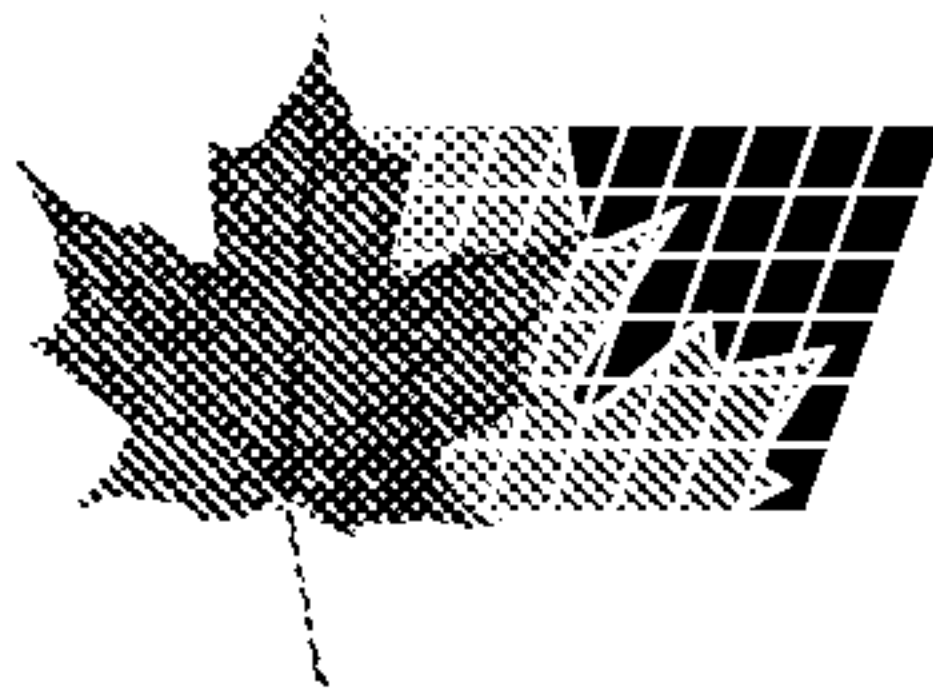




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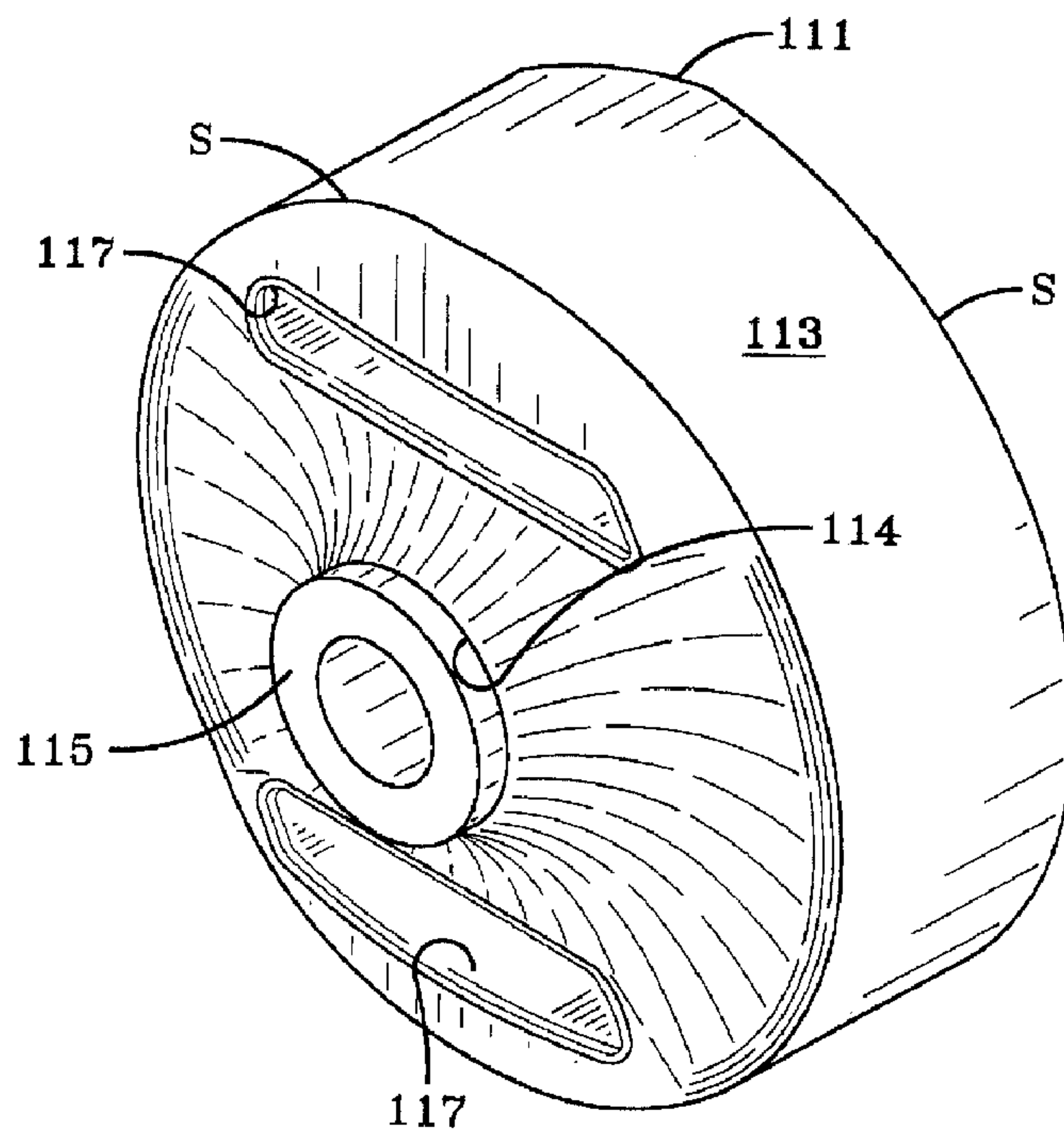
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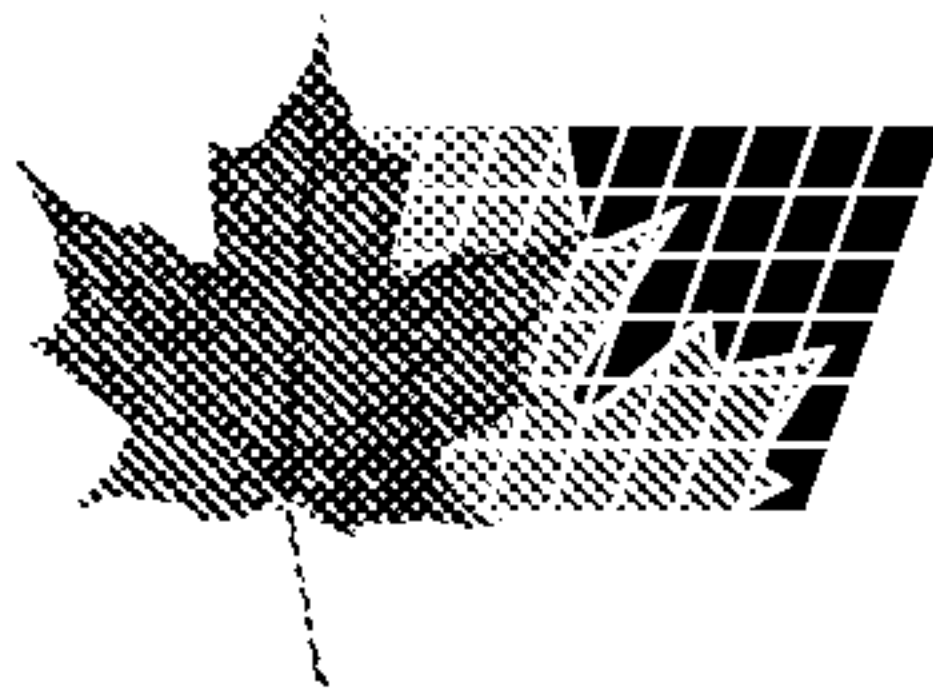
(54) **SYSTEME DE SUSPENSION D'ESSIEU DU TYPE A POUTRE**

(54) **BEAM-TYPE AXLE SUSPENSION SYSTEM**



(57) L'invention concerne un système de suspension pneumatique d'essieu du type à poutre pour semi-remorques ou autres véhicules poids-lourds, ledit système comprenant un récepteur de freinage d'un ensemble de freinage pneumatique monté sur la poutre, cette dernière étant conique. De manière spécifique, chaque poutre du système de suspension d'essieu passe d'une largeur étroite à son extrémité fixée de manière pivotante à un longeron de châssis de la remorque, à une largeur plus importante à son extrémité opposée. La largeur la plus importante permet à un plongeur de réglage du frein de l'ensemble de freinage d'être placé à l'intérieur de la poutre, mais de rester accessible pour des

(57) An air-ride beam-type axle suspension system for tractor-trailers and other heavy-duty wheeled vehicles having a brake chamber of an air brake assembly mounted on the beam, wherein the beam is tapered. Specifically, each beam of the axle suspension system tapers from a narrower width at its end that is pivotally attached to a frame rail of the trailer, to a wider width at its opposite end. The wider width of the beam enables a slack adjuster of the brake assembly to be disposed within the confines of the beam and still be accessible for repair, removal and/or replacement, without requiring an access cutout in the beam which could potentially weaken the beam structure. The tapered beam also



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réparations, démontages et/ou remplacements, sans nécessiter le découpage d'un accès dans la poutre qui risquerait d'affaiblir la structure de la poutre. Cette poutre conique assure, au niveau de ses parties les plus larges, un support efficace pour l'essieu et les ressorts pneumatiques du système de suspension, facilite le montage du système de suspension sur les longerons de châssis de remorques existants et facilite l'incorporation d'un porte-pivot de taille réduite à l'extrémité la plus étroite de la poutre, et permet d'optimiser le poids du système de suspension d'essieu.

provides, at its wider portions, efficient support for the axle and air springs of the suspension system, easier mounting of the suspension system on existing trailer frame rails and incorporation of a reduced-size pivot bushing at the narrower end of the beam, and optimizes the weight of the axle suspension system.

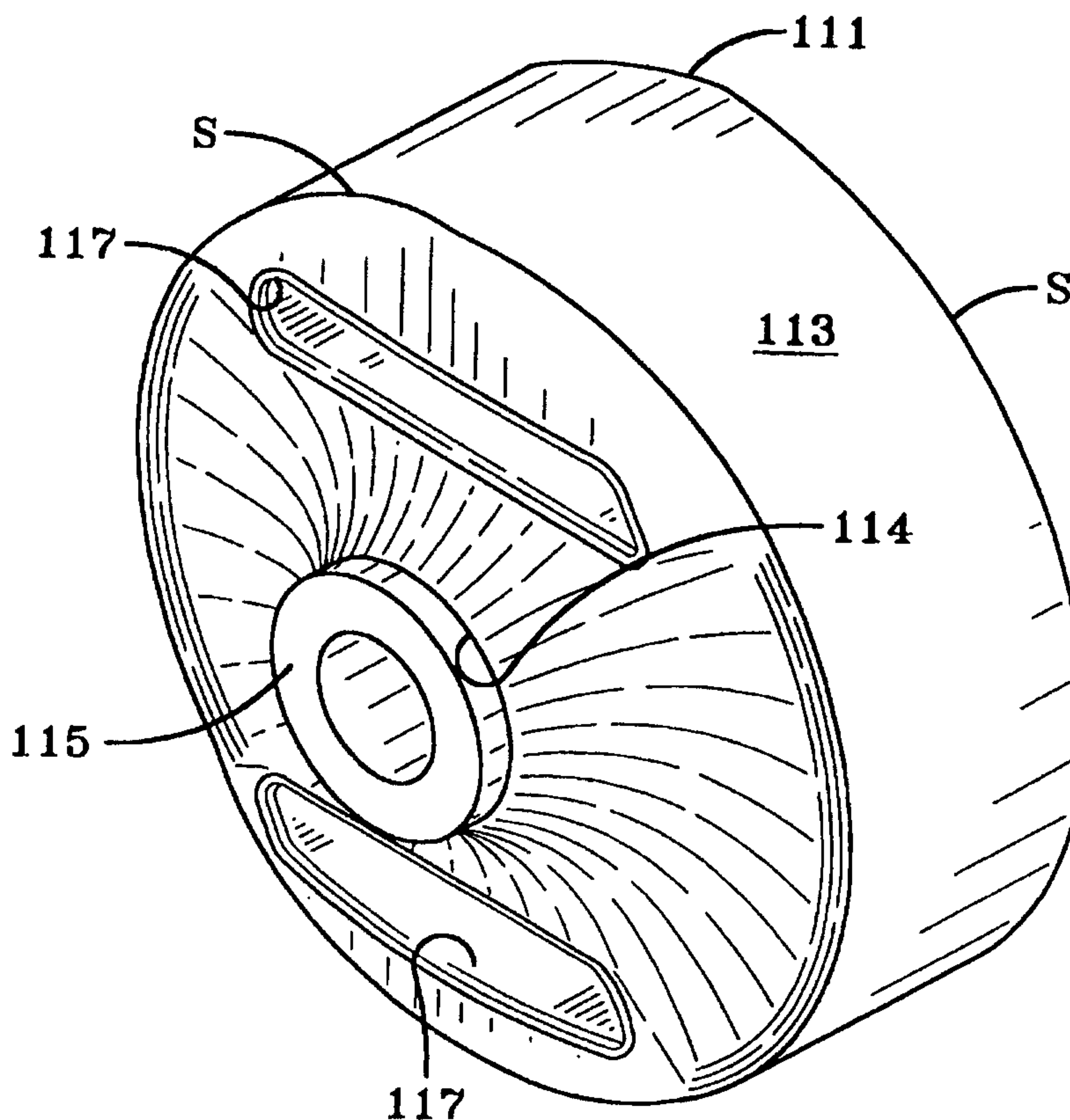
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(21) International Application Number: PCT/US97/15096 (22) International Filing Date: 27 August 1997 (27.08.97) (30) Priority Data: 08/704,090 28 August 1996 (28.08.96) US 08/841,795 5 May 1997 (05.05.97) US (71) Applicant: THE BOLER COMPANY [US/US]; Suite 1010, 500 Park Boulevard, Itasca, IL 60143-1285 (US). (72) Inventors: DILLING, Scott, Allen; 6391 Harborview Avenue, N.W., Canton, OH 44718 (US). RAMSEY, John, Edward; 5048 Sherman Church Avenue, S.W., Canton, OH 44706 (US). (74) Agent: DURESKA, David, P.; 6190 Margate Avenue, N.W., Canton, OH 44718 (US).			(81) Designated States: AL, AU, BA, BB, BG, BR, CA, CN, CU, CZ, EE, GE, HU, IL, IS, JP, KP, KR, LC, LK, LR, LT, LV, MG, MK, MN, MW, MX, NO, NZ, PL, RO, SG, SI, SK, TR, TT, UA, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: BEAM-TYPE AXLE SUSPENSION SYSTEM**(57) Abstract**

An air-ride beam-type axle suspension system for tractor-trailers and other heavy-duty wheeled vehicles having a brake chamber of an air brake assembly mounted on the beam, wherein the beam is tapered. Specifically, each beam of the axle suspension system tapers from a narrower width at its end that is pivotally attached to a frame rail of the trailer, to a wider width at its opposite end. The wider width of the beam enables a slack adjuster of the brake assembly to be disposed within the confines of the beam and still be accessible for repair, removal and/or replacement, without requiring an access cutout in the beam which could potentially weaken the beam structure. The tapered beam also provides, at its wider portions, efficient support for the axle and air springs of the suspension system, easier mounting of the suspension system on existing trailer frame rails and incorporation of a reduced-size pivot bushing at the narrower end of the beam, and optimizes the weight of the axle suspension system.



BEAM-TYPE AXLE SUSPENSION SYSTEM**BACKGROUND OF THE INVENTION**

5

TECHNICAL FIELD

The invention relates to axle suspension systems for wheeled vehicles, and in particular to beam-type axle suspension systems for wheeled vehicles. More particularly, the invention is directed to a beam-type axle suspension system for tractor-trailers in which each beam tapers from a narrower width at its end that is pivotally attached to the trailer frame without special mounting accessories, to a wider width at its opposite end so that an axle and air spring of the suspension system are adequately supported and a brake assembly slack adjuster can be accessibly disposed within the beam without lessening the strength of the beam.

20 **BACKGROUND ART**

The use of air-ride beam-type axle suspension systems and air brakes has become very popular in the heavy-duty truck and tractor-trailer industry. Although such suspensions can be found in wide and varying structural forms, in general their structure is similar in that each system typically includes a pair of longitudinally extending beams. Each beam is located adjacent to and below a respective one of a pair of spaced-apart longitudinally extending frame rails which depend from the trailer. More specifically, each beam is pivotally connected at one of its ends to a hanger which is attached to and depends from a respective one of the frame rails. An axle extends transversely between and is mounted in openings formed in the beams generally adjacent to the end of the beam opposite from the pivotal connection end. The opposite end of each beam also is connected to a bellows

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air spring or its equivalent which in turn is connected to a respective one of the trailer rails. A brake assembly and shock absorber typically also are mounted on each of the beams. The beam may extend rearwardly or frontwardly relative to the front end of the tractor-trailer, thus defining a trailing arm or leading arm beam suspension system, respectively.

However, conventional or prior art beam-type axle suspension systems have been found to operate less than optimally for their intended purpose. Due to the design of typical beam-mounted brake assemblies used in heavy-duty truck and tractor-trailer applications, a slack adjuster of the brake assembly, which provides means for transferring in-line loads from a brake chamber to a torsional load on a cam shaft, has been mounted within the spaced side walls of each beam. In order to allow enough room to remove the slack adjuster from the cam shaft of the brake assembly for servicing or replacement, a cut-out is formed in the inboard sidewall of each beam. However, this cutout can become a weak area in the beam structure, and this weakness can be even more pronounced in systems where the air springs of the air-ride suspension must be moved further from the pivot attachment end of the beam, such as in low ride-height or increased capacity situations.

Also, it is well-known that air-ride beam-type axle suspension systems generally require a substantial bushing at the pivotal attachment point of each beam to the trailer frame rails for satisfactory reaction to static loads, roll moments and braking forces. This bushing requirement results in a wide hanger bracket depending from each of the trailer frame rails, which requires shims and other accessories for proper anchoring to the frame rails. This additional mounting equipment is a penalty when compared to prior art narrow leaf spring designs which generally fit within the confines of the trailer frame rails and therefore can be mounted thereto without additional assemblies.

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Moreover, the weight of beam-type air suspension systems generally is greater than leaf spring suspension systems.

Finally, beam-type air suspension systems
5 generally support the axle less efficiently than leaf spring suspension systems, since the large air springs of an air suspension system must be offset inboard to avoid interference with the tires of the tractor-trailer. Thus, the beams of the suspension also must be located further
10 inboard to adequately support the air springs, which results in less efficient axle support.

The present invention solves the problem of potentially weakened beams in an air suspension system resulting from accessible placement of the slack adjuster
15 of the associated brake assembly, and thereby additionally solves other problems found in prior art air-ride beam-type axle suspension systems, including complicated mounting of the beams to the trailer rails, overall excessive weight of the system, and less efficient axle
20 and air spring support. These problems have been solved in the present invention by replacing the conventional constant width beam with a beam which tapers from a narrower width at its pivotal attachment end, to a wider width at its air spring attachment end. This design
25 enables access to and/or removal of the slack adjuster of the brake assembly without a structural weakening cutout. The present invention further allows attachment of the pivotal end of the beam to a frame bracket which fits within the confines of a conventional trailer frame rail
30 and is relatively easily anchored thereto, which in turn also enables use of a smaller pivot bushing. Moreover, the present invention optimizes the weight of the beam by removing material in its lower stress portions adjacent to the pivotal attachment end, and by adding material in its
35 higher stress areas adjacent to the air spring/axle end. Finally, the present invention optimizes the load capacity of the axle of the suspension system by effectively moving the axle seat centers in the beams outboard, yet maintains

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excellent inboard support of the air springs by the suspension beams.

5 GB-A-2071265 discloses an elastic bushing for an engine mount, comprising an annular elastic body fitted in an outer mounting tube and having a central opening for attachment to an oscillating body and a pair of diametrically opposed voids which extend the entire length of the elastic body to improve the fatigue strength.

10 The fitted elastic body may have various end face conformations including outwardly concave and outwardly convex.

AMENDED SHEET

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excellent inboard support of the air springs by the suspension beams.

SUMMARY OF THE INVENTION

5 Objectives of the present invention include providing an air-ride beam-type axle suspension system for tractor-trailers, in which the slack adjuster of the associated brake assembly can be accessibly housed within the confines of the beam for easy
10 repair/removal, without compromising the structural integrity of the beam.

 Another objective of the present invention is to provide such an axle suspension system for tractor-trailers which can be mounted on the trailer
15 frame rails without special mounting accessories, and which includes a reduced size pivot bushing that exhibits satisfactory durability and reaction to static loads, roll moments, lateral forces, and braking forces.

20 Still another objective of the present invention is to provide such an axle suspension system which provides improved and efficient support for the axle and air springs of the suspension system.

25 A further objective of the present invention is to provide such an axle suspension system for tractor-trailers which has an optimal weight.

 These objectives and advantages are obtained by a bushing for a vehicle suspension, the bushing includes an elastic, generally cylindrical-shaped body
30 having a pair of spaced-apart sides and being formed with a central opening which passes completely through the body and each of the sides about a horizontal pivotal axis of the body, the body having an edge formed at an interface of each of the sides with a
35 peripheral end of the body, the sides with a peripheral end of the body, and the edge generally being free of a, and the edge generally being free of a radius, a rigid sleeve immovably mounted in the central opening, the rigid sleeve outside diameter being generally
40 equal to the central opening diameter, the sleeve

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extending substantially the entire width of the central opening to facilitate mounting of the bushing on a vehicle suspension, a pair of spaced apart voids formed in each of the elastic body sides, the pair of voids being formed in each of the sides above and below the central opening, and an imaginary vertical center of each of the voids being disposed about 90 degrees from an imaginary horizontal plane passing transversely through the body when the bushing is mounted on a vehicle suspension, the voids each being generally horizontal rectangular-shaped, the elastic body being generally solid apart from the voids and the central opening, the sides each having a generally concave shape about the imaginary horizontal plane, and a generally concave shape from a radially innermost edge of each of the voids inward to the rigid sleeve and a generally sidewardly protruding shape from a radially outermost edge of each of the voids outward to the peripheral end of the elastic body, so that the bushing is more rigid in the direction of the horizontal plane than in the direction of the vertical center when the vehicle suspension is subjected to horizontal and vertical loads, respectively. Preferably, the elastic body has a width of 58-71 mm (2.3 to 2.8 inches) and a diameter of about 159 mm (6.25 inches).

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the invention, illustrative of the best mode in which applicants have contemplated applying the principles, is set forth in the following description and is shown in the drawings and is particularly and distinctly pointed out and set forth in the appended claims.

FIG. 1 is a fragmentary inverted perspective view of a prior art air-ride beam-type axle suspension system for a tractor-trailer, showing the manner of removal of the brake assembly slack adjuster in phantom lines and exploded format;

FIG. 2 is a reduced inboard elevational view of the prior art suspension system shown in FIG. 1, with portions thereof shown in section and phantom lines;

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FIG. 3 is a fragmentary upright top plan view of the prior art suspension system of FIG. 2 attached to a trailer frame rail, with portions thereof broken away and shown in section and phantom lines, and showing the manner
5 of removal of the brake assembly slack adjuster in exploded format;

FIG. 4 is an upright outboard elevational view of the prior art suspension system of FIGS. 1-3, with portions thereof shown in section and phantom lines;

10 FIG. 5 is a fragmentary inverted perspective view of another prior art air-ride beam-type axle suspension system for a tractor-trailer having an increased-length beam, showing the manner of removal of the brake assembly slack adjuster in phantom lines and exploded
15 format;

FIG. 6 is a reduced inboard elevational view of the prior art suspension system shown in FIG. 5, with portions thereof shown in section and phantom lines;

20 FIG. 7 is a fragmentary upright top plan view of the prior art suspension system of FIG. 6 attached to a trailer frame rail, with portions thereof shown in section and phantom lines, and showing the manner of removal of the brake assembly slack adjuster in exploded format;

25 FIG. 8 is an upright outboard elevational view of the prior art suspension system of FIGS. 5-7, with portions thereof shown in section and phantom lines;

FIG. 9 is a fragmentary inverted perspective view of an air-ride tapered beam-type axle suspension system for a tractor-trailer of the present invention,
30 showing the manner of removal of the brake assembly slack adjuster in phantom lines and exploded format;

FIG. 10 is a reduced inboard elevational view of the suspension system of the present invention shown in FIG. 9, with portions thereof shown in section and phantom
35 lines;

FIG. 11 is a fragmentary upright top plan view of the present invention suspension system of FIG. 10 attached to a trailer frame rail, with portions thereof

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broken away and shown in section and phantom lines, and showing the manner of removal of the brake assembly slack adjuster in exploded format;

FIG. 12 is an upright outboard elevational view
5 of the present invention suspension system of FIGS. 9-11, with portions thereof shown in section and phantom lines;

FIG. 13 is a fragmentary inverted perspective
view of a second embodiment of an air-ride tapered beam-
type axle suspension system for a tractor-trailer of the
10 present invention, showing the manner of removal of the
brake assembly slack adjuster in phantom lines and exploded
format;

FIG. 14 is a reduced inboard elevational view of
the suspension system of the present invention shown in
15 FIG. 13, with portions thereof shown in section and
phantom lines;

FIG. 15 is a fragmentary upright top plan view
of the present invention suspension system of FIG. 14 at-
tached to a trailer frame rail, with portions thereof
20 shown in section and phantom lines, and showing the manner
of removal of the brake assembly slack adjuster in exploded
format;

FIG. 16 is an upright outboard elevational view
of the present invention suspension system of FIGS. 13-15,
25 with portions thereof shown in section and phantom lines;

FIG. 17 is a perspective view of a prior art
conventional-size voided pivot bushing;

FIG. 18 represents a front and rear end view,
wherein the views are identical, of the prior art voided
30 bushing of FIG. 17;

FIG. 19 is a perspective view of a prior art
reduced-size solid pivot bushing;

FIG. 20 is a side view of the prior art solid
bushing of FIG. 19;

35 FIG. 21 is a sectional view taken along line 21-
21 of FIG. 20;

FIG. 22 is a side view showing the prior art
solid bushing of FIGS. 19-21 press fitted into a mounting

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tube of a beam-type axle suspension system, and further showing a common area of crack initiation or rubber deterioration caused in the bushing after it is subjected to loading conditions;

5 FIG. 23 is a sectional view taken along lines 23-23 of FIG. 22, without depicting the crack initiation shown in FIG. 22;

 FIG. 24 is a perspective view of a first embodiment of the reduced-size voided pivot bushing of the
10 present invention;

 FIG. 25 is a side view of the reduced-size voided bushing of FIG. 24;

 FIG. 26 represents a top and bottom end view, wherein the views are identical, of the reduced-size
15 voided bushing of FIGS. 24 and 25;

 FIG. 26A represents a front and rear end view, wherein the views are identical, of the reduced-size voided bushing of FIGS. 24-26;

 FIG. 27 is a sectional view taken along line 27-
20 27 of FIG. 25;

 FIG. 28 is a sectional view taken along line 28-28 of FIG. 25;

 FIG. 29 is a perspective view showing the reduced-size voided bushing of FIGS. 24-28 press-fitted
25 into a mounting tube of a beam-type axle suspension system and further showing the compressed state of the bushing;

 FIG. 30 is a side view of the bushing of FIG. 29;

 FIG. 31 is a sectional view taken along line 31-
30 31 of FIG. 30;

 FIG. 32 is a sectional view taken along line 32-32 of FIG. 30.

