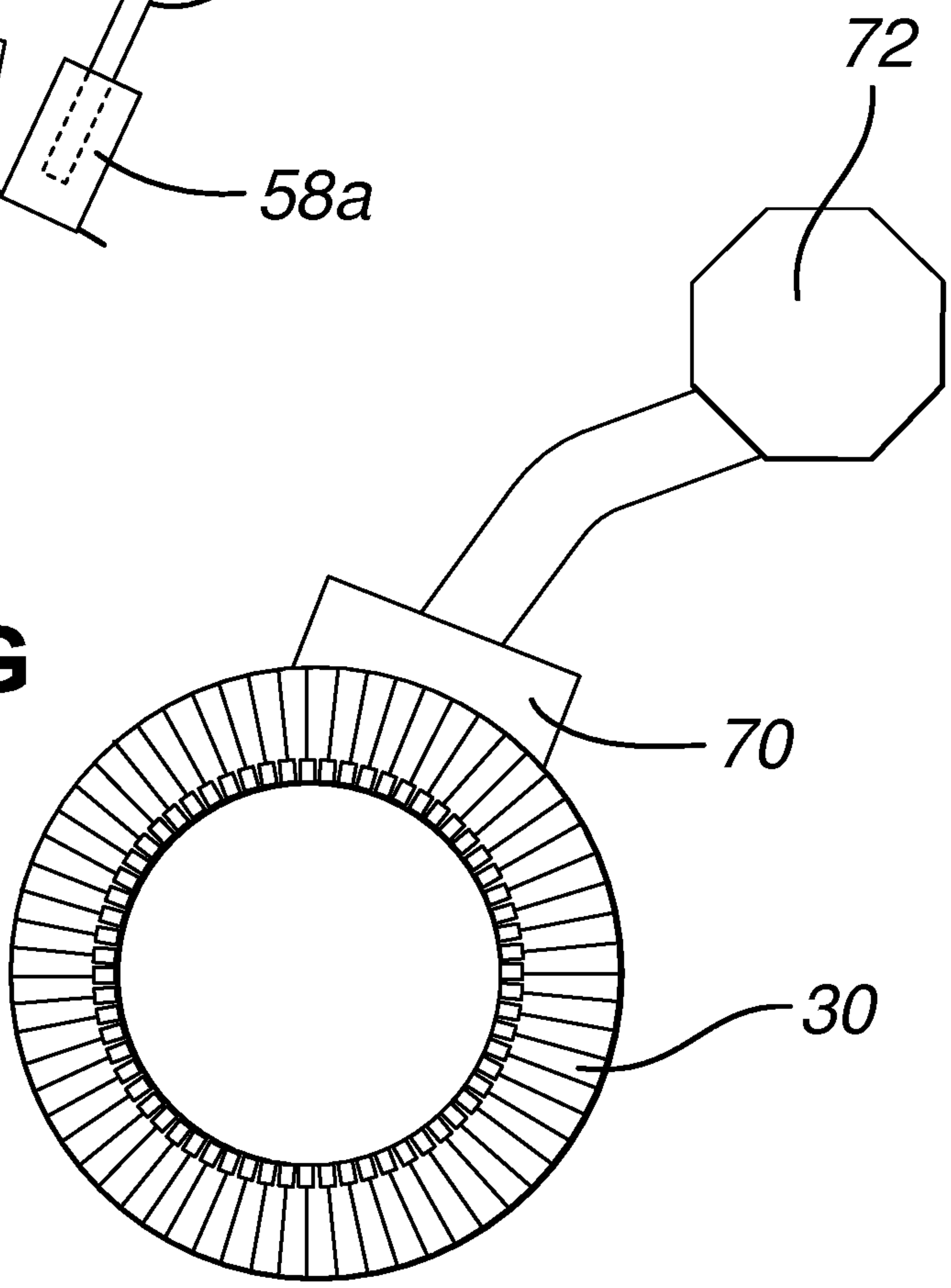

Fig. 3A