 FIG. 33 is a perspective view of a second embodiment of the reduced-size voided pivot bushing of the
35 present invention;

 FIG. 34 is a side view of the reduced-size voided bushing of FIG. 33;

 FIG. 35 is an end view of the reduced-size

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voided bushing of FIGS. 33 and 34;

FIG. 36 is a sectional view taken along line 36-36 of FIG. 34;

FIG. 37 is a perspective view showing the
5 reduced-size voided bushing of FIGS. 33-36 press-fitted into a mounting tube of a beam-type axle suspension system and further showing the compressed state of the bushing;

FIG. 38 is a side view of the bushing assembly of FIG. 37;

10 FIG. 39 is a sectional view taken along line 39-39 of FIG. 38; and

FIG. 40 is a sectional view taken along line 40-40 of FIG. 38.

15 Similar numerals refer to similar parts throughout the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A prior art air-ride beam-type trailing arm axle suspension system for a tractor-trailer is indicated
20 generally at 20 and is shown in FIG. 1. Inasmuch as axle suspension system 20 includes generally identical suspension assemblies 21 each suspended from a respective one of a pair of hangers 22, only one of the suspension assemblies will be described in detail herein, and shown in
25 FIGS. 1-4. Hanger 22 is, by any suitable means, securely mounted on and depends from a respective one of a pair of spaced-apart, parallel longitudinally extending elongated frame rails 38 which are secured to and depend from the underside of the trailer of a semi-trailer (FIG. 3).

30 A bushing assembly 23 is rigidly attached to the front end of a trailing arm or beam 24 by any suitable means such as welding. More specifically, and as best shown in FIG. 3, bushing assembly 23 includes a beam mounting tube 100 which is welded to the front end of beam
35 24. A prior art conventional-size voided pivot bushing 101 is press-fitted into tube 100 in a manner well known to the art and to the literature. Each one of a pair of alignment collars 102 is rigidly mounted in a respective

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slot (not shown) formed in each sidewall of hanger 22 to properly align tube 100 relative to the hanger. Prior art voided bushing 101 of the type heretofore utilized in beam-type trailing arm axle suspension systems 20 and other suspension applications for trucks and tractor-trailers and the like, is best shown in FIGS. 17 and 18. Prior art bushing 101 includes an elastic, generally cylindrical-shaped body 103 formed with a central opening 104 which passes completely through the body about its longitudinal axis. A rigid metal sleeve 105 is friction fitted in opening 104 of body 103 and is bonded to the body at the peripheral surface of the sleeve by any suitable adhesive. Sleeve 105 extends slightly outwardly from both ends of opening 104 to provide means for pivotally attaching bushing 101 to suspension hanger 22 by passing a bolt 39 through metal sleeve 105 and a pair of wear pads 106 formed of any suitable plastic, each one of the pair being loosely disposed over a respective one of the ends of the metal sleeve (FIG. 3). Wear pads 106 protect the ends of beam mounting tube 100, each one of the ends of which abuts a respective one of the sidewalls of hanger 22. Elastic body 103, when used in tractor-trailer suspensions having a GAWR of from about 18,000 lbs. to about 25,000 lbs., preferably is formed of natural rubber having a durometer of from about 50 to about 75. Metal sleeve 105 can be made of any suitable hard metal such as steel. A pair of spaced-apart voids 107 is formed in each side of elastic body 103 of bushing 101. More specifically, a generally radially inwardly curving, rectangular-shaped void 107 is formed in each of the top and bottom portions of each side of body 103. Voids 107 enable prior art bushing 101 to achieve multifunctional characteristics. More specifically, the multifunctional characteristics include required load and deflection ratios, or static rates, of varying levels in different directions for semi-trailer axle suspension system applications. The bushing static rate is stiff in the horizontal radial direction, so that axle suspension

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system 20 remains substantially perpendicular to the direction of movement of the tractor-trailer despite horizontal loading which may be placed on the suspension system, and relatively soft in the vertical radial direction, to enable the suspension system and bushing 101 to absorb vertical loading shocks and provide a smooth ride for the vehicle occupants and any cargo carried by the vehicle.

Keeping in mind that FIGS. 1 and 2 are inverted views, beam 24 generally is rectangular-shaped and includes spaced-apart top and bottom walls 25 and 26, respectively, and spaced-apart parallel inboard and outboard sidewalls 27 and 28, respectively. Top wall 25 is formed integrally with sidewalls 27, 28, and bottom wall 26 extends between, is welded to, and interconnects the sidewalls. An air spring 29 is suitably mounted on and extends between the upper surface of the rear end of top wall 25 and frame rail 38. A shock absorber 30 extends between and is mounted on inboard sidewall 27 of suspension beam 24 and hanger 22. An air brake chamber 31 of the semi-trailer braking system (only portions shown) is mounted on bottom wall 26 of suspension beam 24 by any suitable means such as welding. A piston 32 of brake chamber 31 in turn is pivotally attached to a slack adjuster 33, which in turn is immovably mounted on a cam shaft 34 of the braking system to provide for transfer of in-line loads from the brake chamber piston into a torsional load on the cam shaft. An axle 35 extends between and is immovably captured in suspension beam 24 and its corresponding opposite suspension beam of axle suspension system 20.

The location of brake chamber 31 on bottom wall 26 of beam 24 necessitates disposition of slack adjuster 33 between sidewalls 27, 28 of the beam. To enable servicing/removal/replacement of slack adjuster 33, inboard sidewall 27 is provided with a cutout 36 to enable the slack adjuster to be accessed and/or removed from cam shaft 34.

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Despite its use on tractor-trailers, the above-described prior art suspension system 20 has potential shortcomings. First, cutout 36 causes a potential weak spot in the structure of beam 24, which could weaken the suspension assembly 21 and/or suspension system 20 in certain situations such as when the beam is subjected to increased load capacity. Although beam 24 can be reinforced to counteract the potential weak spot, reinforcement would add unwanted weight and cost to suspension system 20.

Also, air-ride beam-type axle suspension systems 20 as described hereinabove, in general utilize a large bushing 101 (FIGS. 17 and 18) which corresponds to the size/width of beam 24 and reacts to static loads, roll moments and braking forces encountered by the suspension system during normal operation. Thus, a wide hanger 22 is required to accommodate bushing 23 and typically is wider than the typical width of original equipment trailer frame rails 38, as best shown in FIG. 3. This size discrepancy requires shims and other accessory structures (not shown) to properly anchor hanger 22 to its respective frame rail 38. This is a penalty when compared to narrow leaf spring suspension system designs which generally fit within the typical trailer frame rail confines.

Moreover, leaf spring axle suspension systems generally are lighter in weight than air-ride beam-type axle suspension systems such as described at 20 above and shown in FIGS. 1-4.

Furthermore, axle suspension system 20 must overcome less efficient axle support centers than a typical leaf spring axle suspension system, because large air spring 29 must be offset inboard to avoid hitting a tire (not shown) of trailer wheel 37, as best shown in FIG. 3. Trailing arm beam 24 must in turn be disposed further inboard to support air spring 29, thus moving the seat centers of axle 35 inboard with a resultant loss in axle support efficiency.

A prior art modified air-ride beam-type trailing

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arm axle suspension system for a tractor-trailer is indicated generally at 40 and is shown in FIG. 5. Axle suspension system 40 is modified in that a beam 44 of the system generally is longer than conventional suspension beams such as beam 24 shown in FIGS. 1-4, to provide for a more rearward location of an air spring 49 of the system as required in low ride-height and increased load capacity semi-trailer applications. Otherwise, axle suspension system 40, as shown in FIGS. 5-8, is substantially similar in structure and operation to axle suspension system 20 shown in FIGS. 1-4 and described hereinabove. Thus, only a general description of the structure of axle suspension system 40 will be set forth hereinbelow, with the more detailed description of the structure and operation of system 20 being hereby fully incorporated by reference into the description of the structure and operation of system 40, and differences between the two systems being highlighted. Axle suspension system 40 includes generally identical suspension assemblies 41 each suspended from a respective one of a pair of hangers 42.

Hanger 42 is securely mounted on and depends from a respective one of the pair of trailer frame rails 38. A bushing assembly 43 is pivotally mounted on hanger 42 by any suitable means such as bolt 59. The front end of a trailing arm or beam 44 in turn is rigidly attached to bushing assembly 43 such as by welds.

Keeping in mind that FIGS. 5 and 6 are inverted views, beam 44 generally is rectangular-shaped and includes spaced-apart top and bottom walls 45 and 46, respectively, and spaced-apart parallel inboard and outboard sidewalls 47 and 48, respectively. Top wall 45 and sidewalls 47, 48 are longer than conventional beam sidewalls and top wall such as those shown in FIGS. 1-4 for beam 24 of prior art suspension system 20. The purpose of this lengthening is so that air spring 49 can be mounted in a more rearward location than is found in a typical suspension system. This rearward adjustment of air spring 49 enables improved operation of air suspension

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system 40 in low ride height and/or increased load capacity situations. Air spring 49 is suitably mounted on and extends between the upper surface of the rear end of extended-length top wall 45 and trailer frame rail 38. A
5 shock absorber 50 extends between and is mounted on inboard sidewall 47 of suspension beam 44 and hanger 42. An air brake chamber 51 is mounted on bottom wall 46 of suspension beam 44. A piston 52 of brake chamber 51 in turn is pivotally attached to a slack adjuster 53, which
10 in turn is immovably mounted on a cam shaft 54 of the braking system. An axle 55 extends between and is immovably captured in suspension beam 44 and its corresponding opposite suspension beam of axle suspension system 40.

The location of brake chamber 51 on bottom wall
15 46 of beam 44 necessitates disposition of slack adjuster 53 between sidewalls 47, 48 of the beam. To enable servicing/removal/replacement of slack adjuster 53, inboard sidewall 47 is provided with a cut-out 56 to enable the slack adjuster to be accessed and/or removed
20 from cam shaft 54.

Despite its use on semi-trailers, the above-described modified prior art suspension system 40 has the same potential shortcomings as those described hereinabove for suspension system 20. More specifically, as with
25 suspension system 20, reinforcement of beam 44 would be required to maintain the structural integrity of the beam, but would be costly and add unwanted weight to system 40.

A first embodiment of an air-ride beam-type trailing arm axle suspension system for a tractor-trailer
30 of the present invention is indicated generally at 60 and is shown in FIG. 9. Inasmuch as axle suspension system 60 includes generally identical suspension assemblies 61 each suspended from a respective one of a pair of hangers 62, only one of the suspension assemblies will be described in detail herein and shown in FIGS. 9-12. All components of
35 system 60 are formed of a suitable strong metal or other sturdy material, unless otherwise noted. Hanger 62 is, by any suitable means, securely mounted on and depends from

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a respective one of the pair of spaced-apart, parallel longitudinally extending elongated frame rails 38 which are secured to and depend from the underside of the trailer of a tractor-trailer.

5 In accordance with one of the main features of the present invention, and as best shown in FIG. 11, the width of hanger 62, identified as W, is less than the width of prior art suspension assembly hangers such as those identified at 22 and 42 in FIGS. 1-4 and 5-8,
10 respectively, hereinabove. The reason for this decreased width W of hanger 62 will be described in detail hereinbelow. However, the decreased width of hanger 62 results in two practical advantages which require immediate description. First, reduced width hanger 62 closely matches the
15 width of trailer frame rails 38, thus enabling hanger 62 to be directly mounted on its respective frame rail 38 without requiring shims or other special accessory parts as is required for many prior art hangers which are wider than the frame rail. Second, a pivot bushing assembly 63
20 for pivotal mounting in hanger 62 and rigid attachment to the front end of a trailing arm or beam 64 by any suitable means such as welding, can be of reduced size/width, which assists in reducing the overall weight of suspension assembly 61.

25 Bushing assembly 63 (FIG. 11) includes a beam mounting tube 110 which is welded to the front end of beam 64. In accordance with another key feature of the present invention, a reduced-size voided pivot bushing 111, 111' is press-fitted into tube 110. The basic structure of a
30 first embodiment reduced-size bushing 111 of the present invention, as well as a second embodiment reduced-size bushing 111' of the present invention, is described briefly immediately below, with a more detailed description of the structure and the key features of the
35 first and second embodiment bushings appearing thereafter hereinbelow. Each one of a pair of alignment collars 112 is rigidly mounted in a respective slot (not shown) formed in each sidewall of hanger 62 to properly align tube 110

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relative to the hanger. As best shown in FIGS. 24 and 33, each reduced-size pivot bushing 111, 111' includes, respectively, an elastic, generally cylindrical-shaped body 113, 113' formed with a central opening 114, 114' which passes completely through the body about its horizontal pivotal axis. A rigid metal sleeve 115, 115' is friction fitted in opening 114, 114' of body 113, 113' and is bonded to the body at the peripheral surface of the sleeve by any suitable adhesive. Sleeve 115, 115' extends slightly outwardly from both ends of opening 114, 114' to provide means for pivotally attaching bushing 111, 111' to suspension hanger 62 by passing a bolt 79 through metal sleeve 115, 115' and a pair of wear pads 116 formed of any suitable plastic, each one of the pair being loosely disposed over a respective one of the ends of the metal sleeve (FIG. 11). Wear pads 116 protect the ends of beam mounting tube 110, each one of the ends of which abuts a respective one of the sidewalls of hanger 62. Metal sleeve 115, 115' can be made of any suitable hard metal such as steel. A pair of spaced-apart voids 117, 117' is formed in each side of elastic body 113, 113' of bushing 111, 111'. More specifically, a generally horizontal, rectangular-shaped void 117 is formed in each of said top and bottom portions of each side of body 113.

Keeping in mind that FIGS. 9 and 10 are inverted views, beam 64 generally is rectangular shaped and includes spaced-apart top and bottom walls 65 and 66, respectively, and spaced-apart inboard and outboard sidewalls 67 and 68, respectively. Top wall 65 is formed integrally with sidewalls 67, 68, and bottom wall 66 extends between, is welded to, and interconnects the sidewalls.

In accordance with another key feature of the present invention, sidewall 67 is angled rearwardly inboard relative to its respective frame rail 38 (FIG. 11). This rearward inboard disposition of inboard sidewall 67, when combined with the non-angular front-rear disposition of outboard sidewall 68 making it generally

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parallel to its respective frame rail 38, results in beam 64 having a taper from being narrower at hanger 62, to wider as it fans out rearwardly therefrom. Thus, beam 64 possesses less mass in the lower stressed portion of the beam adjacent to hanger 62 and bushing assembly 63, enabling use of a reduced size/width hanger and bushing 111, 111'. However, the tapered design enables beam 64 to possess greater mass in its high stress portions toward the rear of the beam, thus optimizing its weight. An air spring 69 is one factor which places stress on the rear portion of trailing arm beam 64. Air spring 69, formed of any suitable elastomer, is securely mounted on and extends between the upper surface of the rear end of top wall 65 and frame rail 38. Although the width of the front end of beam 64 is less than prior art beams, it can be appreciated that the inboard taper of sidewall 67 enables beam 64 to adequately support air spring 69 (FIG. 11) which is by necessity disposed slightly inboard to avoid interfering with a tire (not shown) of trailer wheel 77. Moreover, the outboard taper of sidewall 67 toward the front of the trailer causes the seat centers of an axle 75, which extends between and is immovably captured in suspension beam 64 and its corresponding opposite suspension beam of axle suspension system 60, to be wider or more outboard than prior art axle seat centers, thus improving the efficiency of the support of axle 75.

A shock absorber 70 extends between and is mounted on inboard sidewall 67 of suspension beam 64 and hanger 62. An air brake chamber 71 of the semi-trailer braking system (only portions shown) is mounted on bottom wall 66 of suspension beam 64 by any suitable means such as welding. A piston 72 of brake chamber 71 in turn is pivotally attached to a slack adjuster 73, which in turn is immovably mounted on a cam shaft 74 of the braking system to provide for transfer of in-line loads from the brake chamber piston into a torsional load on the cam shaft.

As with prior art suspension assemblies, the

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location of brake chamber 71 on bottom wall 66 of beam 64 necessitates disposition of slack adjuster 73 between sidewalls 67, 68 of the beam.

However, in accordance with still another major feature of the present invention, and unlike prior art beams, inboard sidewall 67 of beam 64 is free of a cutout for providing access to/removal/replacement of slack adjuster 73. Rather, axle suspension system 60 of the present invention provides access to/removal/replacement of slack adjuster 73 due to the rearward taper of inboard sidewall 67 providing adequate clearance for access to and especially removal/replacement of the slack adjuster from its location within beam 64, as best shown in FIGS. 9 and 11.

In accordance with yet another major feature of the present invention, reduced-size voided pivot bushing embodiments 111, 111' useful in suspension assembly 61 display desirable multifunctional characteristics heretofore observed only in conventional-size voided pivot bushings of the type shown in FIGS. 17 and 18 and described hereinabove. In contrast, prior art reduced-size solid bushings 121 of the type shown in FIGS. 19-21, while offering smaller size and weight characteristics, have been unsuccessful in achieving the desirable multifunctional characteristics of their conventional-size voided counterparts. Prior art reduced-size solid bushing 121 includes an elastic, generally cylindrical-shaped body 123 formed with a central opening 124 which passes completely through the body about its horizontal pivotal axis. A rigid metal sleeve 125 is friction fitted in opening 124 of body 123, and is bonded to the body at the peripheral surface of the sleeve by any suitable adhesive. Sleeve 125 extends slightly outwardly from both ends of opening 124 to provide means for pivotally attaching bushing 121 to a hanger of a suspension assembly as has been described above for reduced-size voided pivot bushings 111, 111' of the present invention. Elastic body 123, when used in tractor-trailer suspensions having a

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GAWR of from about 18,000 lbs. to about 25,000 lbs., is formed of natural rubber having a durometer of from about 50 to about 75. Metal sleeve 125 is made of any hard metal such as steel. Although reduced-size solid pivot bushing 121 provides the required vertical load-deflection found in bushings exhibiting multifunctional characteristics, bushing 121 fails to provide adequate horizontal load-deflection. Specifically, horizontal load-deflection controls the lateral or side-to-side motion of suspension system 60. Solid bushing 121 allows unacceptable excessive lateral motion due to its lower load-deflection characteristics in the horizontal direction. Moreover, and as best shown in FIG. 22, when subjected to loading conditions of the type encountered in service in air-ride, beam-type trailing arm axle suspension system 60, bushing 121 exhibited reduced durability as evidenced by crack initiation C of bushing body 123 from friction fitted adhesively bonded bushing metal sleeve 125. The high strain gradient at the metal sleeve 125 to bushing body central opening 124 interface caused the premature cracking during the suspension fatigue test. Also, it should be noted that when reduced-size solid bushing 121 is press-fitted into a beam mounting tube 120 in a usual manner, another problem is observed (FIGS. 22 and 23). Since the width of reduced-size solid bushing 121 is reduced by about fifty percent of the width of conventional-size bushing 101, the contact surface area and resulting compression fit between the peripheral surface of bushing body 123 and the inner surface of mounting tube 120 also is reduced. Such reduced compression fit can cause unsatisfactory side-to-side or even twisting movement of bushing 121 in mounting tube 120, which in turn can cause premature wear of suspension components. Finally, and as best shown in FIG. 23, press fitting of solid bushing 121 in mounting tube 120 causes the normally linear tapering sides of bushing 121 (FIG. 21) to bulge outwardly, thus further reducing the contact surface area between the bushing and the

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mounting tube. Specifically, the contact surface area is reduced because the width of bushing body 123 must be significantly less than the width of mounting tube 120, otherwise the bulging sides of bushing 121 would extend outwardly from the ends of the mounting tube, thus making it impossible to mount bushing assembly 63 within hanger 62.

First embodiment reduced-size voided pivot bushing 111 of the present invention useful in air-ride beam-type axle suspension systems of the type indicated at 60 and shown and described herein, having been briefly generally described hereinabove is now described in greater detail and is shown in FIGS. 24 through 32. As best shown in FIG. 26, the widths W and W_2 of elastic bushing body 113, like the width of reduced-size solid bushing body 123, each is about fifty percent of the width of conventional-size voided bushing 101, but its diameter D is larger than bushings 101 and 121 by about one-quarter of an inch. Specifically, W is about 60mm (2.35 inches) and W_2 is about 72mm (2.82 inches) and D is about 159mm (6.25 inches).

Also, in contrast to reduced-size solid bushing 121, the profile of bushing 111 of the present invention is significantly different. Specifically, rather than having constant linear tapering sides and decreasing width moving away from metal sleeve 125 of reduced-size solid bushing 121 as shown in FIG. 21, reduced-size voided bushing 111 has two distinct surface profiles on each of its sides. A first surface profile exists generally about an imaginary horizontal line parallel to section line 28-28 shown in FIG. 25, and can be described as generally concave (FIGS. 26A and 28). A second surface profile exists generally about an imaginary vertical line parallel to section line 27-27 shown in FIG. 25, and can be described as generally concave from the radially inner most edge of each void 117 and on inward to metal sleeve 115. From the radially outermost edge of each void 117 and on outward to the periphery or end of elastic body 113, the second surface profile can be described as generally sidewardly protruding as best shown in FIGS. 24-27.

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It is also important to note that reduced-size solid bushing 121 has a radiused or rounded edge R between each of its sides and its peripheral end, as best shown in FIGS. 19 and 21. In contrast, and as best shown in FIGS. 24, and 26 through 28, the corresponding edge S' of reduced-size voided bushing 111 is generally free of a pronounced radius or rounding and is sharper in shape.

Also, the durometer range of reduced-size solid bushing 121 is from about 50 to about 75. In further contrast, elastic body 113, when used in tractor-trailer suspensions having a GAWR from about 18,000 lbs. to about 25,000 lbs., preferably is formed of natural rubber having a durometer of from about 75 to about 90, more preferably from about 75 to about 84, and most preferably from about 75 to about 79, with the rubber being available from the Goodyear Tire & Rubber Company of Akron, Ohio.

In accordance with still another important feature of the present invention, and as best shown in FIGS. 24, 25 and 27, each void 117 is a generally horizontal rectangular slot having radiused or rounded edges and generally rounded ends.

It should be noted that the total area of each void preferably is from about 1400mm^2 (2.17 square inches) to about 1860mm^2 (2.89 square inches), more preferably from about 1430mm^2 (2.23 to about 1790mm^2 (2.77 square inches), and most preferably from about 1470mm^2 (2.29 to about 1710mm^2 (2.65 square inches). Moreover, and as best shown in FIG. 25, it is important to note that the total area of each void 117 which extends outwardly beyond a pair of spaced, imaginary vertical lines T_f and T_r , respectively, which are tangential to the front and rear outer surfaces of metal sleeve 115, preferably is from about 27 percent to about 46 percent of the total area of each void 117, more preferably from about 29 percent to about 43 percent, and most preferably from about 31 percent to about 40 percent of the total area of each of the voids.

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Thus, first embodiment reduced-size voided bushing 111 of the present invention overcomes all of the problems associated with prior art reduced-size solid bushing 121. Specifically, the combination of the
5 variable concave/protruding side profile and unradiused side to peripheral edge profile of bushing 111, together with elongated straight horizontal voids 117 having generally rounded ends and choice of rubber durometer, enables bushing 111 to achieve the multifunctional
10 characteristics heretofore demonstrated only in conventional-size voided bushing 101. Specifically, the multifunctional characteristics of bushing 111 include required load and deflection ratios, or static rates, of varying levels in different directions for semi-trailer
15 axle suspension system applications. The bushing static rate is stiff in the horizontal radial direction, so that axle suspension system 60 remains substantially perpendicular to the direction of movement of the vehicle despite horizontal loading which may be placed on the
20 suspension system, and relatively soft in the vertical radial direction, to enable the suspension system and bushing 111 to absorb vertical loading shocks and provide proper roll-stability for the trailer. It should further be noted that the shape and positioning of voids 117 is
25 important for other reasons as well. The slightly rounded ends of each void 117 assists in preventing premature crack sites in bushing body 113 adjacent to the ends of voids 117 by reducing localized buckling or puckering. Moreover, the above-described combination of features of
30 bushing 111 prevents the type of cracking observed in reduced-size solid bushing 121 as shown in FIG. 22, namely, cracking separation of bushing body 123 from metal sleeve 125.