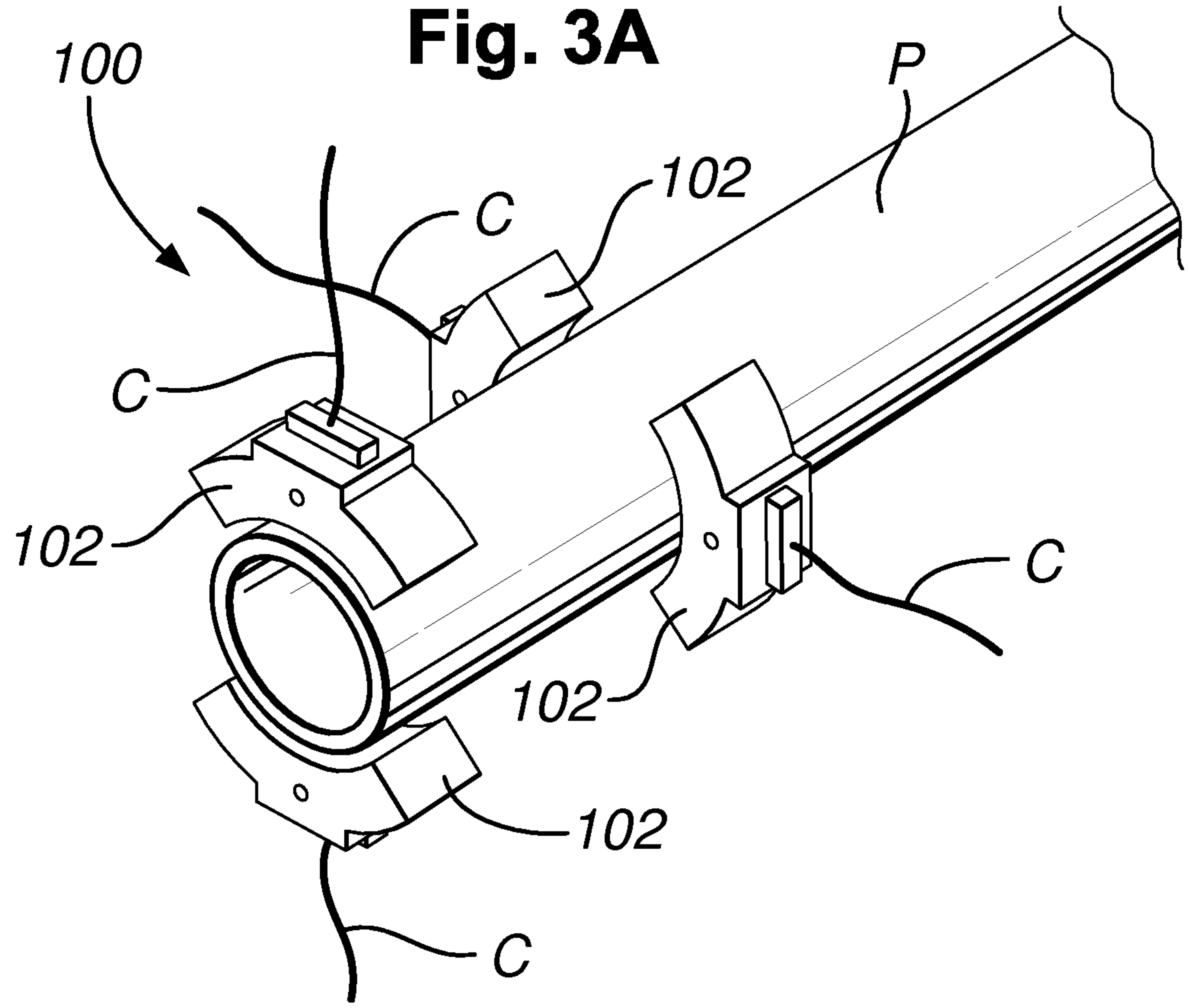

Fig. 3B