Moreover, the protruding portions of the sides
35 of bushing 111, combined with the larger outside diameter of the bushing prevent the migration and twisting problem described hereinabove for prior art solid bushing 121. More specifically, the larger diameter of bushing body 113

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enables greater compression force when bushing 111 is press fitted into beam mounting tube 110, as best shown in FIGS. 29-32. This compression force of bushing body 113 against beam mounting tube 110 is about 19 percent compared to about 13 percent for solid bushing 121, which translates to increased interference pressure to hold bushing 111 in place in tube 110. The variable concave/protruding side profile and unradiused side to periphery edge profile of bushing 111 also increases the contact surface area and resulting compression between the peripheral surface of bushing body 113 and the inner surface of mounting tube 110. Thus, as best shown in FIGS. 31 and 32, and in contrast to what is shown in FIG. 23 for prior art solid busing 121, mounting tube 110 is substantially filled by bushing 111. This filling of mounting tube 110 assists bushing 111 in achieving its multifunctional characteristics, and also helps prevent bushing migration or twisting. The choice of durometer of bushing body 113 in combination with the variable side profile, unradiused side to periphery edge profile, and void shape and position, thus all contributes to achieving the multifunctional characteristics.

Second embodiment reduced-size voided pivot bushing 111' of the present invention useful in air-ride beam-type axle suspension systems of the type indicated at 60 and shown and described herein, having been briefly generally described hereinabove is now described in greater detail and is shown in FIGS. 33 through 40. As best shown in FIG. 35, the width W' of elastic bushing body 113', like the width of reduced-size solid bushing body 123, is about 50 percent of the width of conventional size voided bushing 101, but its diameter D' is larger than bushings 101 and 121 by about one-quarter of an inch. Specifically, W' is about 60mm (2.37 inches) and D' is about 159mm (6.25 inches).

Also, in contrast to reduced-size solid bushing 121, the profile of bushing 111' of the present invention is significantly different. Specifically, rather than

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having constant linear tapering sides and decreasing width moving away from metal sleeve 125 of reduced-size solid bushing 121 as shown in FIG. 21, reduced-size voided bushing 111' has a surface profile that can best be described as generally concave, as best shown in FIGS. 33 and 35-36.

It is also important to note that reduced-size solid bushing 121 has a radiused or rounded edge R between each of its sides and its peripheral end, as best shown in FIGS. 19 and 21. In contrast, and as best shown in FIGS. 33 and 35-36, the corresponding edge S' of reduced-size voided bushing 111' is generally free of a pronounced radius or rounding and is sharper in shape.

Also, the durometer range of reduced-size solid bushing 121 is from about 50 to about 75. In further contrast, elastic body 113', when used in tractor-trailer suspensions having a GAWR from about 18,000 lbs. to about 25,000 lbs., preferably is formed of natural rubber having a durometer of from about 75 to about 90, more preferably from about 78 to 88, and most preferably from about 82 to about 86, with the rubber being available from the Goodyear Tire & Rubber Company of Akron, OH.

In accordance with still another feature of the present invention, and as best shown in FIGS. 33 to 34, each void 117' is a generally horizontal rectangular slot having generally rounded ends.

It should be noted that the total area of each void preferably is from about 1240mm^2 (1.93 square inches) to about 1670mm^2 (2.59 square inches), more preferably from about 1280mm^2 (1.99 to about 1600mm^2 2.48 square inches), and most preferably from about 1310mm^2 (2.04 to about 1530mm^2 2.37 square inches). Moreover, and as best shown in FIG. 34, it is important to note that the total area of each void 117' which extends outwardly beyond a pair of spaced, imaginary vertical lines T'_f and T'_r , respectively, which are tangential to the front and rear outer surfaces of metal sleeve 115', preferably is from about 21 percent to about 35 percent of the total area of each void 117', more preferably from about 23 percent to

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about 31 percent, and most preferably from about 25 percent to about 27 percent of the total area of each of the voids.

Thus, second embodiment reduced-size voided bushing 111' of the present invention overcomes all of the problems associated with prior art reduced-size solid bushing 121. Specifically, the combination of the side concavity profile and unradiused side to periphery edge profile of bushing 111', together with elongated straight horizontal voids 117' having rounded ends and choice of rubber durometer, enables bushing 111' to achieve the multifunctional characteristics heretofore demonstrated only in conventional-size voided bushing 101. Specifically, the multifunctional characteristics of bushing 111' include required load and deflection ratios, or static rates, of varying levels in different directions for semi-trailer axle suspension system applications. The bushing static rate is stiff in the horizontal radial direction, so that axle suspension system 60 remains substantially perpendicular to the direction of movement of the vehicle despite horizontal loading which may be placed on the suspension system, and relatively soft in the vertical radial direction, to enable the suspension system and bushing 111' to absorb vertical loading shocks and provide proper roll-stability for the trailer. It should be further noted that the shape and positioning of voids 117' is important for other reasons as well. The slightly rounded ends of each void 117' assists in preventing premature crack sites in bushing body 113' adjacent to the ends of voids 117' by reducing localized buckling or puckering. Moreover, the above-described combination of features of bushing 111' prevents the type of cracking observed in reduced-size solid bushing 121 as shown in FIG. 22, namely, cracking separation of bushing body 123 from metal sleeve 125.

Moreover, the larger outside diameter of bushing 111' assists in preventing the migration and twisting problem described hereinabove for prior art solid bushing

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121. More specifically, the larger diameter of bushing body 113' enables greater compression force when bushing 111' is press-fitted into beam mounting tube 110, as best shown in FIGS. 37-40. This compression force of bushing
5 body 113' against beam mounting tube 110 is about 19 percent compared to about 13 percent for solid bushing 121, which translates to increased interference pressure to hold bushing 111' in place in tube 110. The concave side profile and unradiused side to periphery edge profile
10 of bushing 111' also increases the contact surface area and resulting compression between the peripheral surface of bushing body 113' and the inner surface of mounting tube 110. Thus, as best shown in FIGS. 39 and 40, and in contrast to what is shown in FIG. 23 for prior art solid
15 bushing 121, mounting tube 110 is substantially filled by bushing 111'. This filling of mounting tube 110 assists bushing 111' in achieving its multifunctional characteristics, and also helps prevent bushing migration or twisting. The choice of durometer of bushing body 113'
20 in combination with the concave side profile and unradiused side to periphery edge profile, as well as the void shape and position, thus all contributes to achieving the multifunctional characteristics.

Thus, improved axle suspension system 60 of the
25 present invention shown in FIGS. 9-12 and 24-40, and described above, through its tapered design solves the problem of access to/removal/replacement of slack adjusters for beam-mounted brake assemblies, without potential weakening of the beam due to cutouts and the like common
30 in prior art designs. The tapered beam of the present invention provides the additional benefits of lessening the width of the hanger so that the hanger can be mounted on existing semi-trailer frame rails without special reinforcement techniques. In turn, smaller width improved
35 bushings 111, 111' can be employed in suspension assembly 61, and the improved bushings have been designed to be durable as well as to withstand static loads, roll moments and braking forces encountered during normal operation of

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the semi-trailer. The optimization of beam material to place more material at the high stress air spring/axle area and less material adjacent to the bushing/hanger area is also important because this reduces the overall weight of suspension assembly 61. Finally, the tapered design provides another advantage by moving the effective seat centers of the axle outboard in the axle attachment area to improve the axle support efficiency, while still providing adequate support to the air spring slightly inboard rearward from the axle seat centers.

A second embodiment of the present invention, a modified air-ride beam-type trailing arm axle suspension system for a tractor-trailer is indicated generally at 80 and is shown in FIG. 13. Axle suspension system 80 is modified as will be described in detail hereinbelow and shown in FIGS. 13-16. However, other than the modification, axle suspension system 80 is substantially similar in structure and operation to the first embodiment of the present invention, namely axle suspension system 60 shown in FIGS. 9-12 and described hereinabove. Thus, only a general description of the structure of axle suspension system 80 will be set forth hereinbelow, with the more detailed description of the structure and operation of system 60 being hereby fully incorporated by reference into the description of the structure and operation of system 80, and differences between the two systems being highlighted. Axle suspension system 80 includes generally identical suspension assemblies 81 each suspended from a respective one of a pair of hangers 82. Hanger 82 is securely mounted on and depends from a respective one of the pair of trailer frame rails 38.

In accordance with one of the main features of the present invention, and as best shown in FIG. 15, the width of hanger 82, identified as W' , is less than the width of prior art suspension assembly hangers. The decreased width of hanger 82 results in the same practical advantages as those enjoyed by first embodiment 60 of the present invention, namely, that hanger 82 can be directly

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mounted on its respective trailer frame rail 38 without requiring additional parts. Also, a pivot bushing assembly 83 for pivotal mounting in hanger 82 and rigid attachment to the front end of a trailing arm or beam 84 by any
5 suitable means such as welding, can be of reduced size/width, which aids in reducing the overall weight of suspension assembly 81. Bushing assembly 83 is pivotally mounted on hanger 82 by any suitable means such as a bolt 99. The front end of trailing arm or beam 84 in turn is
10 rigidly attached to bushing assembly 83 such as by welds.

Keeping in mind that FIGS. 13 and 14 are inverted views, beam 84 generally is rectangular-shaped and includes spaced-apart top and bottom walls 85 and 86, respectively, and spaced-apart inboard and outboard
15 sidewalls 87 and 88, respectively. In accordance with another key feature of the present invention, sidewall 87 is angled rearwardly inboard and sidewall 88 is angled rearwardly outboard, both relative to their respective frame rail 38 (FIG. 15). The angle of sidewalls 87, 88
20 results in beam 84 having a taper from being narrower at hanger 82, to wider as it fans out rearwardly therefrom. Thus, beam 84 possesses less mass in the lower stressed portion of the beam adjacent to hanger 82 and bushing assembly 83. However, the tapered design enables beam 84
25 to possess greater mass in its high stress portions toward the rear of the beam, thus optimizing its weight. An air spring 89 is one factor which creates stress in the rear portion of trailing arm beam 84. Air spring 89 is suitably mounted on and extends between the upper surface of
30 the rear end of top wall 85 and frame rail 38. Although the width of the front end of beam 84 is less than prior art beams, it is understood that the rearward inboard taper of sidewall 87 and the rearward outboard taper of sidewall 88 enables beam 84 to adequately support air
35 spring 89 (FIG. 15). Moreover, the frontward outboard taper of sidewall 87 causes the seat centers of an axle 95, which extends between and is immovably captured in suspension beam 84 and its corresponding opposite suspen-

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sion beam of axle suspension system 80, to be wider or more outboard than prior art axle seat centers, thus improving the efficiency of the support of axle 95.

5 A shock absorber 90 extends between and is mounted on inboard sidewall 87 of suspension beam 84 and hanger 82. An air brake chamber 91 is mounted on bottom wall 86 of suspension beam 84. A piston 92 of brake chamber 91 in turn is pivotally attached to a slack adjuster 93, which in turn is immovably mounted on a cam
10 shaft 94 of the braking system.

As with prior art suspension assemblies, the location of brake chamber 91 on bottom wall 86 of beam 84 necessitates disposition of slack adjuster 93 between sidewalls 87, 88 of the beam.

15 However, in accordance with a still further important feature of the second embodiment of the present invention, and unlike prior art beams, inboard sidewall 87 of beam 84 is free of a cutout for providing access to/removal/replacement of slack adjuster 93. Rather, axle
20 suspension system 90 of the present invention provides access to/removal/replacement of slack adjuster 93 due to the rearward inboard taper of sidewall 87 providing sufficient clearance for access to and especially removal/replacement of the slack adjuster from its location
25 within beam 84, as best shown in FIGS. 13 and 15.

Thus, improved axle suspension system 80 of the second embodiment of the present invention shown in FIGS. 13-16 and described immediately above, through its tapered design, solves the problem of access to/removal/replacement of slack adjusters for beam-mounted brake assemblies,
30 without potential weakening of the beam due to cutouts and the like common in prior art designs. As with the first embodiment of the present invention, second embodiment 80 of the present invention provides the additional benefits
35 of convenient mounting of the hanger on existing trailer frame rails, use of improved smaller bushings 111, 111' of the present invention, and more efficient use of beam material leading to optimization of weight of the axle

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suspension assembly, and improved axle support efficiency while firmly supporting the air spring.

Thus, it can be seen that both embodiments of the present invention successfully solve the problem of
5 access to and especially removal/replacement of the slack adjusters of beam-mounted brake assemblies, as well as the problem of convenient mounting of the hanger on existing trailer frame rails and use of a reduced size bushing having durability and multifunctional characteristics
10 therein, and also provide other advantages as a result of solving these problems. It is understood that the concepts of the present invention can be applied to wheeled vehicles other than semi-trailers or heavy trucks. It is also understood that these concepts also apply to
15 front arm or leading arm suspensions as well as trailing arm suspensions.

Accordingly, the improved air-ride beam-type axle suspension system for wheeled vehicles is simplified, provides an effective, safe, inexpensive, and efficient
20 system which achieves all the enumerated objectives, provides for eliminating difficulties encountered with prior beam-type air suspension systems, and solves problems and obtains new results in the art.

In the foregoing description, certain terms have
25 been used for brevity, clearness and understanding; but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are used for descriptive purposes and are intended to be broadly construed.

30 Moreover, the description and illustration of the invention is by way of example, and the scope of the invention is not limited to the exact details shown or described.

Having now described the features, discoveries
35 and principles of the invention, the manner in which the improved beam-type air suspension system is constructed, arranged and used, the characteristics of the construction and arrangement, and the advantageous, new and useful

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results obtained; the new and useful structures, devices, elements, arrangements, parts and combinations are set forth in the appended claims.

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CLAIMS

1. A bushing including:

(a) an elastic, generally cylindrical-shaped body having a pair of spaced-apart generally concave sides and being formed with a central opening which passes completely through said body and each of said sides about a horizontal pivotal axis of the body, said body having an edge formed at an interface of each of said sides with a peripheral end of said body;

(b) a mounting tube in which said elastic body is fitted;

(c) a rigid sleeve immovably mounted in said central opening, of the elastic body, said rigid sleeve outside diameter being generally equal to the central opening diameter, the sleeve extending substantially the entire width of said central opening to facilitate mounting of said bushing;

(d) a pair of spaced apart voids formed in each of said elastic body sides, said pair of voids being formed in each of the sides above and below the central opening, and an imaginary vertical center of each of said voids being disposed about 90 degrees from an imaginary horizontal plane passing transversely through the body when said bushing is mounted on a vehicle suspension, said voids each being generally horizontal rectangular-shaped, said elastic body being generally solid apart from said voids and said central opening, so that said bushing is more rigid in the direction of said horizontal plane than in the direction of said vertical center; said bushing being for use in vehicle suspension; said elastic body being mountable within

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said mounting tube with flattening of the concave sides thereof to substantially fill said tube, and said edge thereof being generally unradiused.

5 2. The bushing of claim 1 in which said elastic body has a width of 58-71mm (2.3 - 2.8 inches) and a diameter of about 159 mm (6.25 inches).

10 3. The bushing of claim 1, in which said bushing body is formed of natural rubber having a durometer of from about 75 to about 90.

15 4. The bushing of claim 1, in which said bushing body is formed of natural rubber having a durometer of from about 78 to about 88.

20 5. The bushing of claim 1, in which said bushing body is formed of natural rubber having a durometer of from about 82 to about 86.

6. The bushing of claim 2, in which the area of each of said voids is from about 1240 mm² (1.93 square inches) to about 1670 mm² (2.59 square inches).

25 7. The bushing of claim 2, in which the area of each of said voids is from about 1280 mm² (1.99 square inches) to about 1600

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mm² (2.48 square inches).

8. The bushing of claim 2, in which the area of each of said voids is from about 1310 mm² (2.04 square inches) to about 1530 mm² (2.37 square inches).

9. The bushing of claim 1, in which from about 21 percent to about 35 percent of the total area of each of said voids extends beyond an area bounded by a pair of spaced imaginary vertical lines located tangential to an outer surface of said sleeve.

10. The bushing of claim 1, in which from about 23 percent to about 31 percent of the total area of each of said voids extends beyond an area bounded by a pair of spaced imaginary vertical lines located tangential to an outer surface of said sleeve.

11. The bushing of claim 1, in which from about 25 percent to about 27 percent of the total area of each of said voids extends beyond an area bounded by a pair of spaced imaginary vertical lines located tangential to an outer surface of said sleeve.

12. A bushing according to claim 1 or 2 in which said generally concave sides have a concave shape between a radially innermost edge of each of said voids and said rigid sleeve and a generally sidewardly protruding shape between a radially outermost edge of each of said voids and said peripheral end of said elastic body.

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13. The bushing of claim 12, in which said bushing body is formed of natural rubber having a durometer of from about 75 to about 90.

5 14. The bushing of claim 12, in which said bushing body is formed of natural rubber having a durometer of from about 75 to about 84.

10 15. The bushing of claim 12, in which said bushing body is formed of natural rubber having a durometer of from about 75 to about 79.

15 16. The bushing of claim 12 as dependent on claim 2, in which the area of each of said voids is from about 1400 mm² (2.17 square inches) to about 1860 mm² (2.89 square inches).

17. The bushing of claim 16 in which the area of each of said voids is from about 1430 mm² (2.23 square inches) to about 1790 mm² (2.77 square inches).

20 18. The bushing of claim 17, in which the area of each of said voids is from about 1470 mm² (2.29 square inches) to about 1710 mm² (2.65 square inches).

25 19. The bushing of claim 12, in which from about 27 percent to about 46 percent of the total area of each of said voids extends

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beyond an area bounded by a pair of spaced imaginary vertical lines located tangential to an outer surface of said sleeve.

20. The bushing of claim 12, in which from about 29 percent to
5 about 43 percent of the total area of each of said voids extends
beyond an area bounded by a pair of spaced imaginary vertical
lines located tangential to an outer surface of said sleeve.

21. The bushing of claim 12, in which from about 31 percent to
10 about 40 percent of the total area of each of said voids extends
beyond an area bounded by a pair of spaced imaginary vertical
lines located tangential to an outer surface of said sleeve.

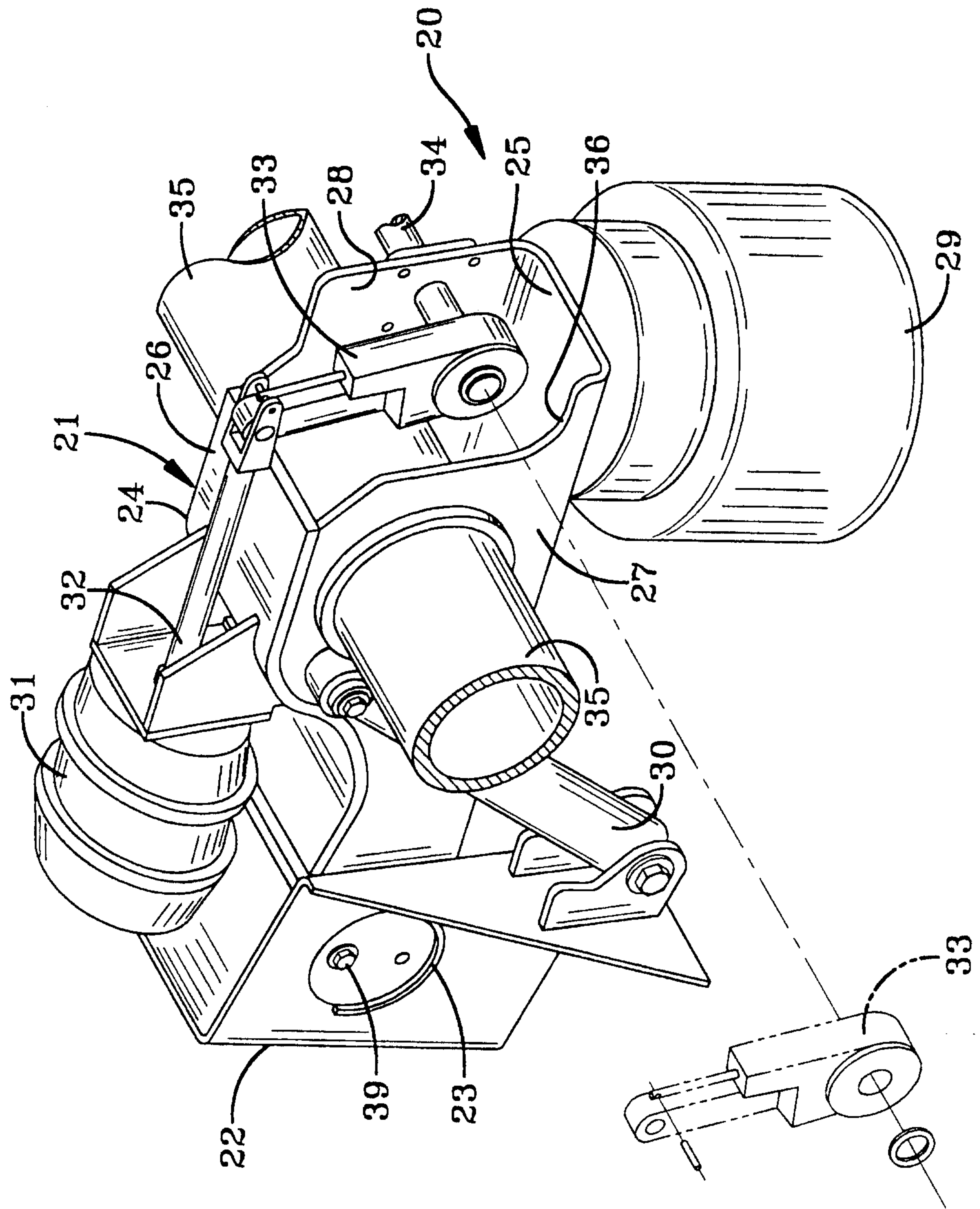


FIG-1
PRIOR ART

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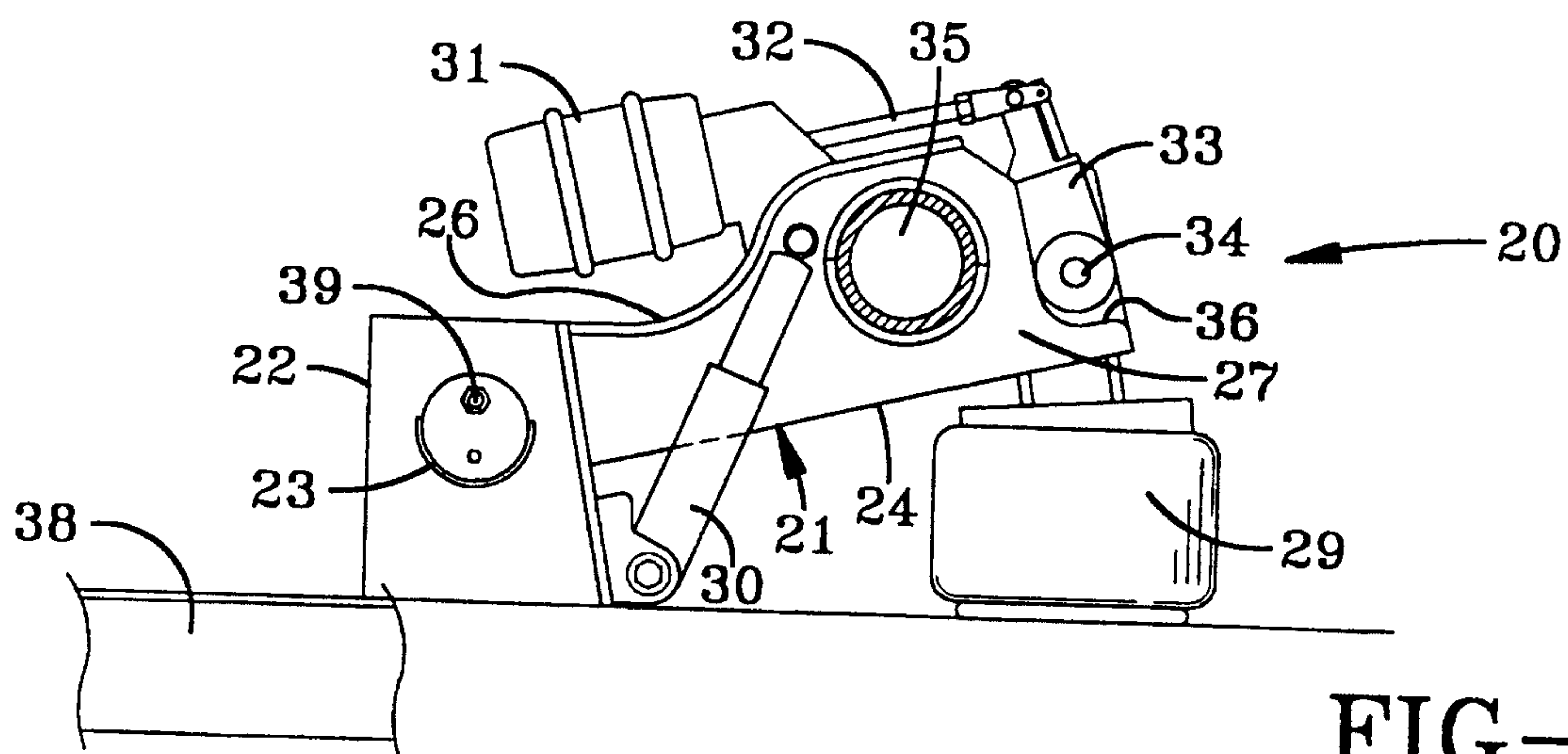


FIG-2
PRIOR ART

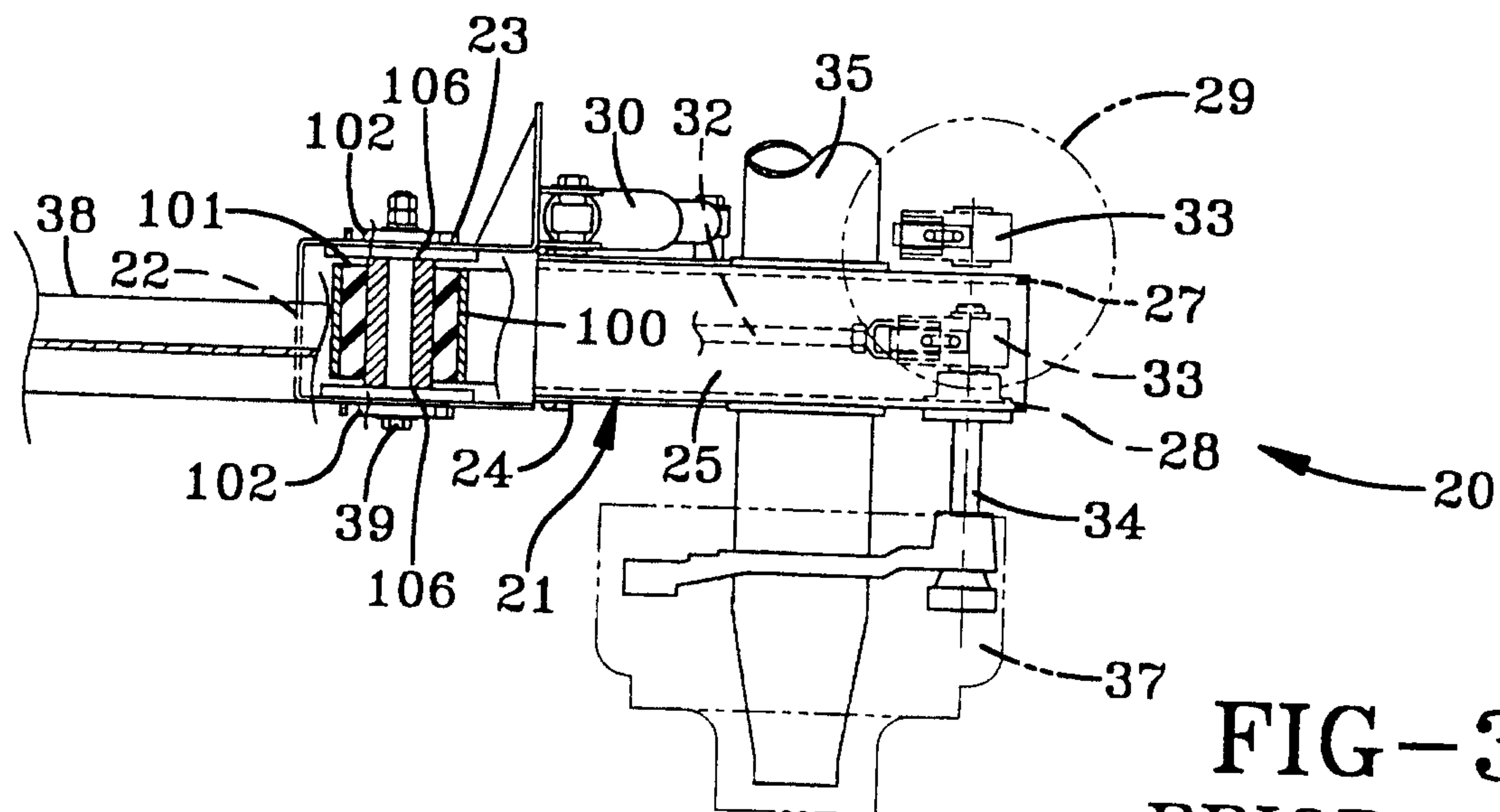


FIG-3
PRIOR ART

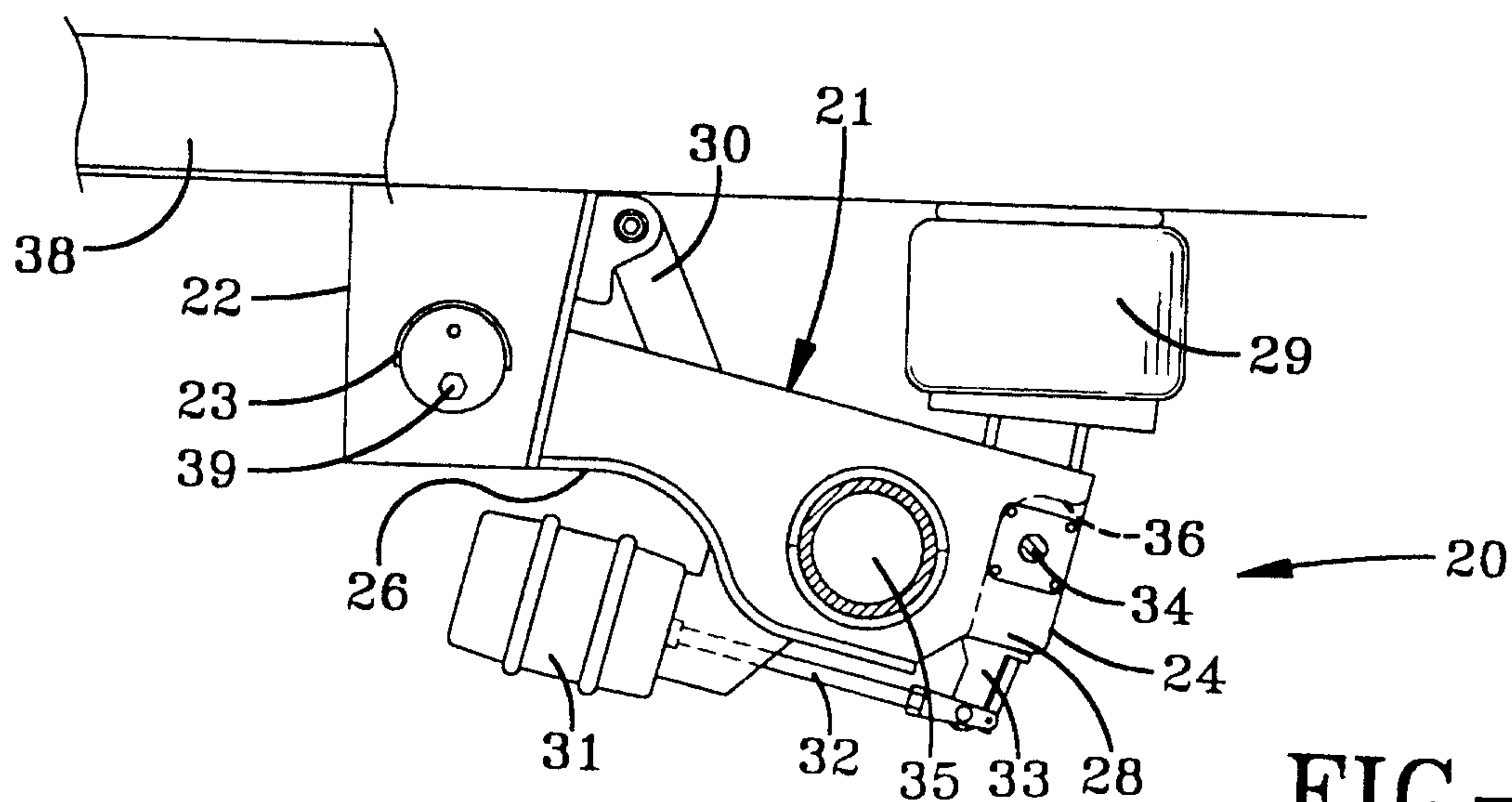


FIG-4
PRIOR ART

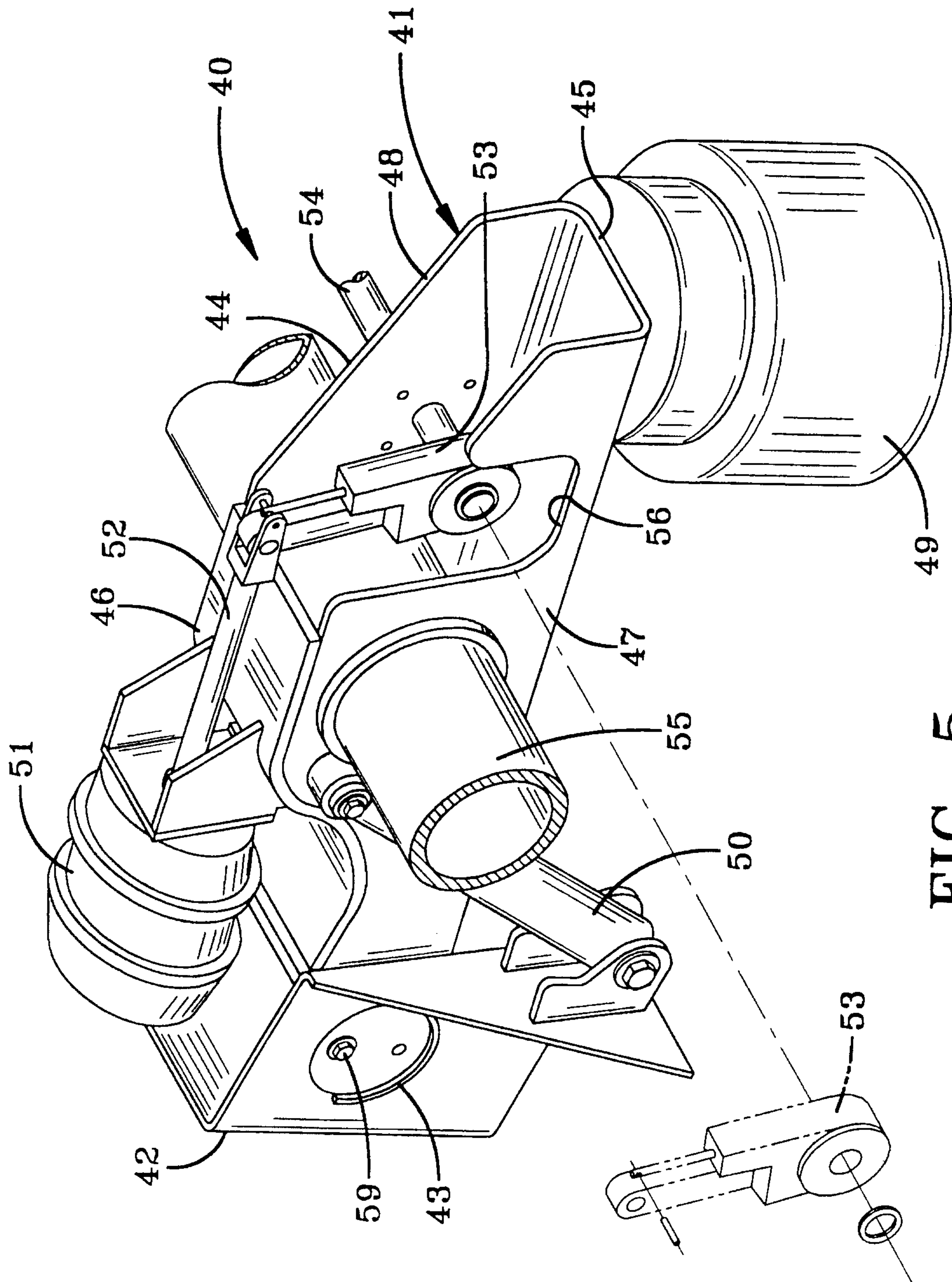
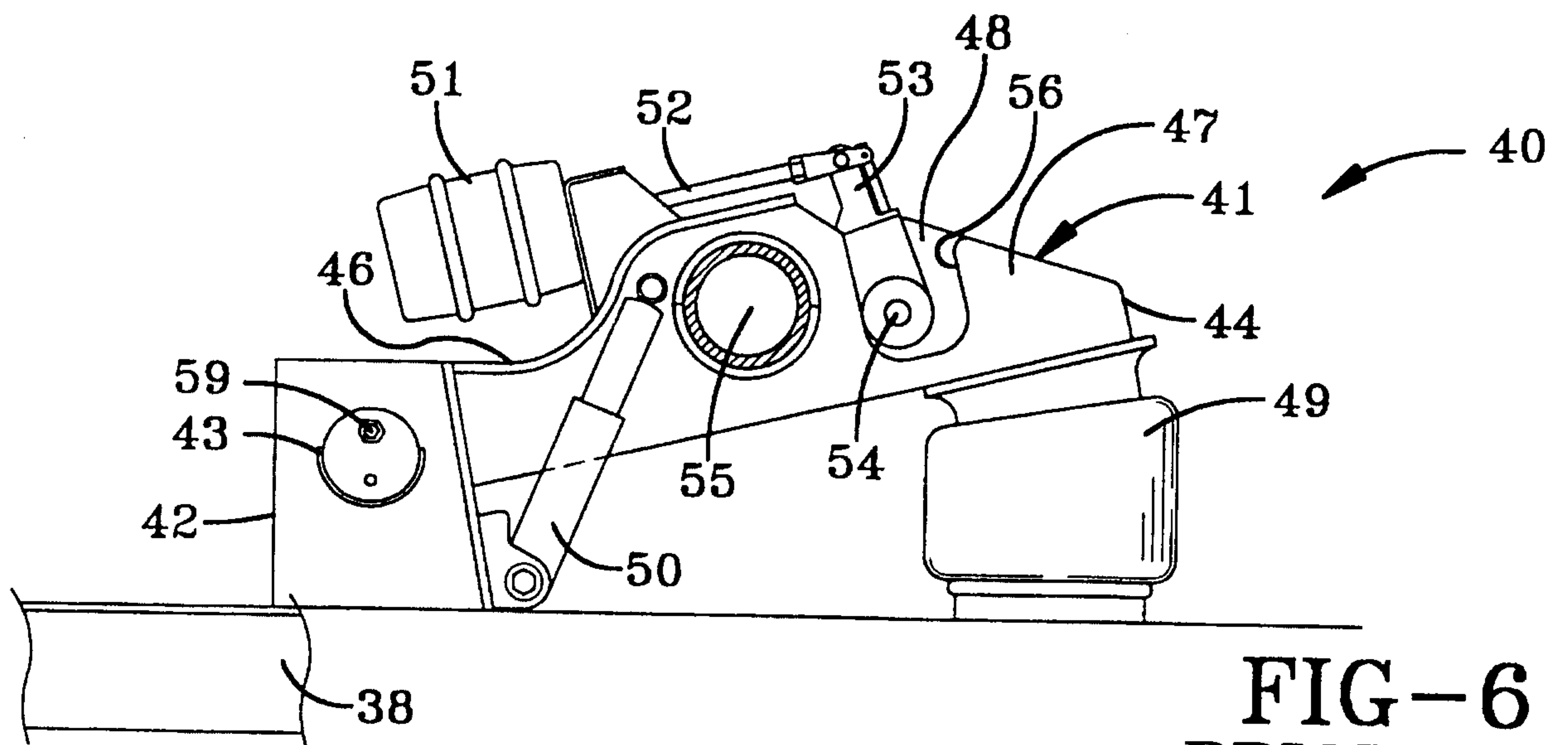
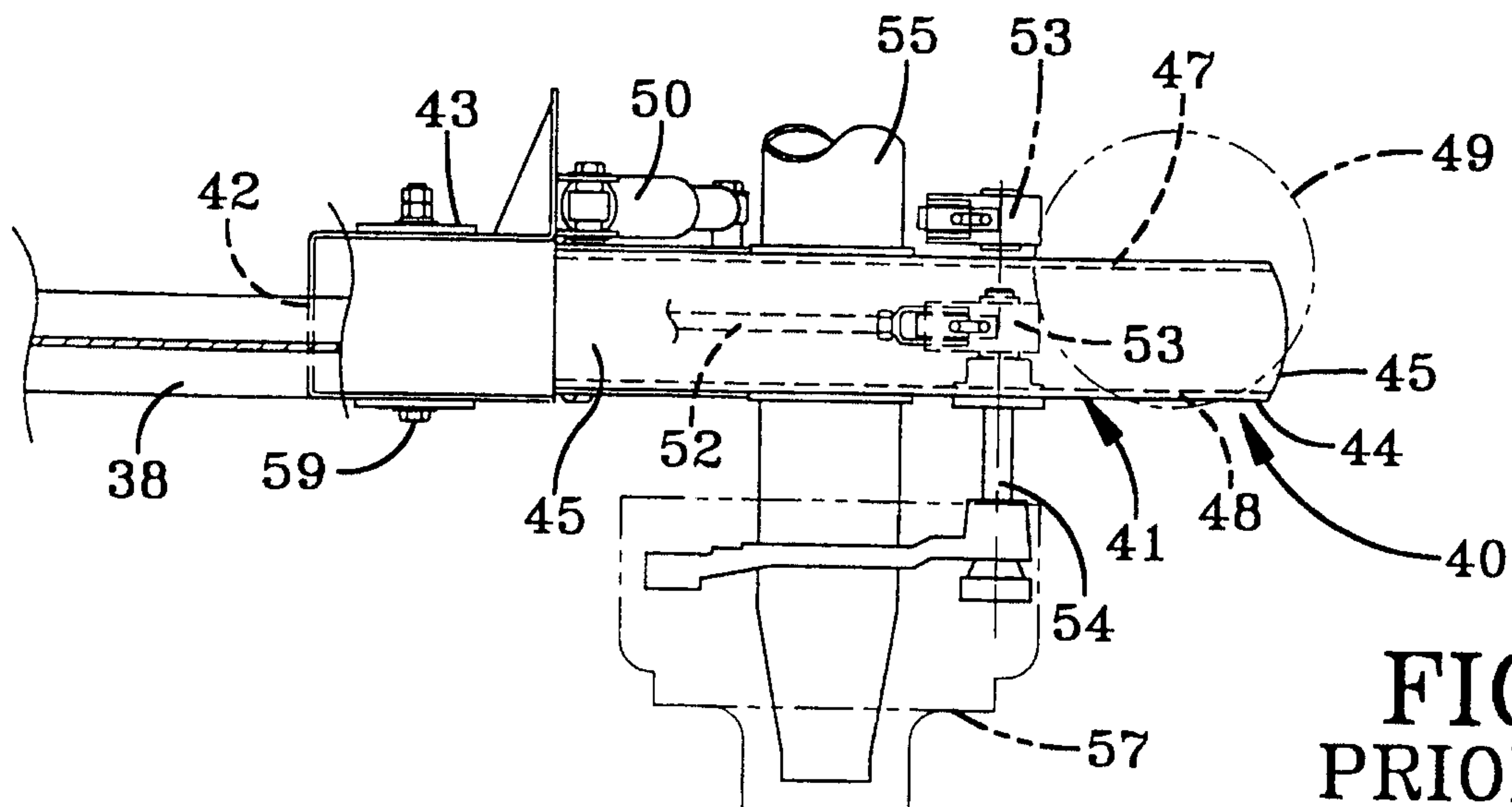
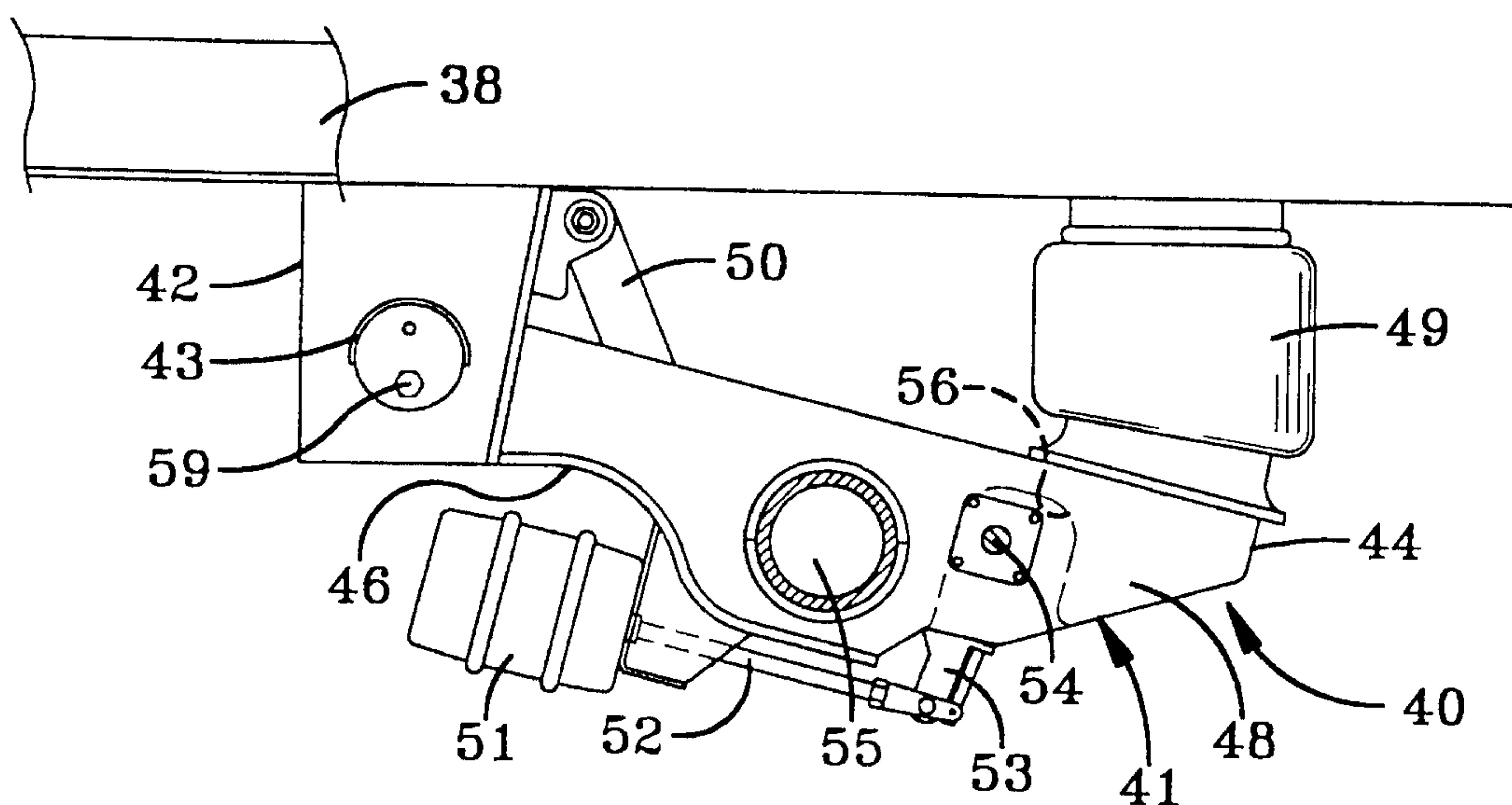


FIG-5
PRIOR ART

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**FIG-6**
PRIOR ART**FIG-7**
PRIOR ART**FIG-8**
PRIOR ART

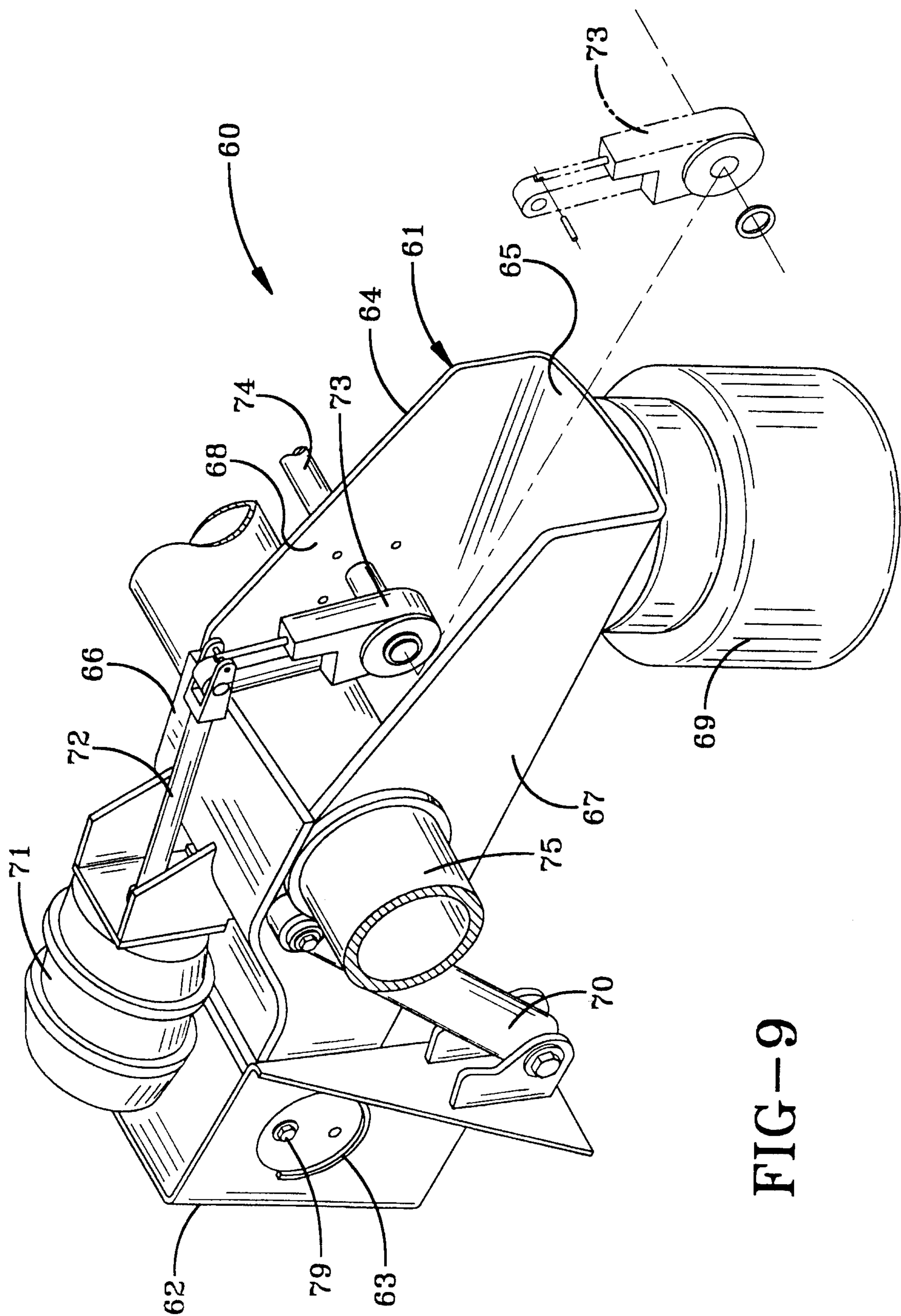


FIG-9

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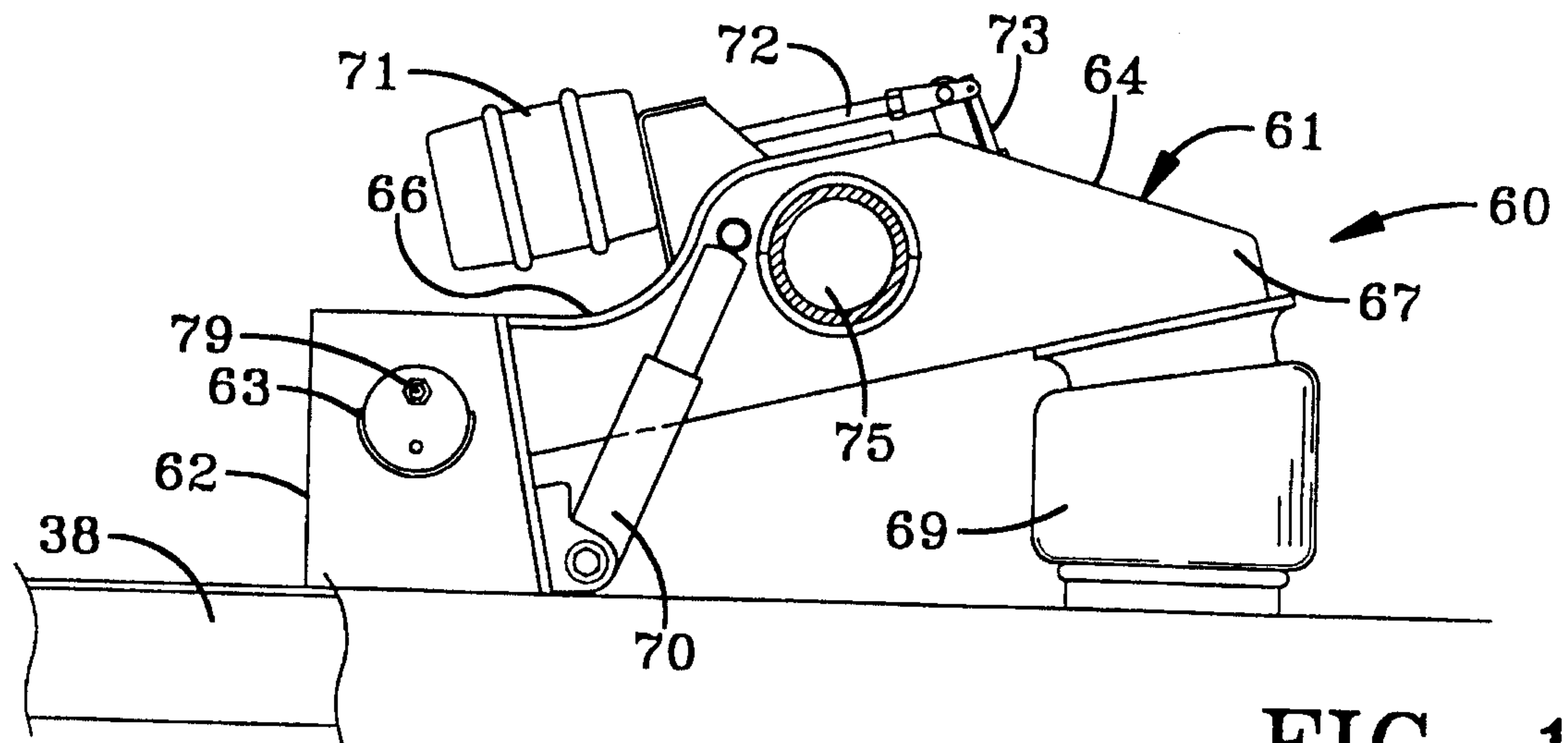