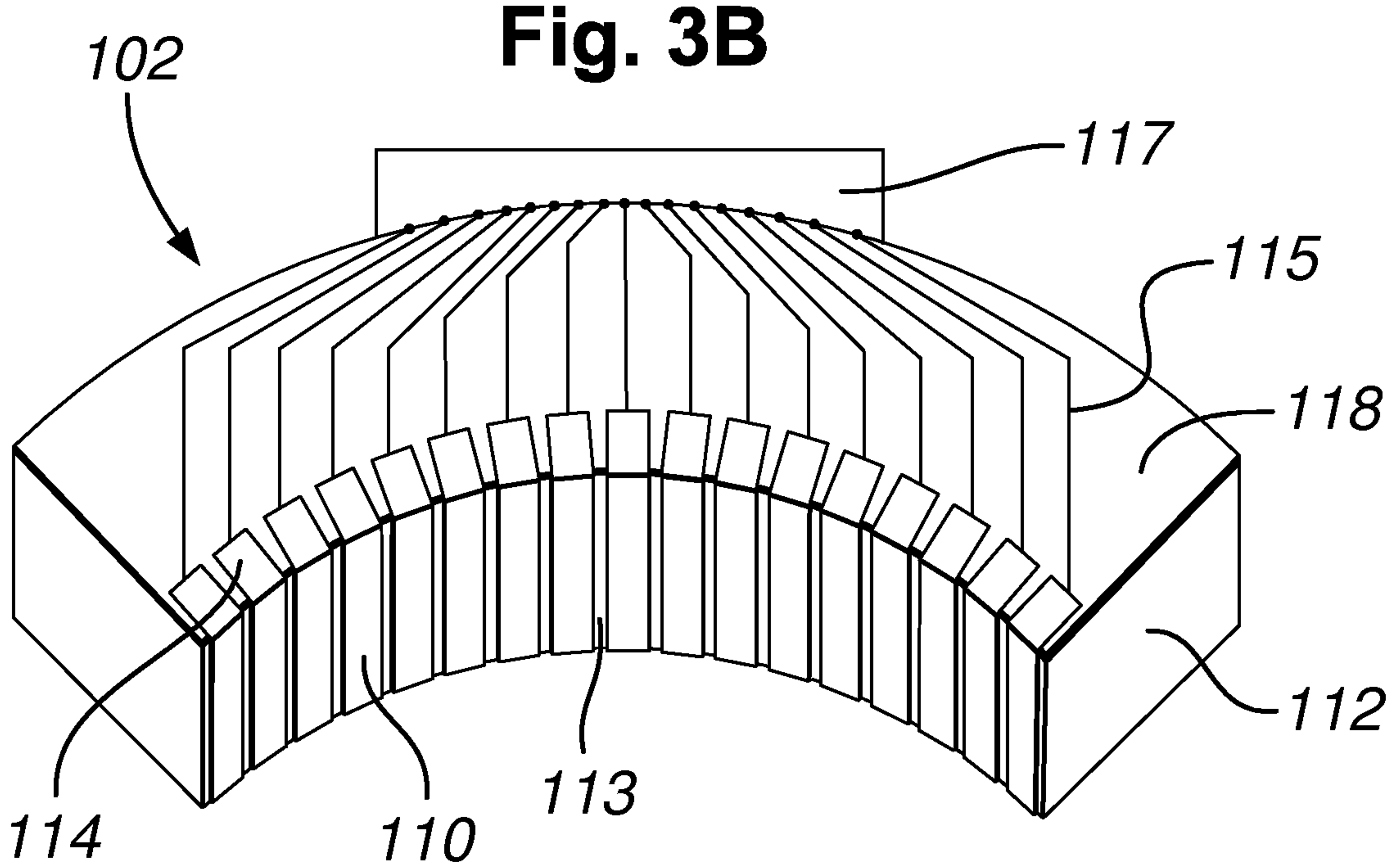

Fig. 3C