FIG-10

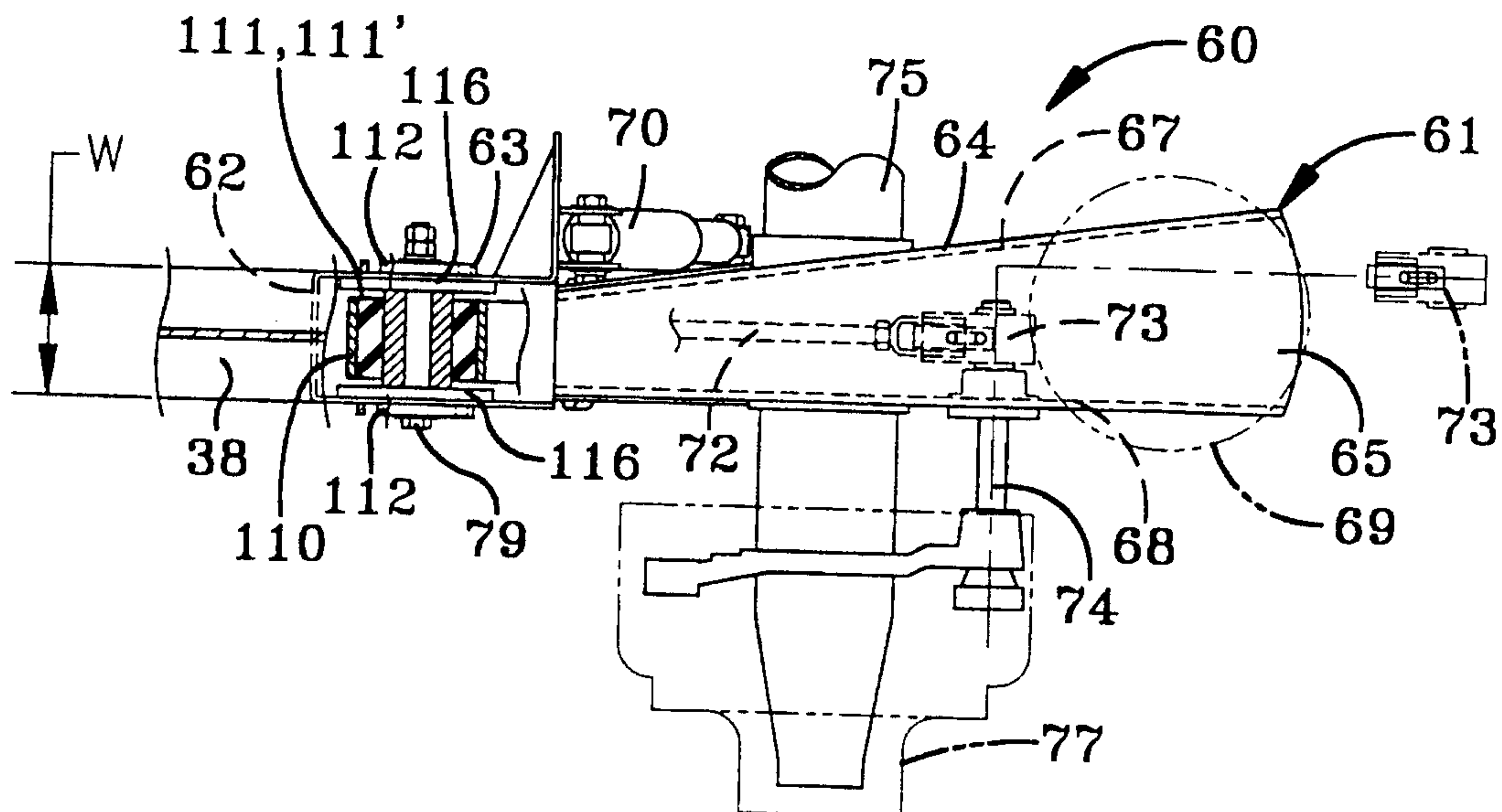


FIG-11

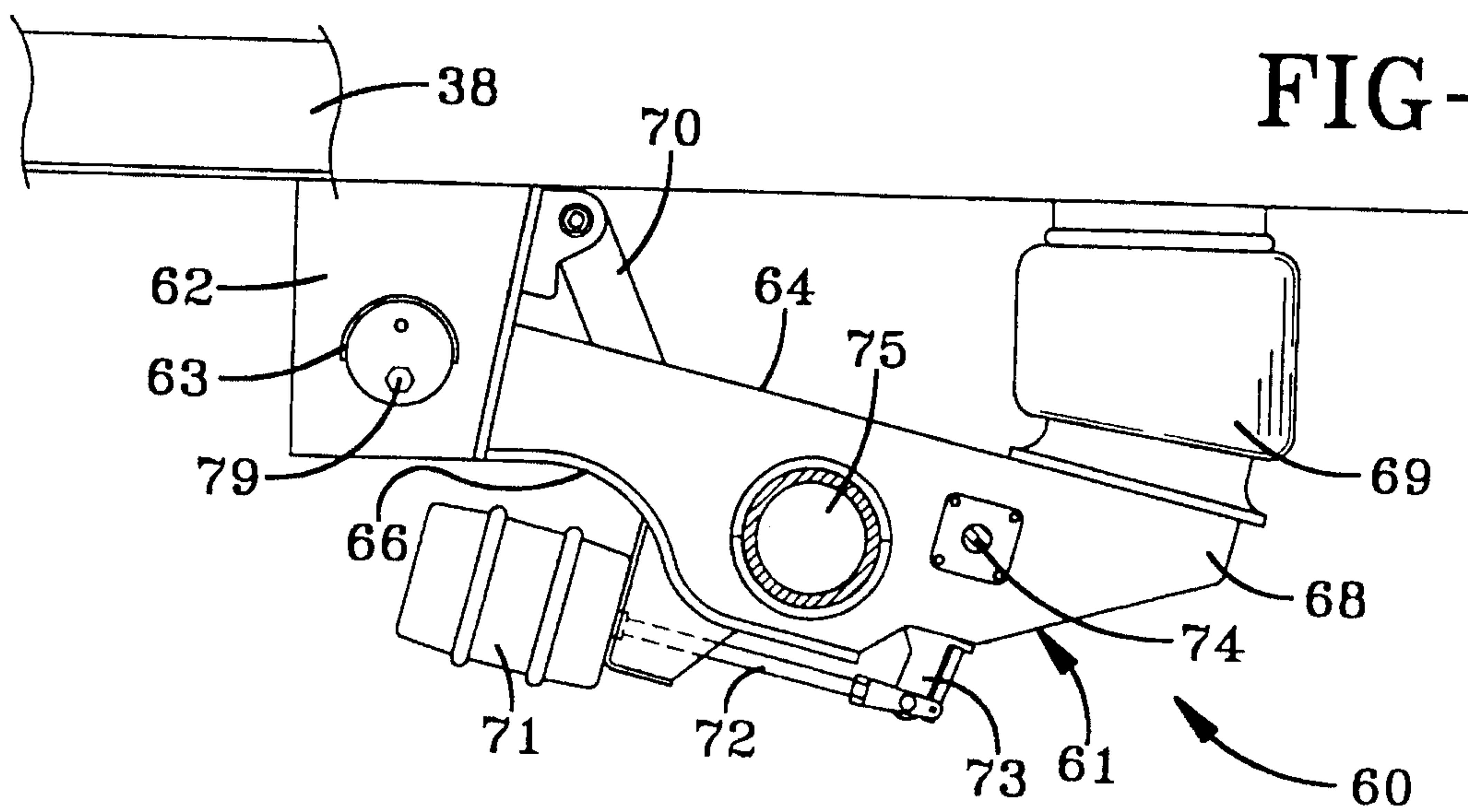


FIG-12

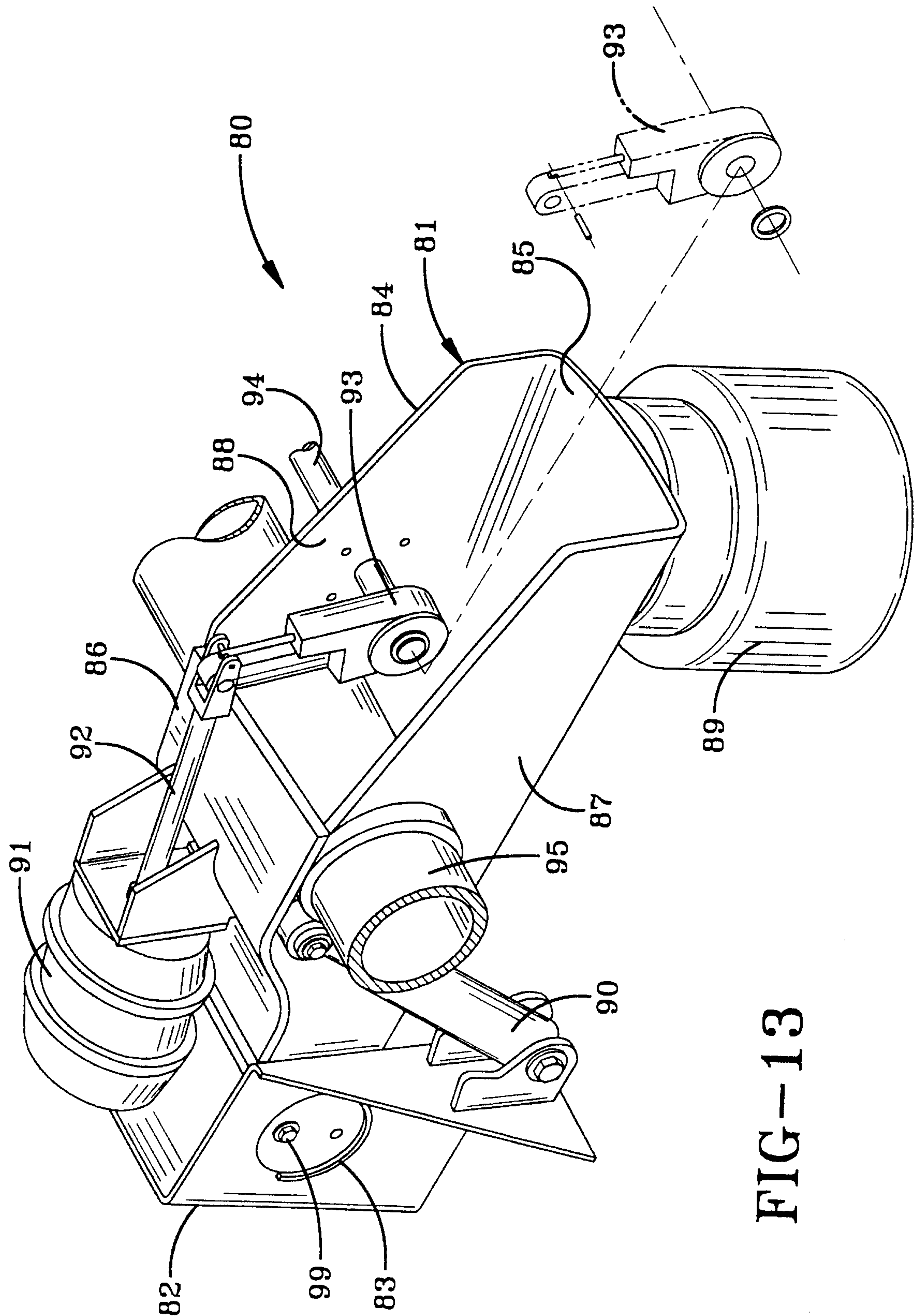


FIG-13

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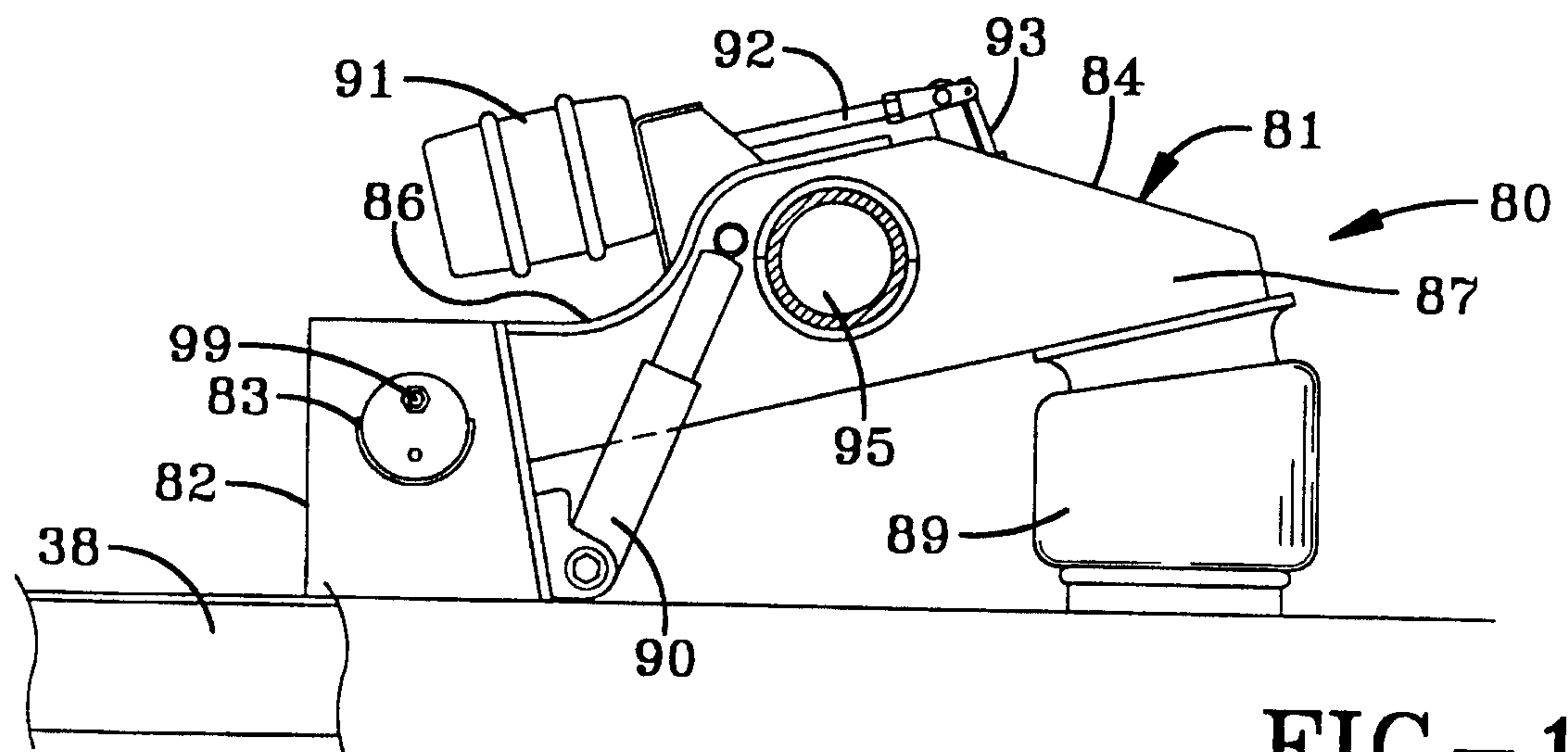


FIG-14

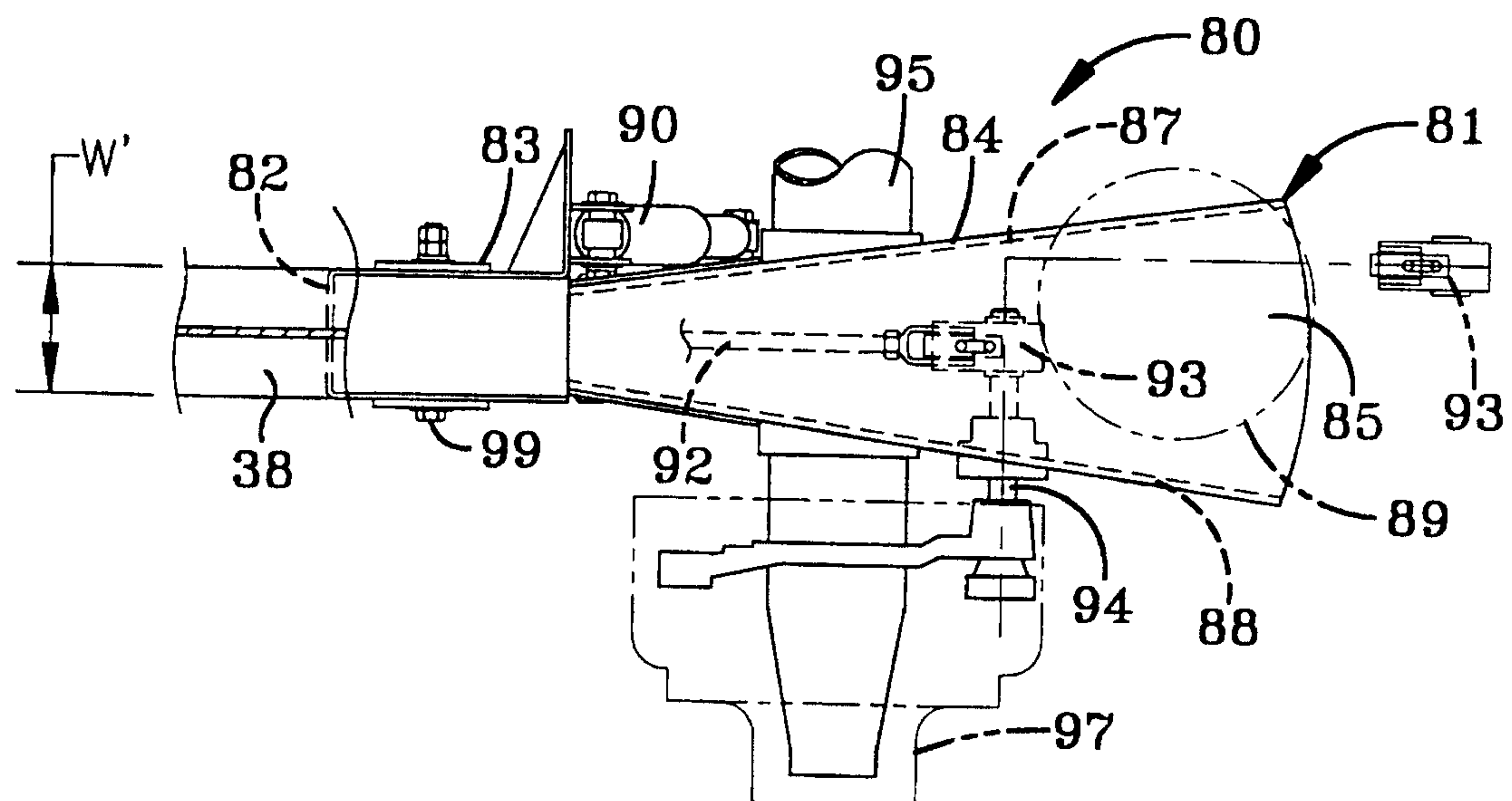


FIG-15

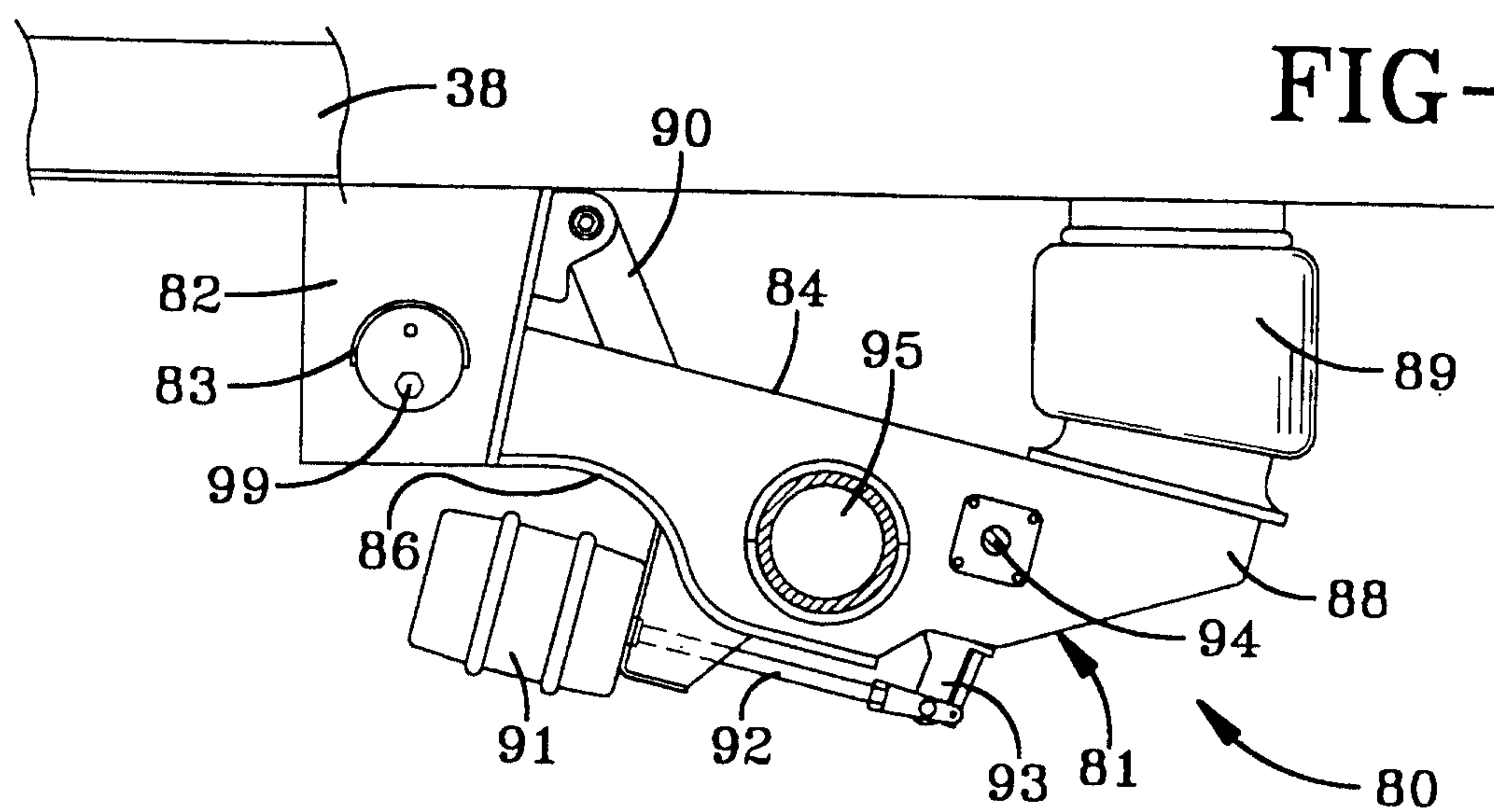


FIG-16

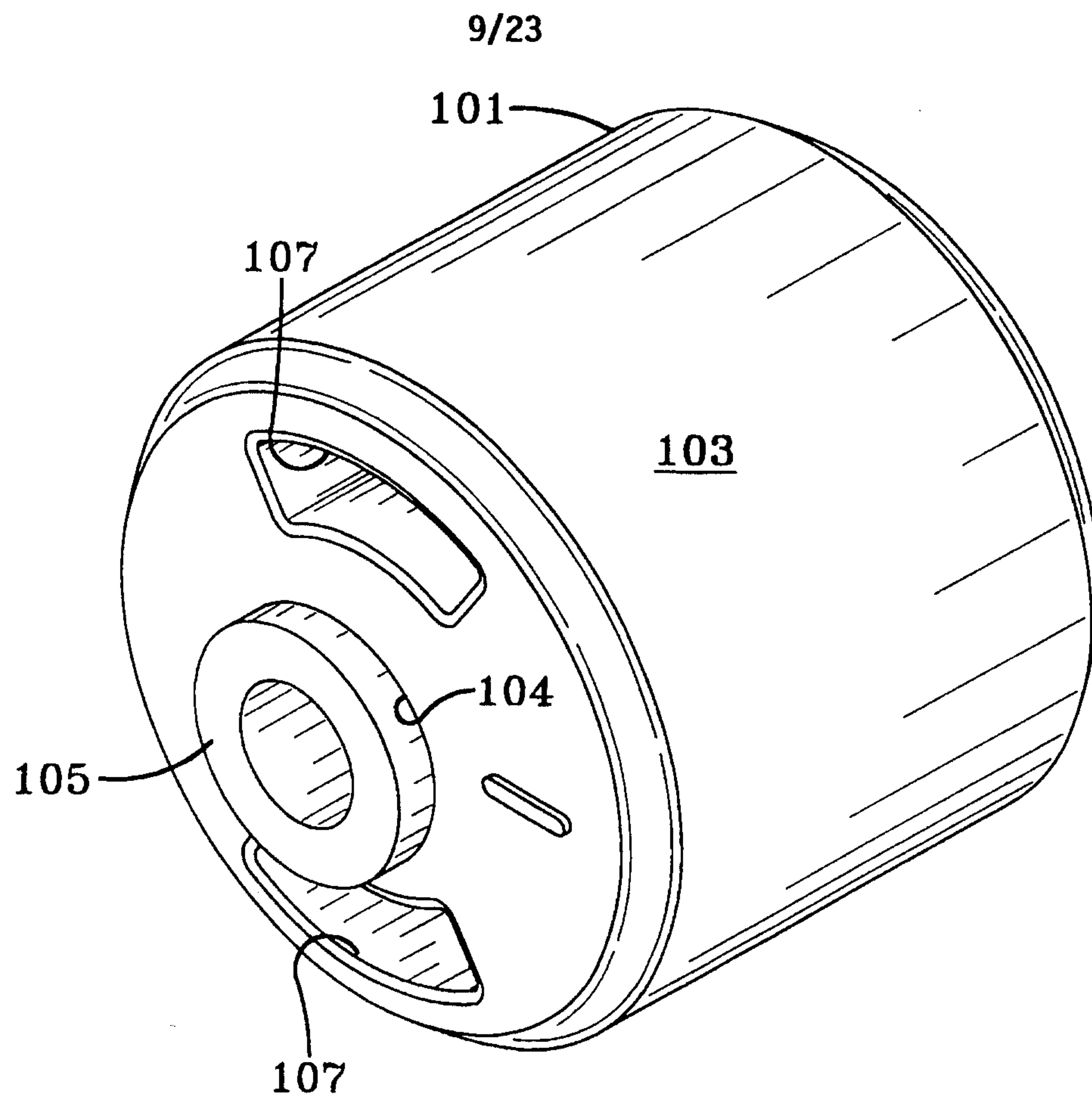


FIG-17
PRIOR ART

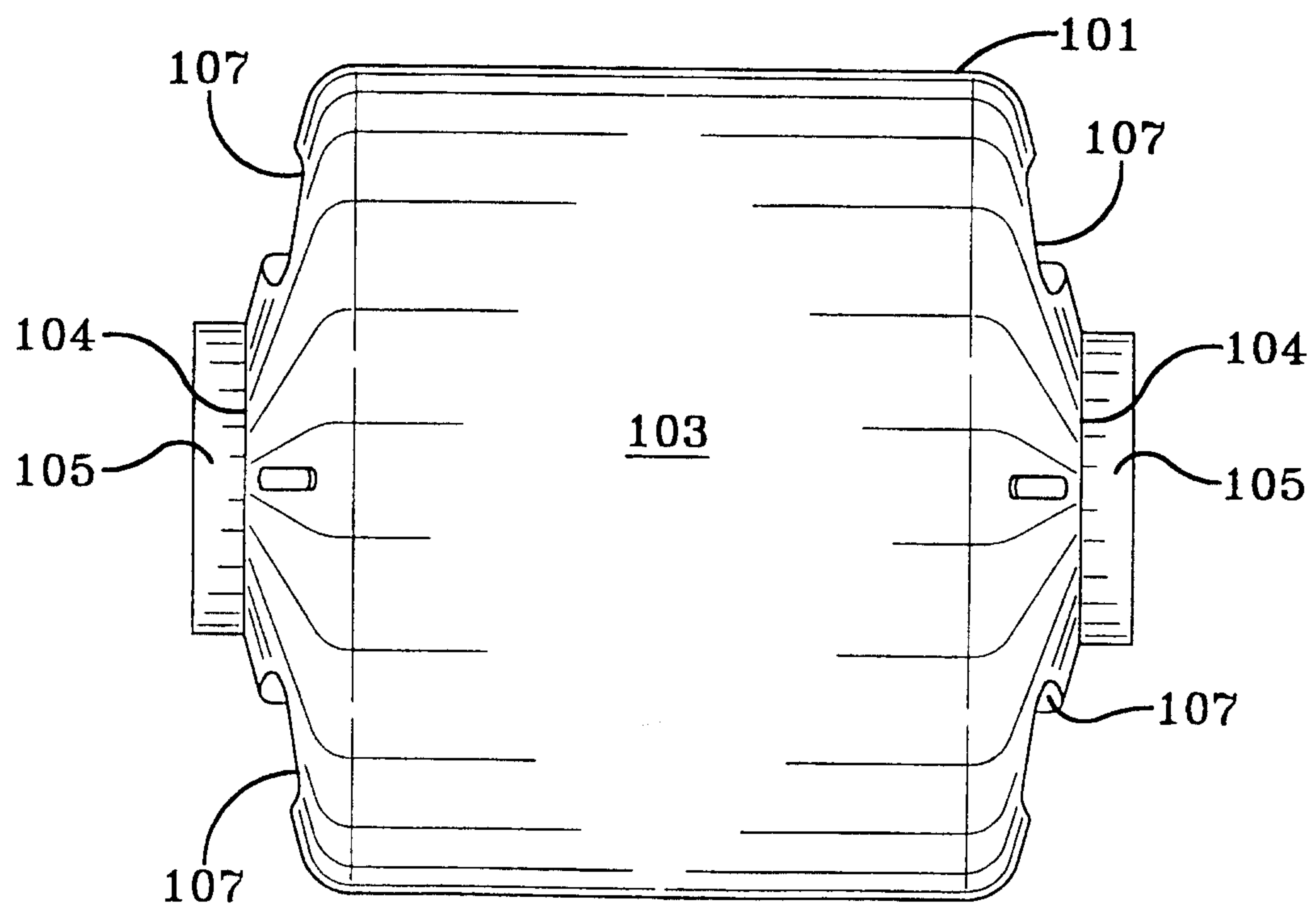


FIG-18
PRIOR ART

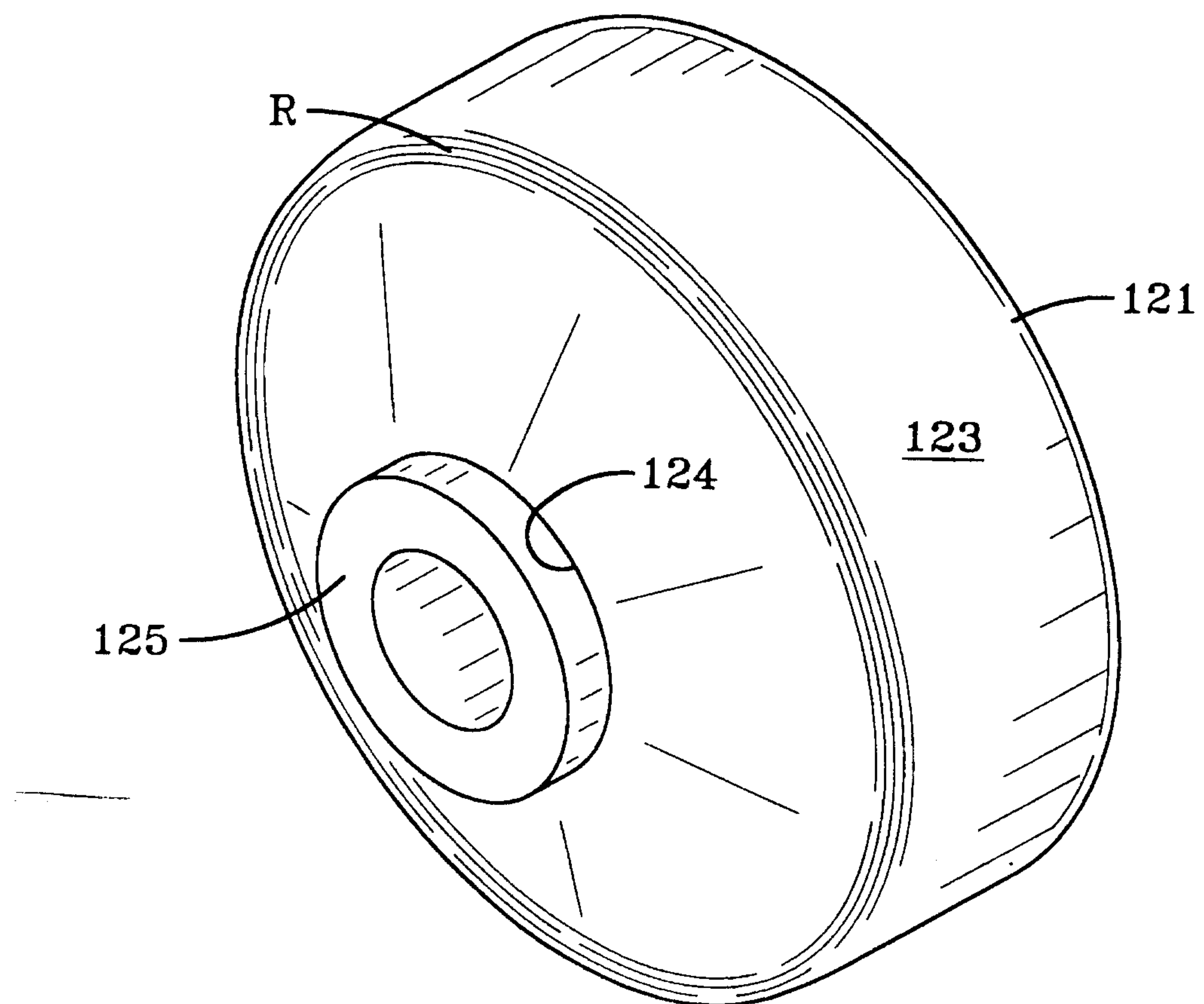


FIG-19
PRIOR ART

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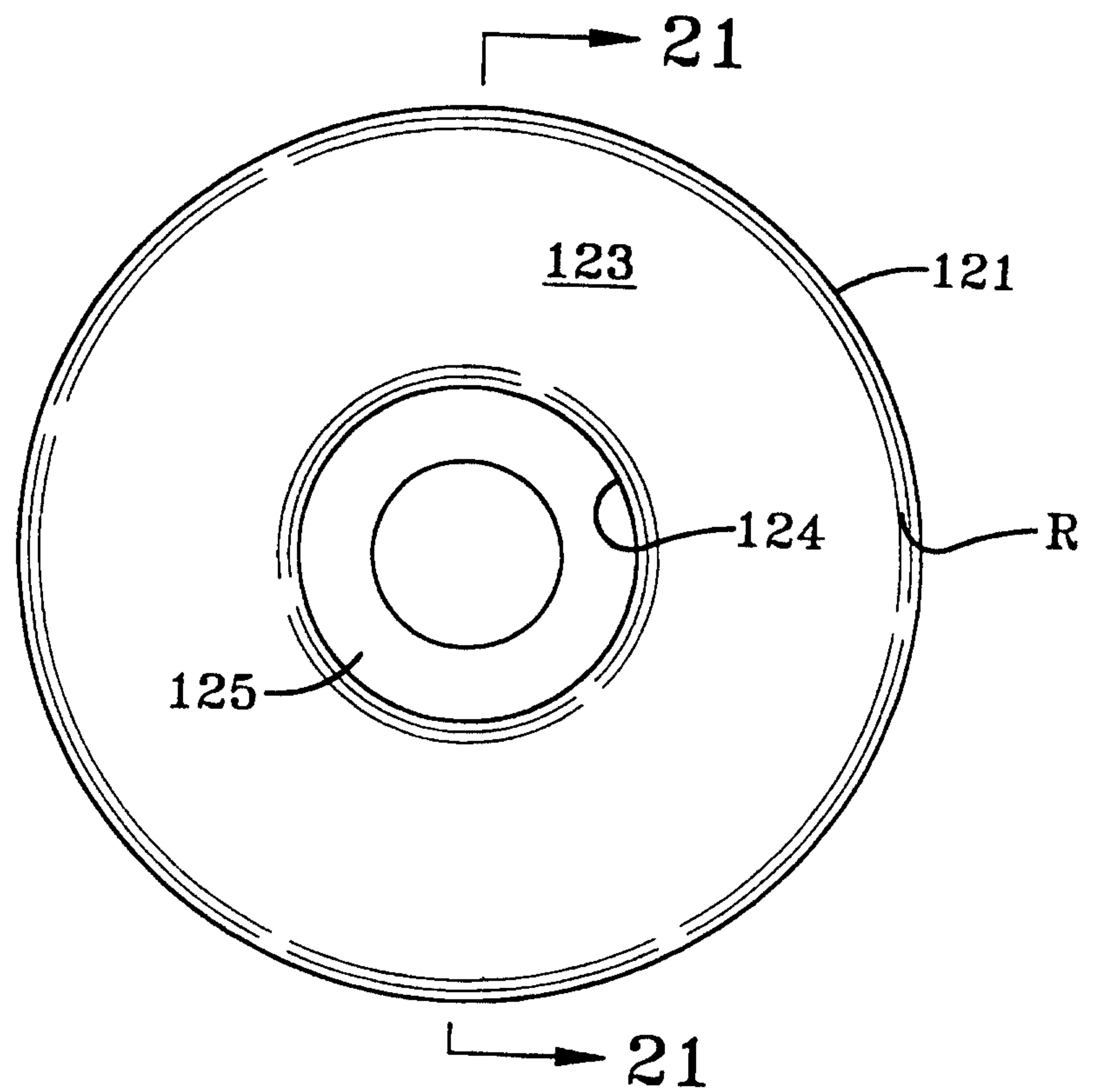


FIG-20
PRIOR ART

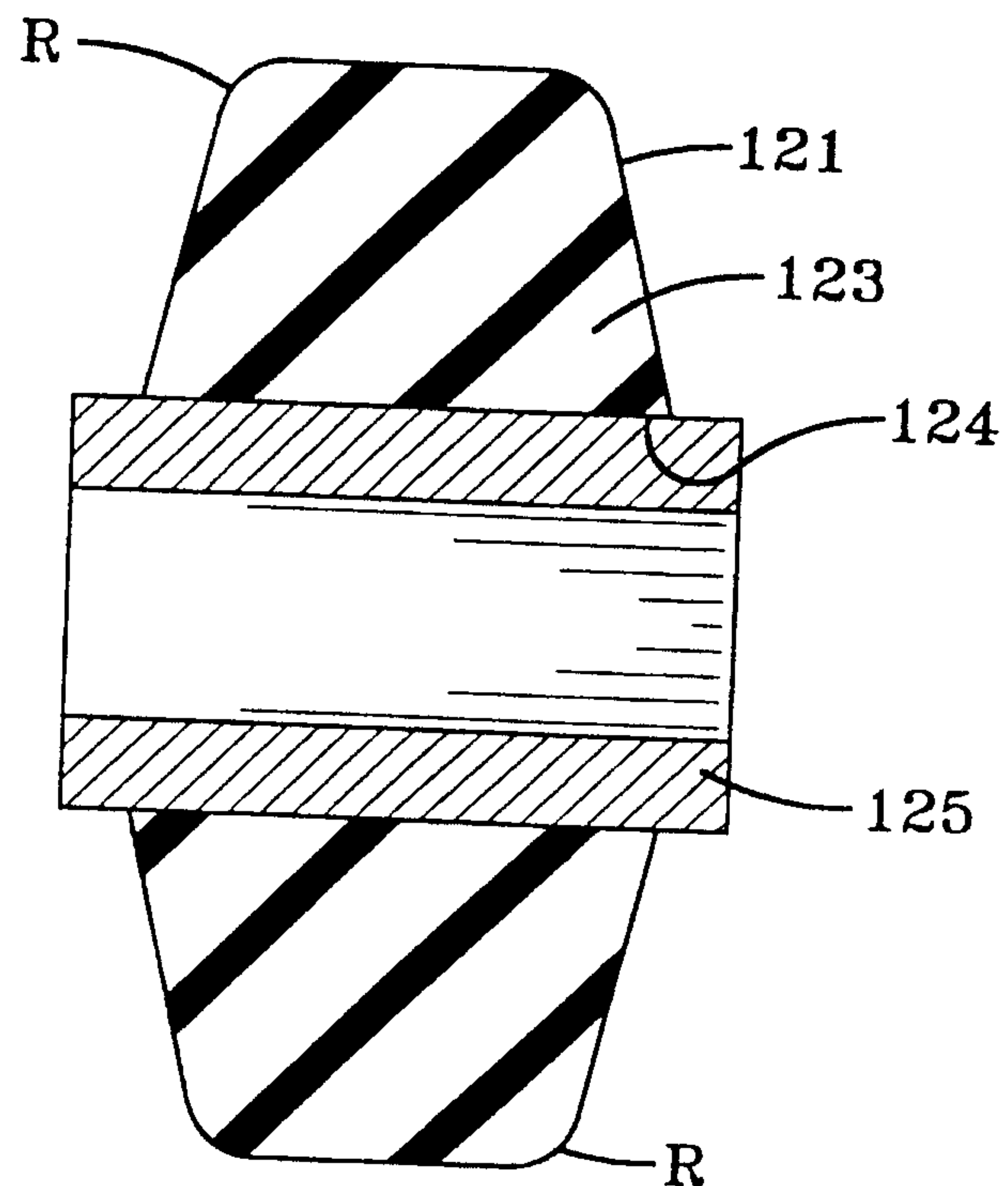


FIG-21
PRIOR ART

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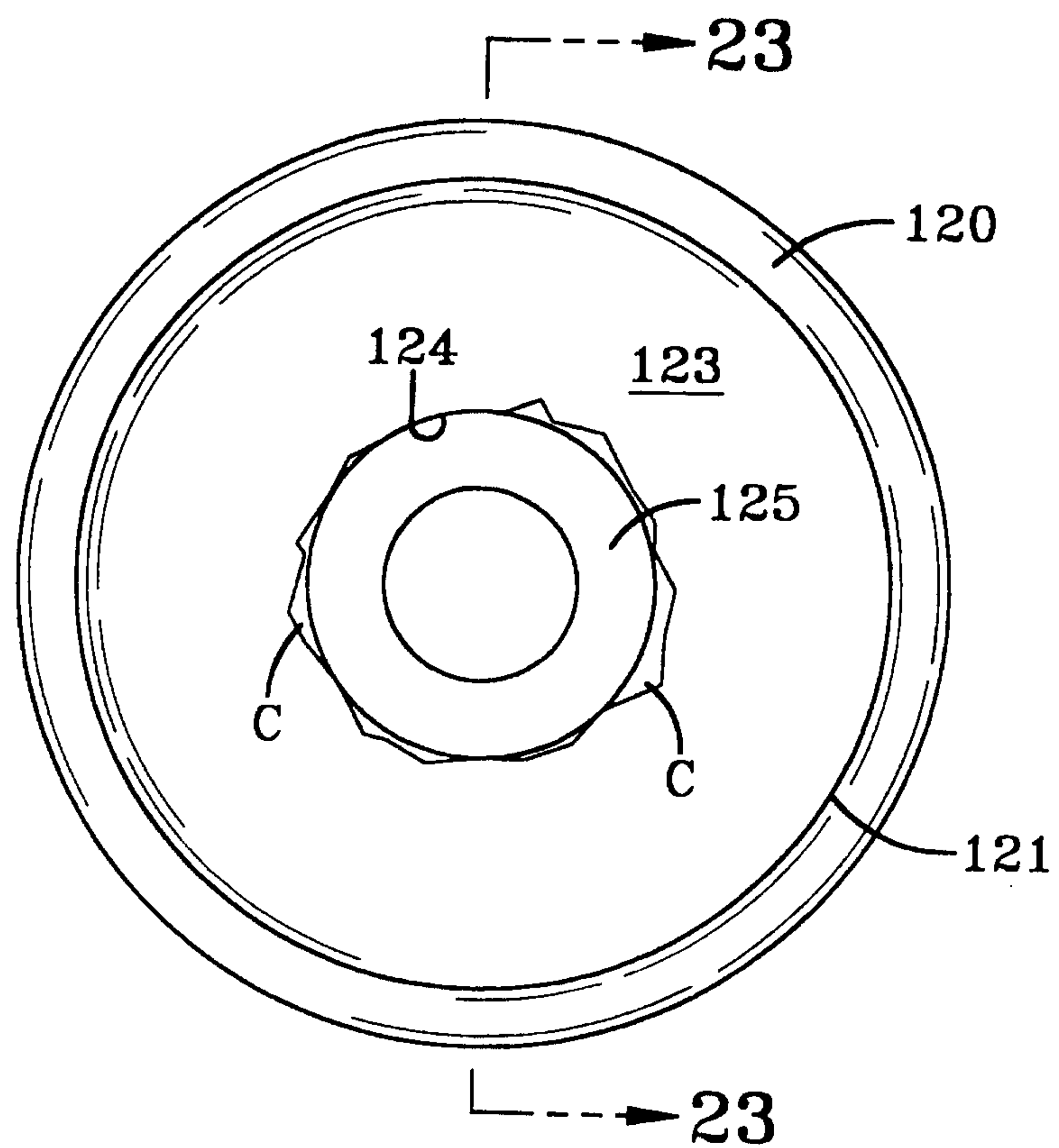