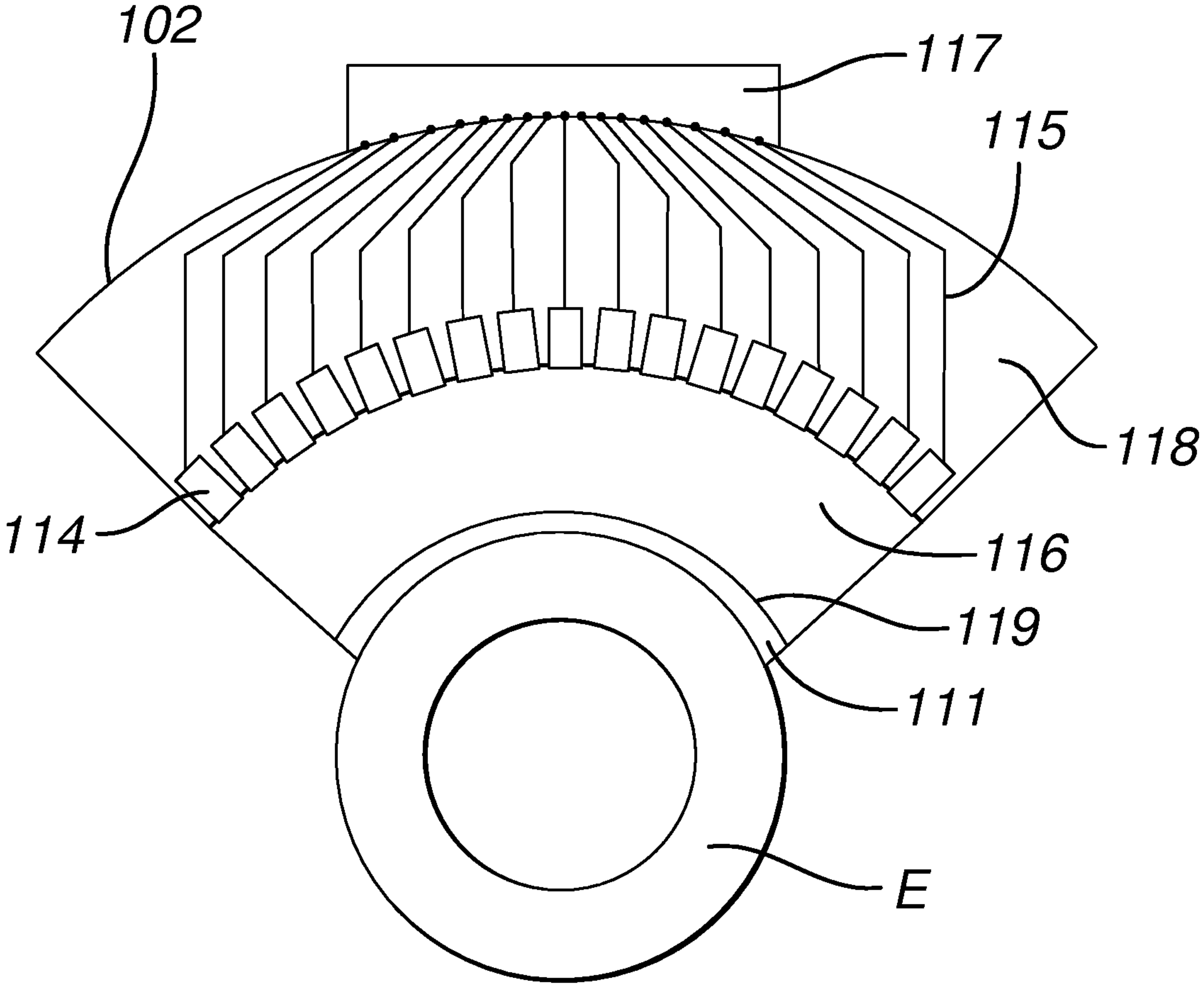

Fig. 3D