FIG-22
PRIOR ART

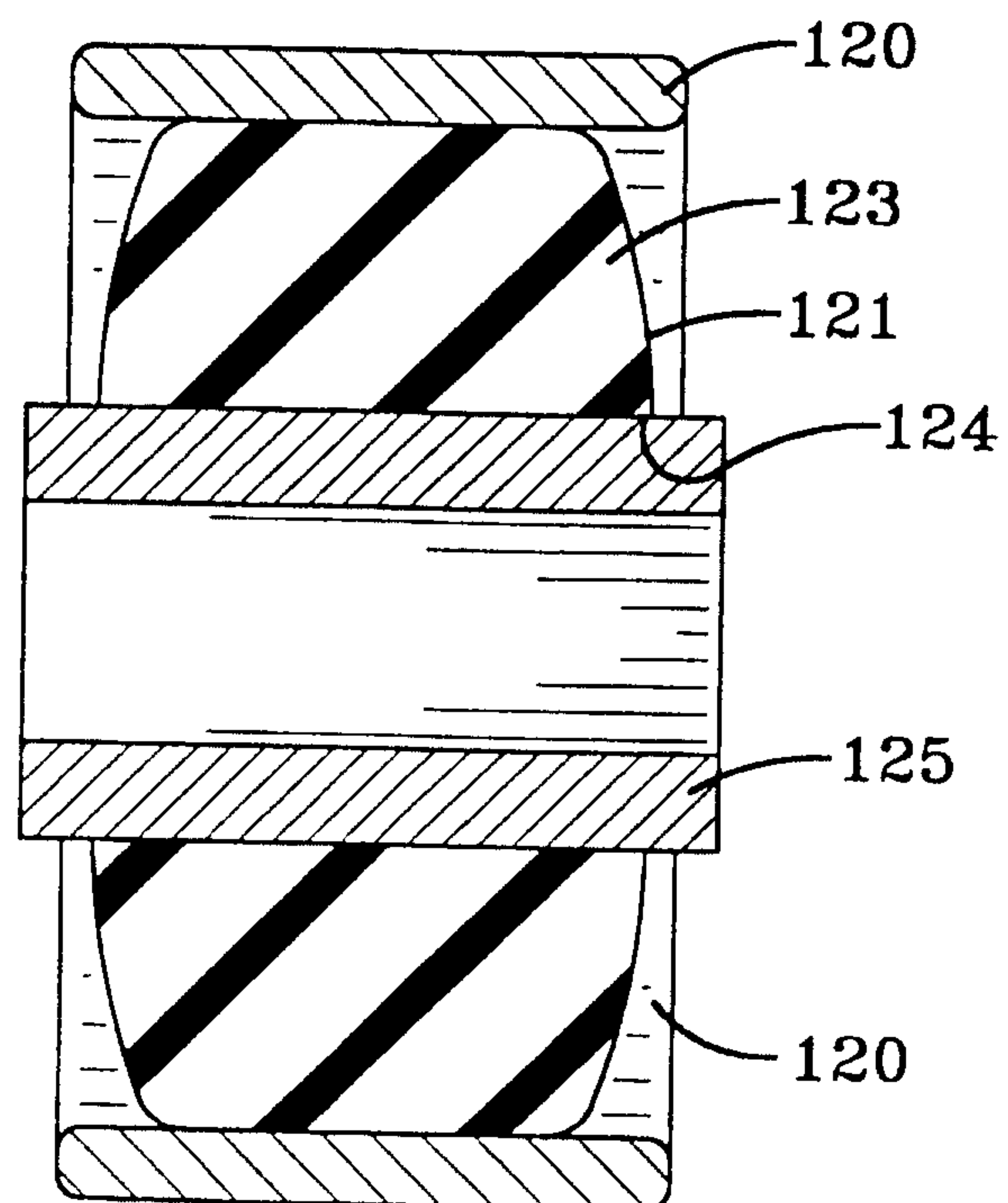


FIG-23
PRIOR ART

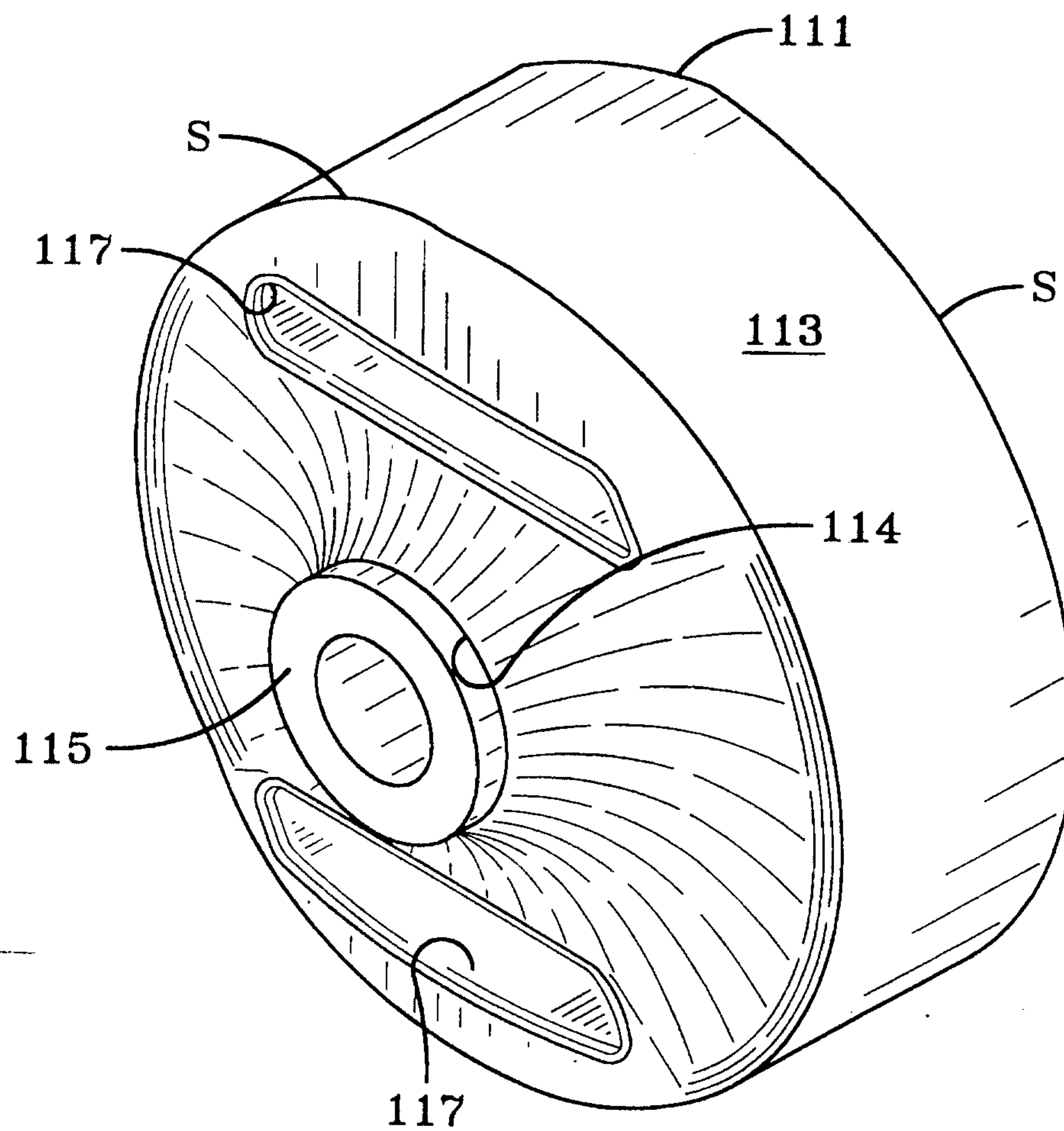


FIG-24

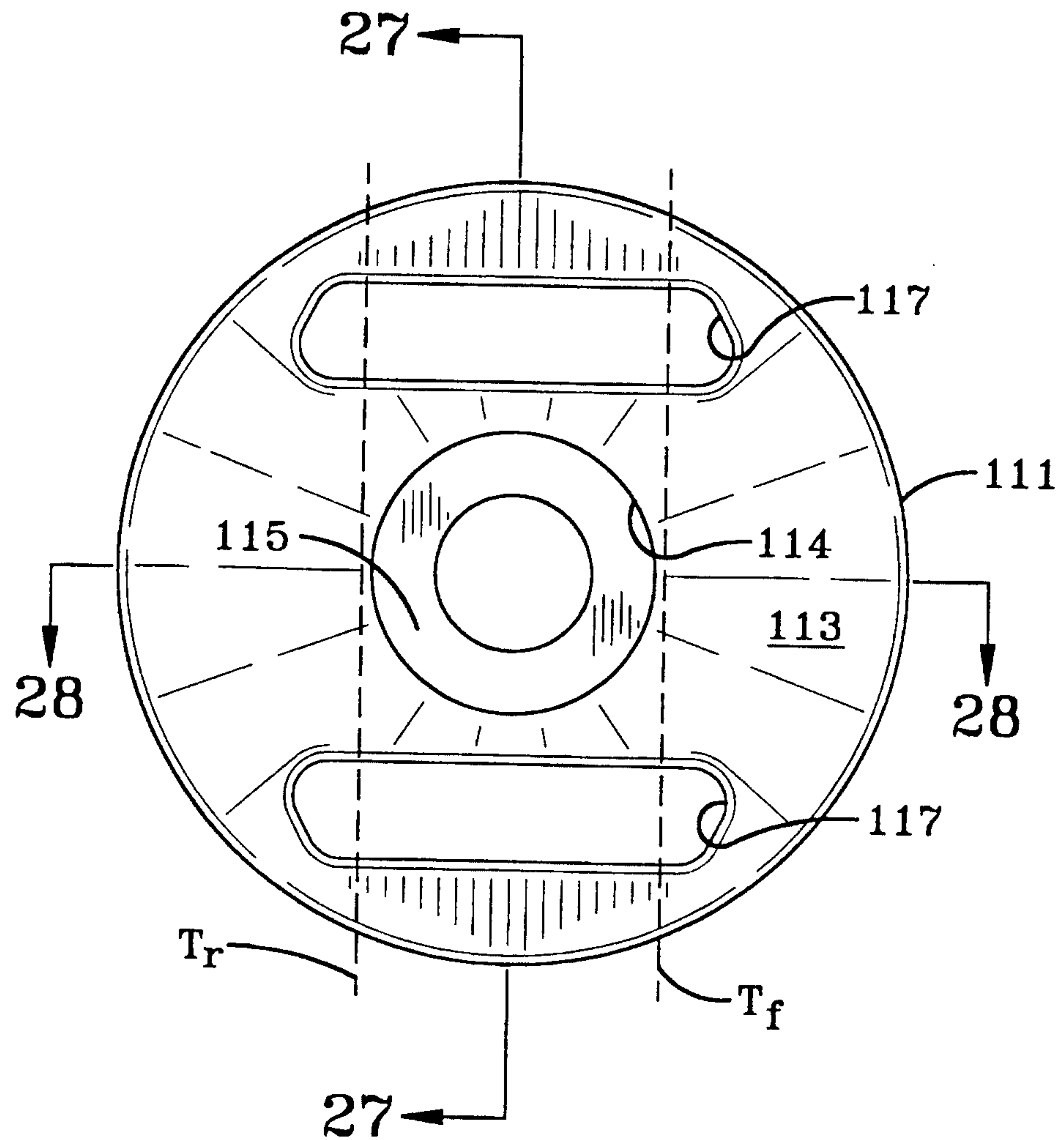


FIG-25

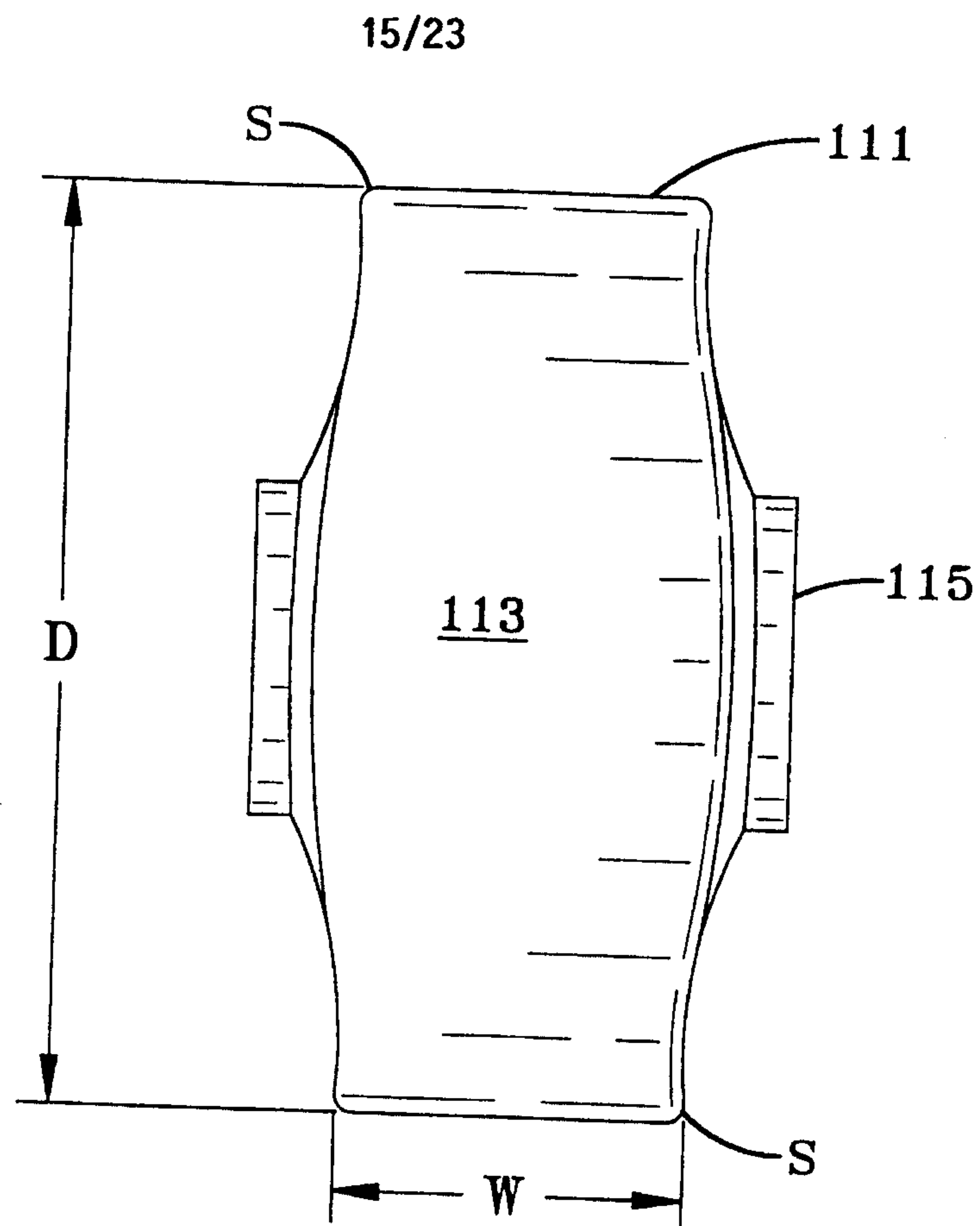


FIG-26

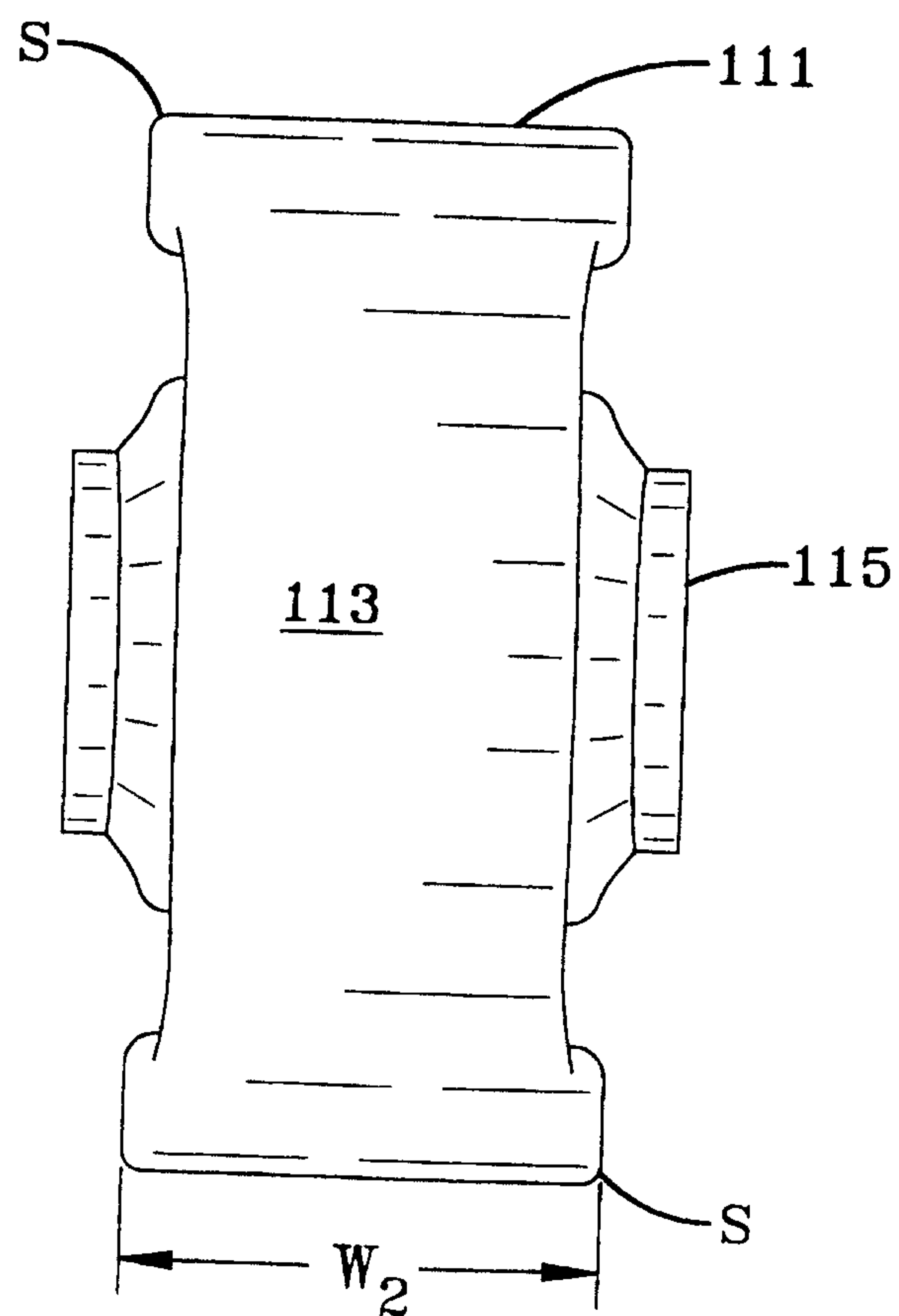


FIG-26A

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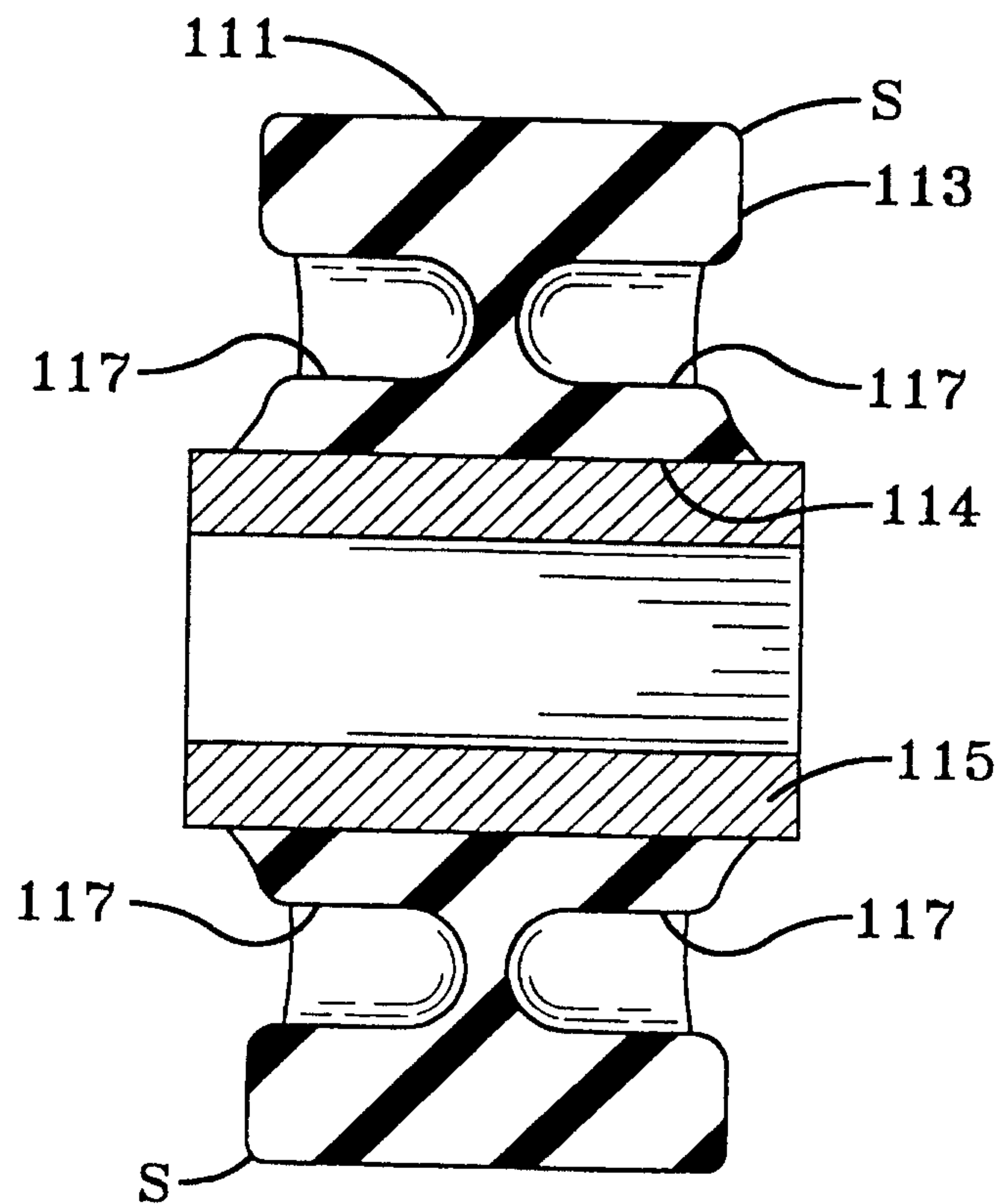


FIG-27

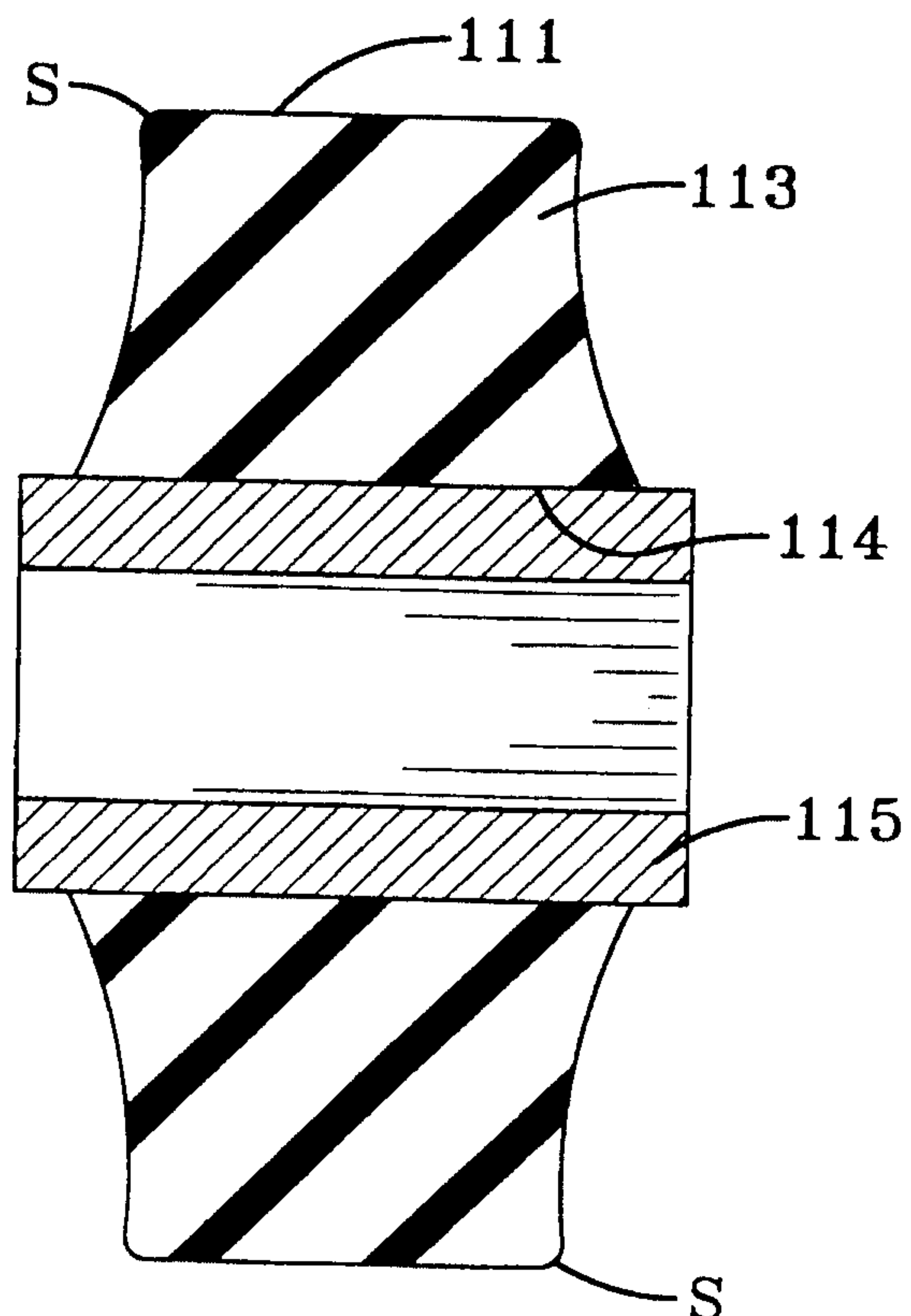
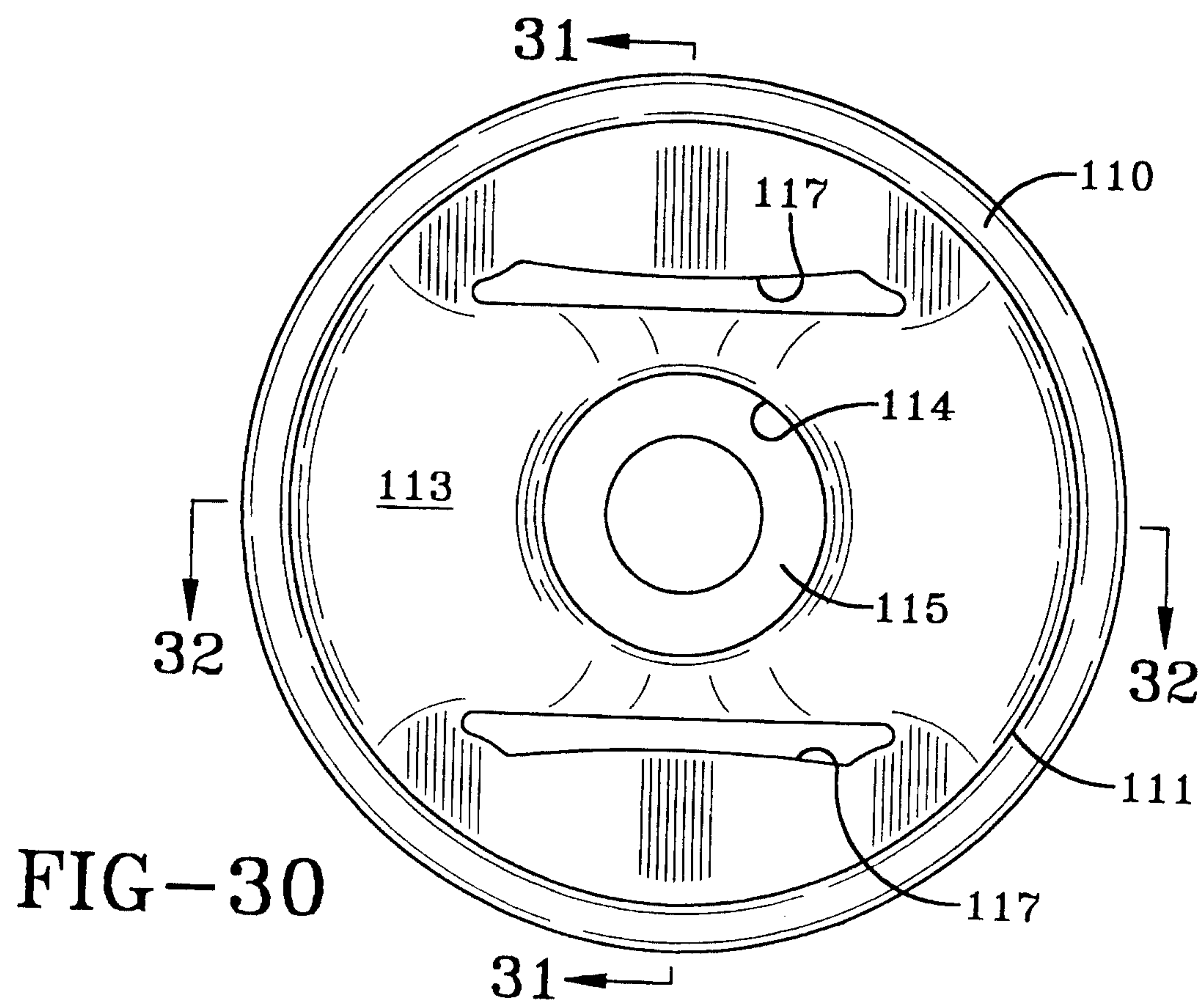
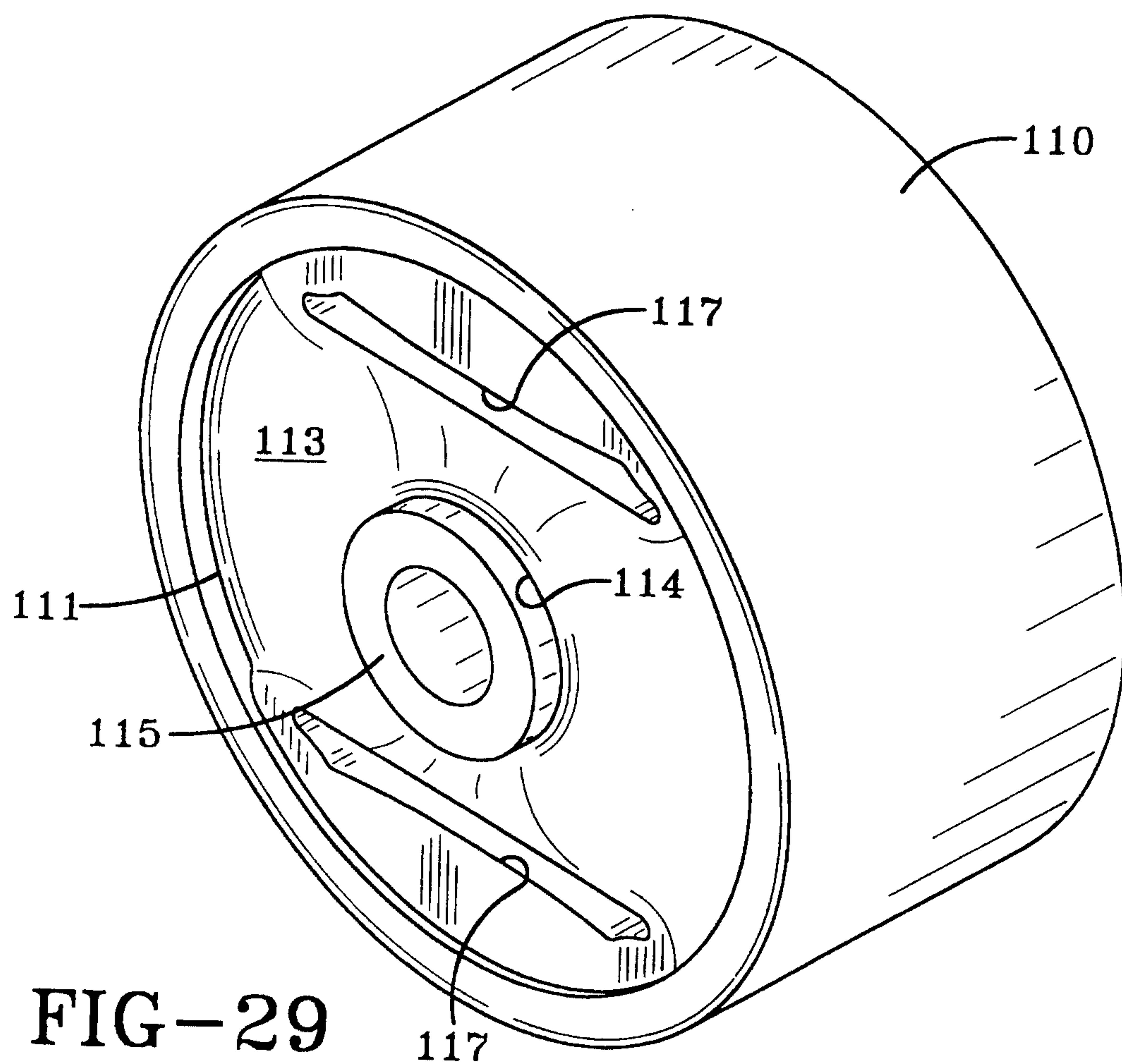