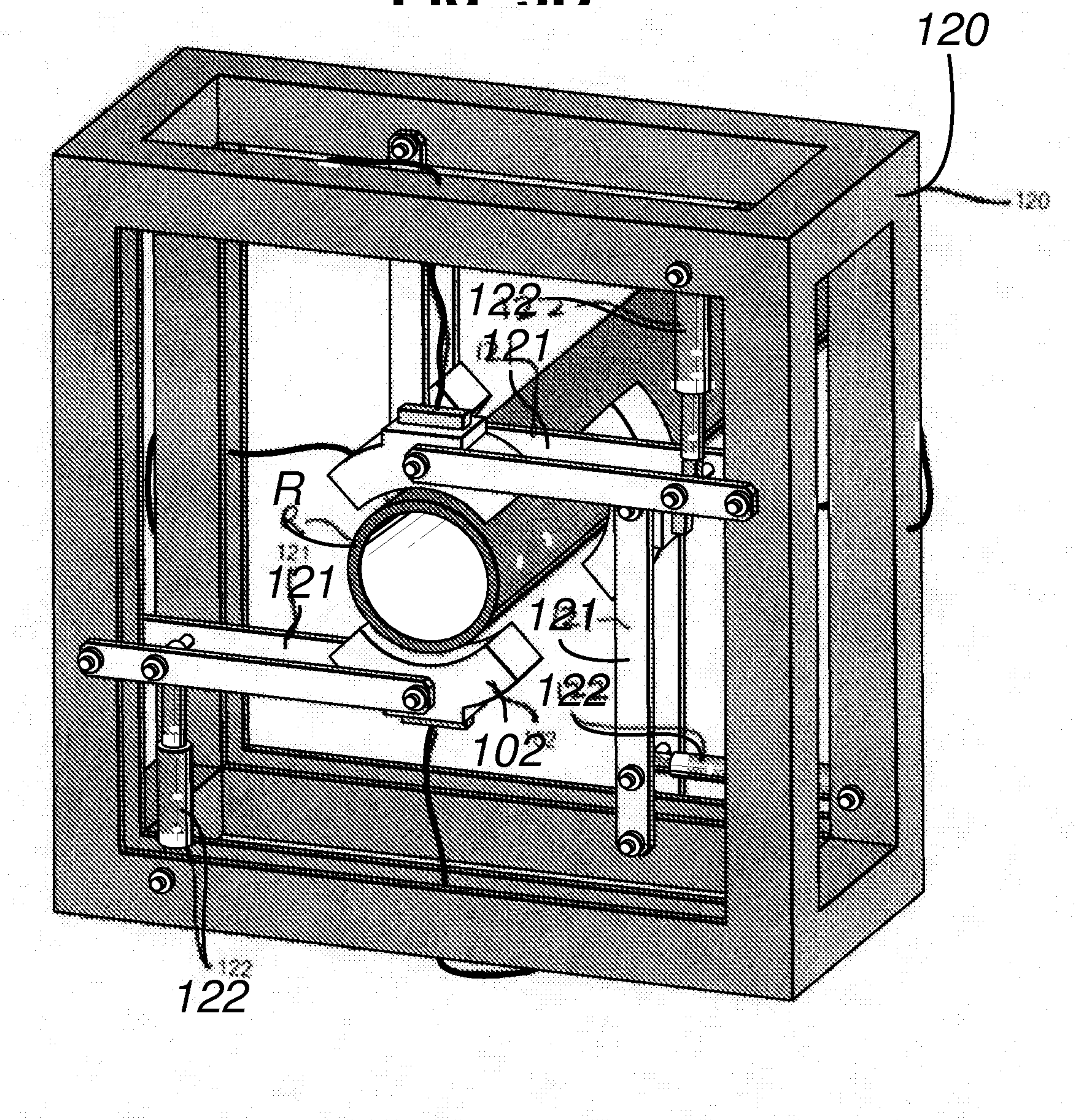

Fig. 3D

Fig. 3E

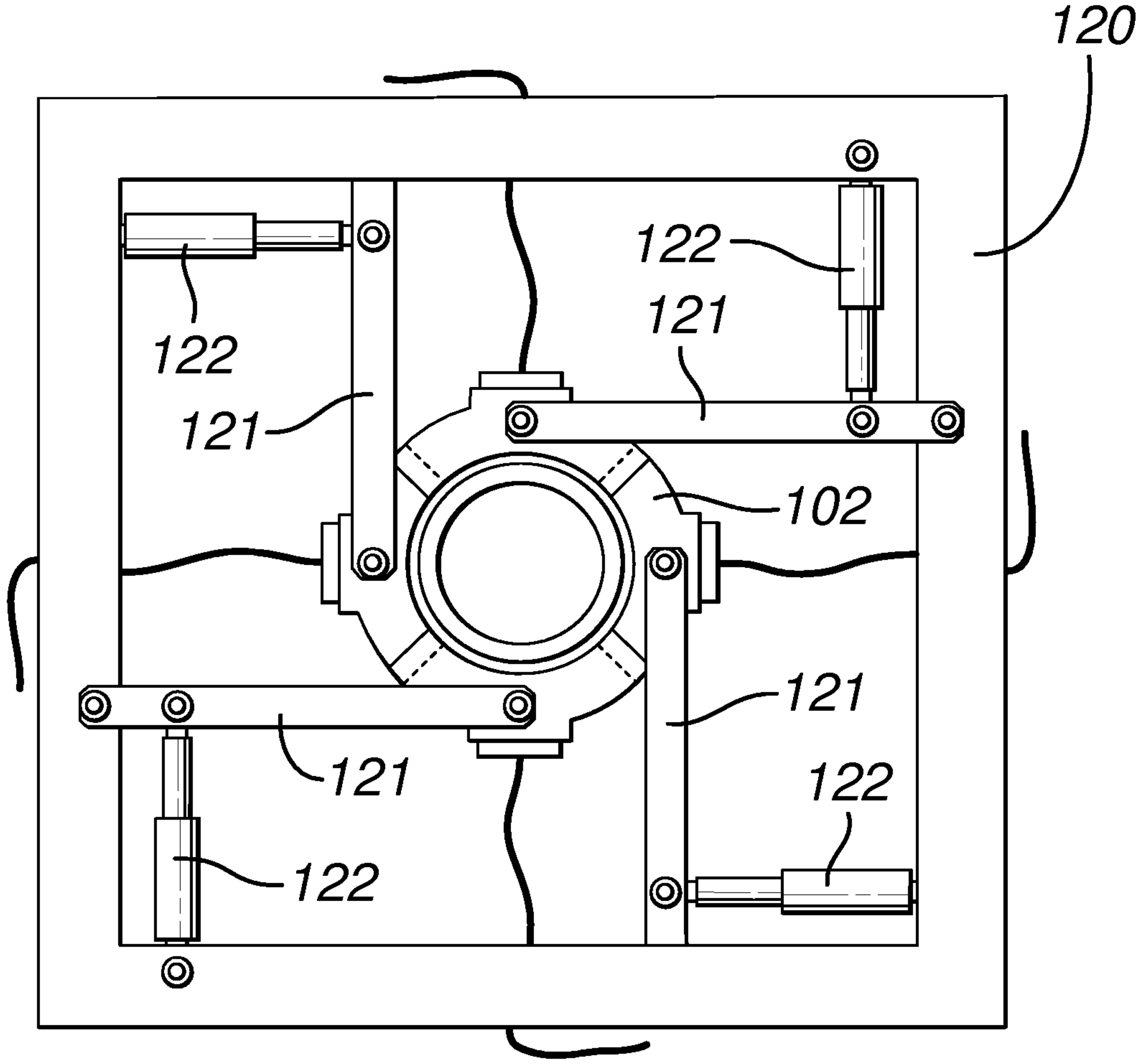

Fig. 1A