FIG-28

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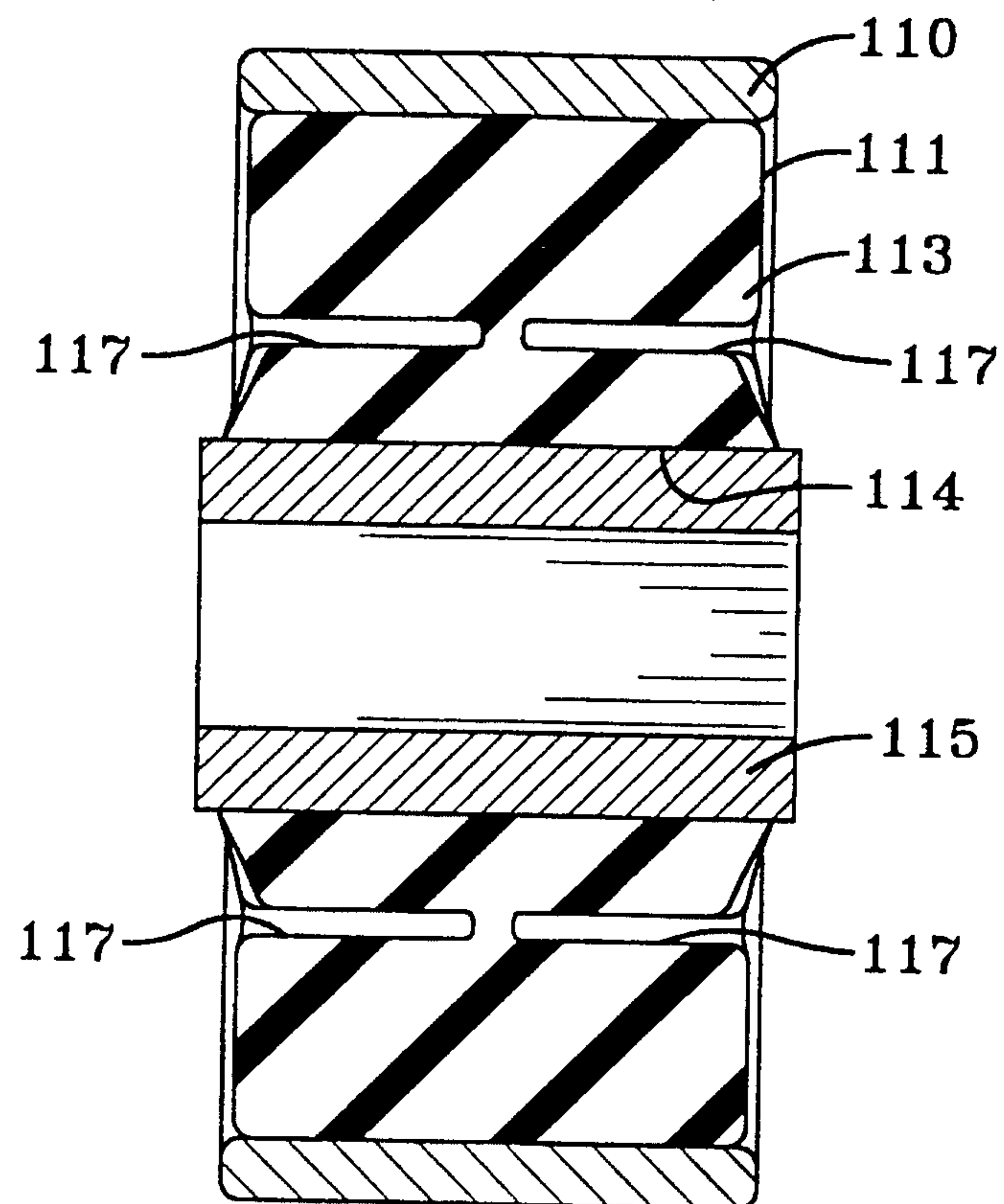


FIG-31

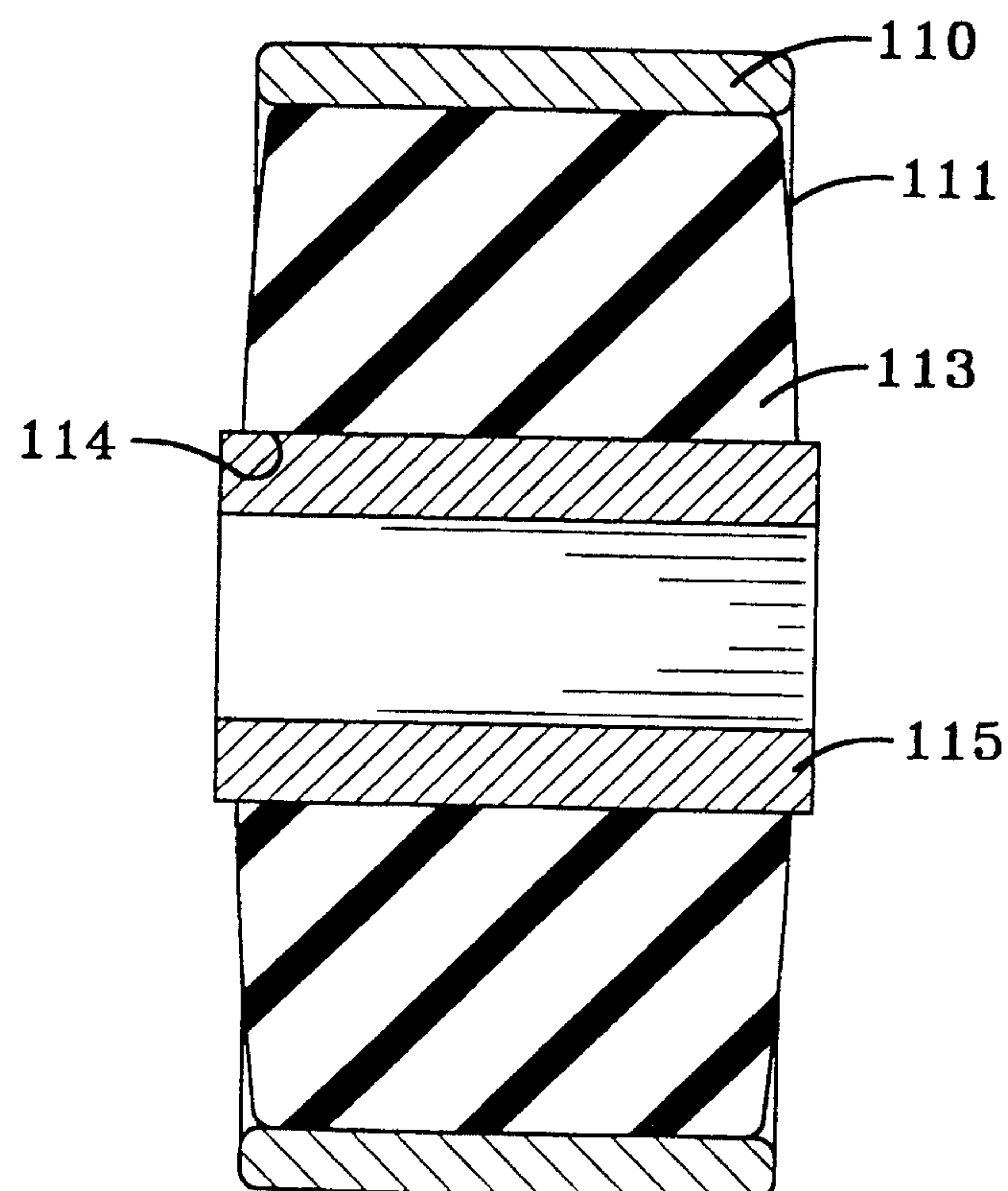


FIG-32

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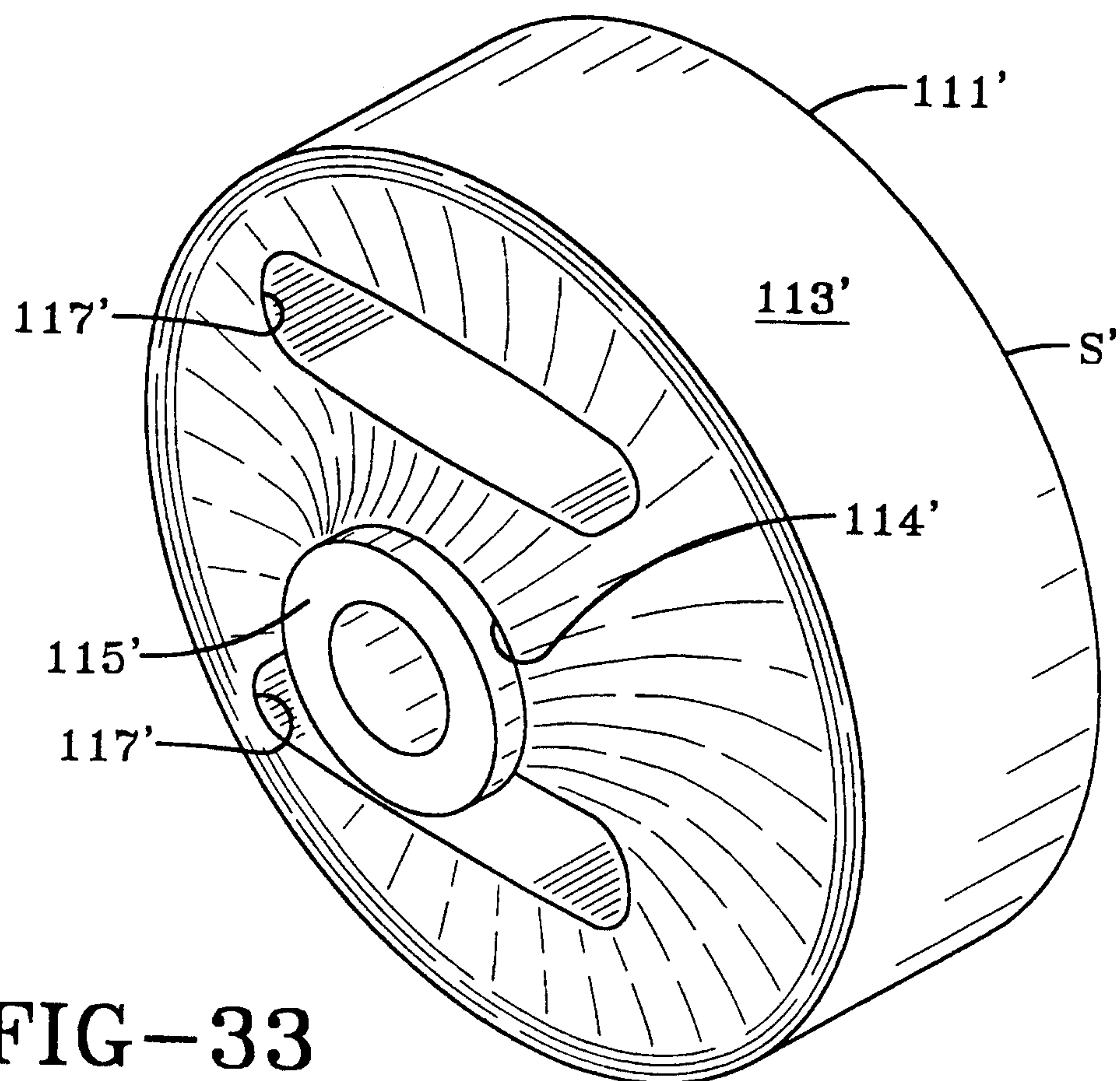


FIG-33

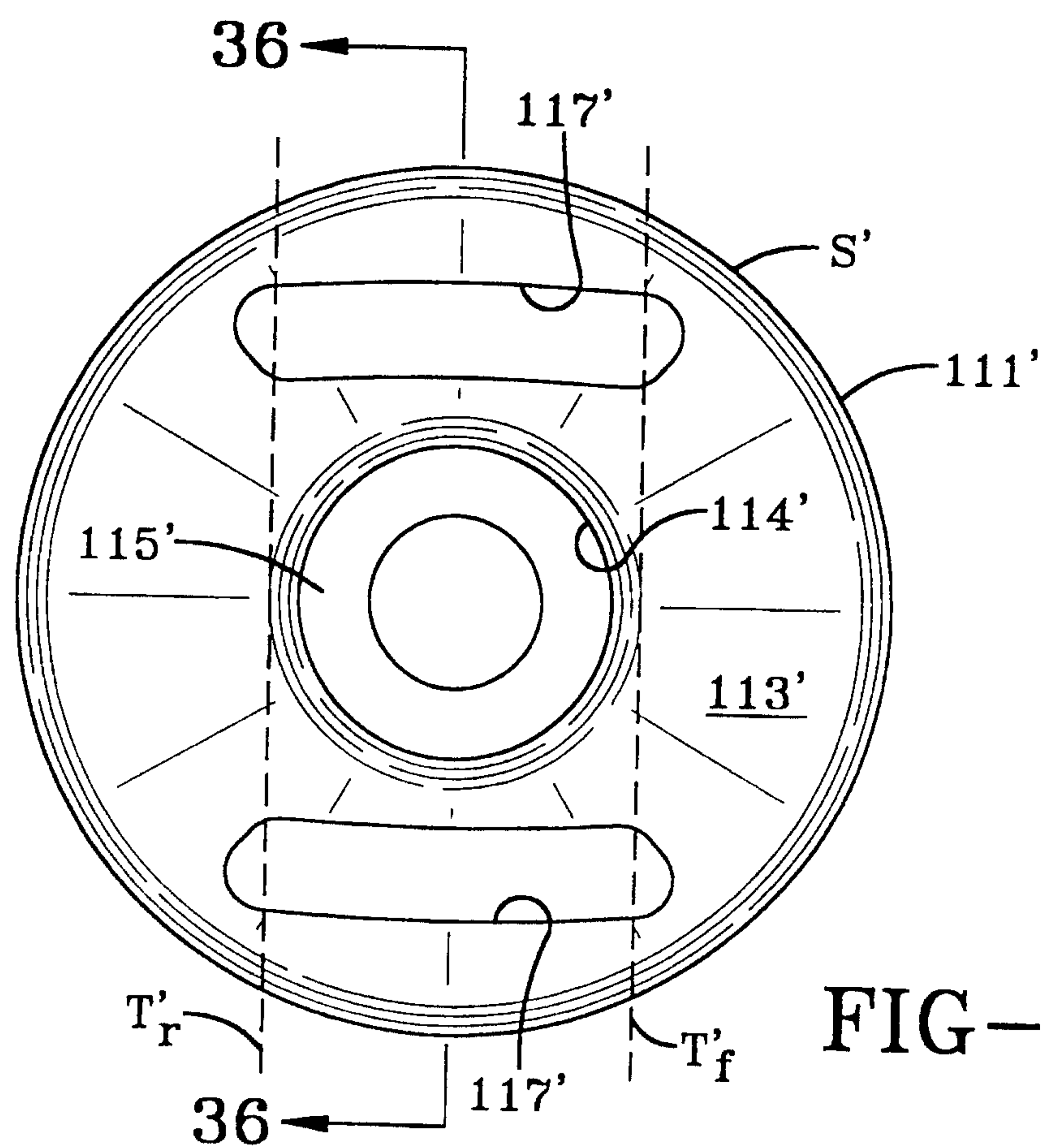


FIG-34

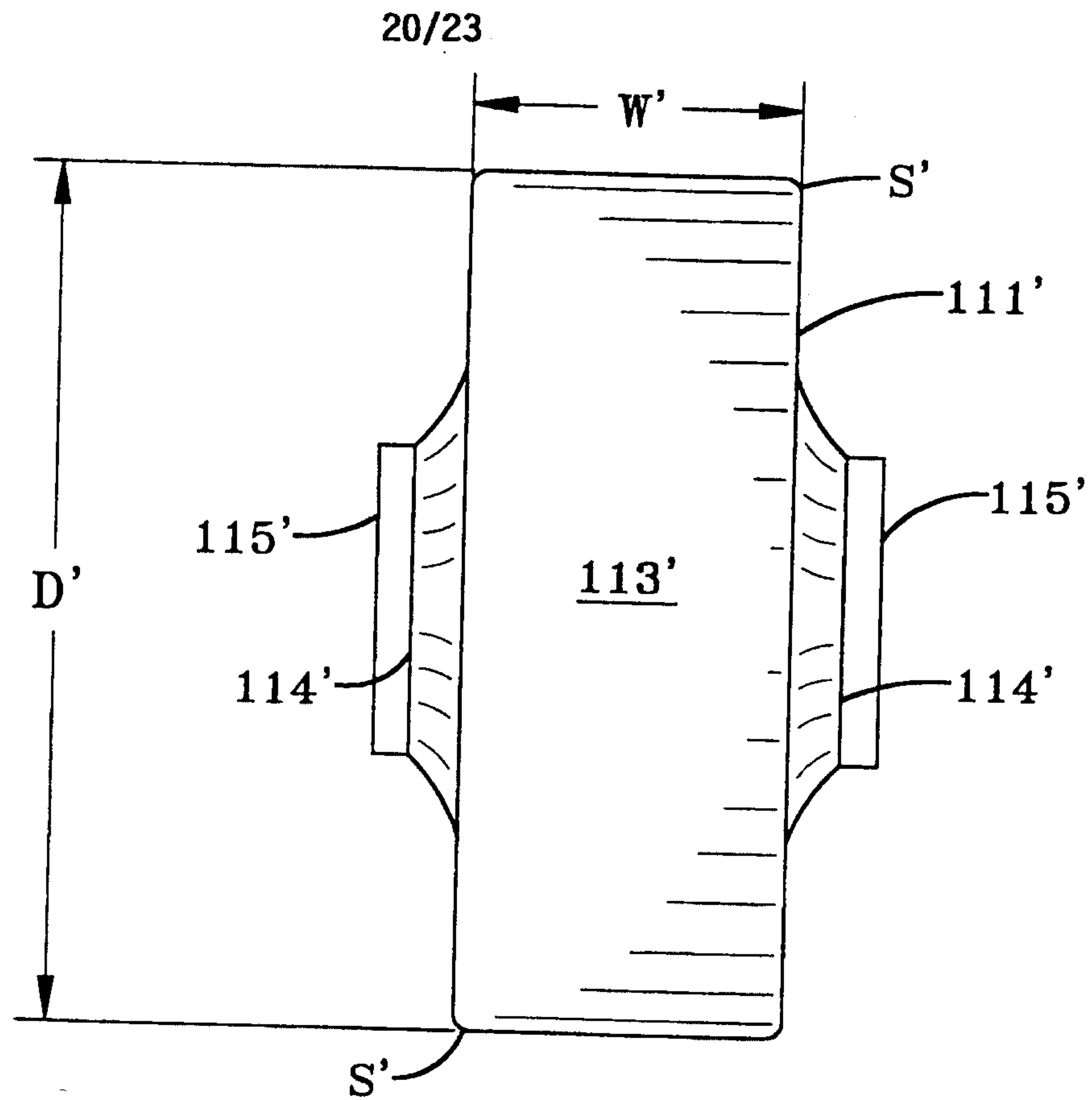


FIG-35

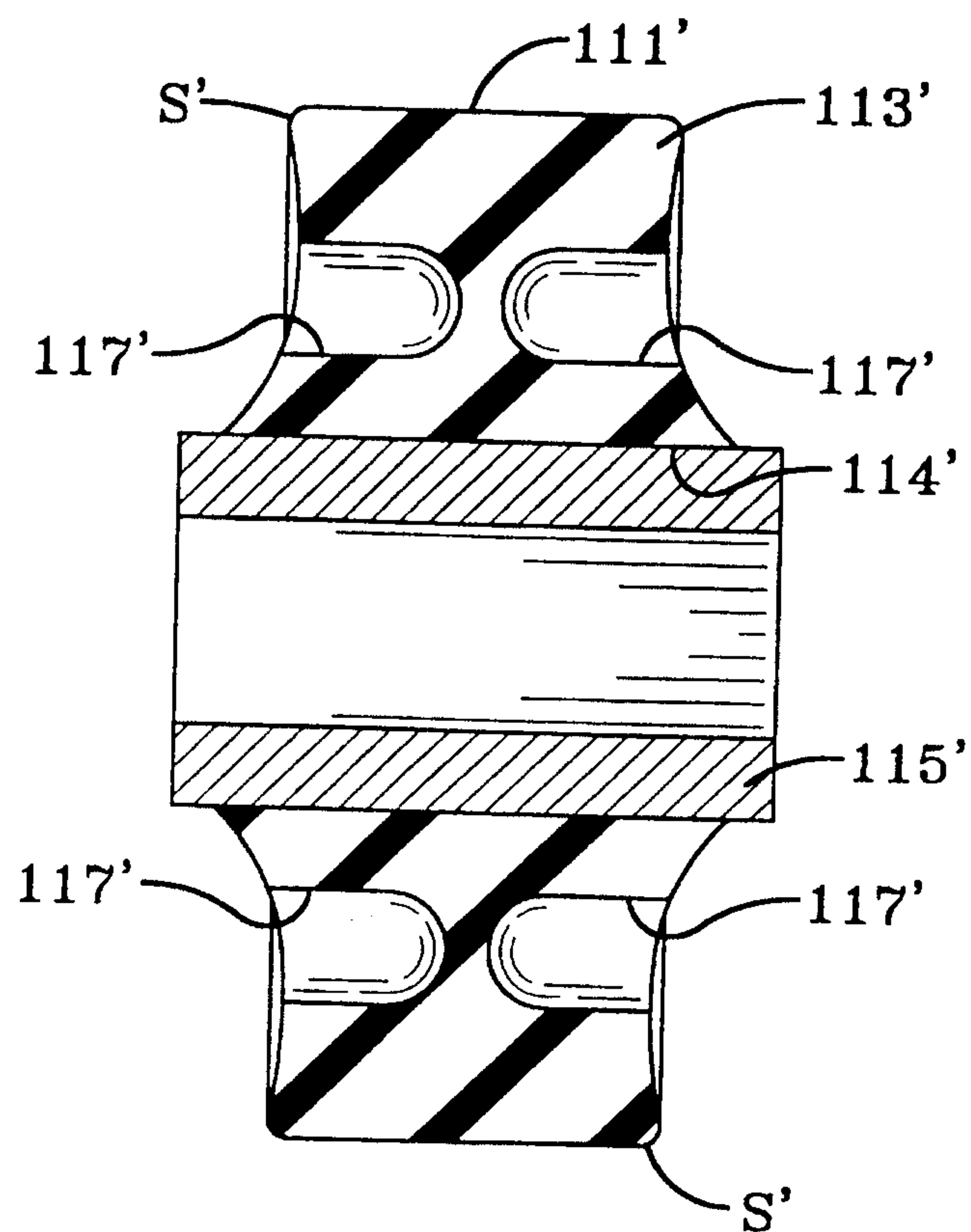


FIG-36

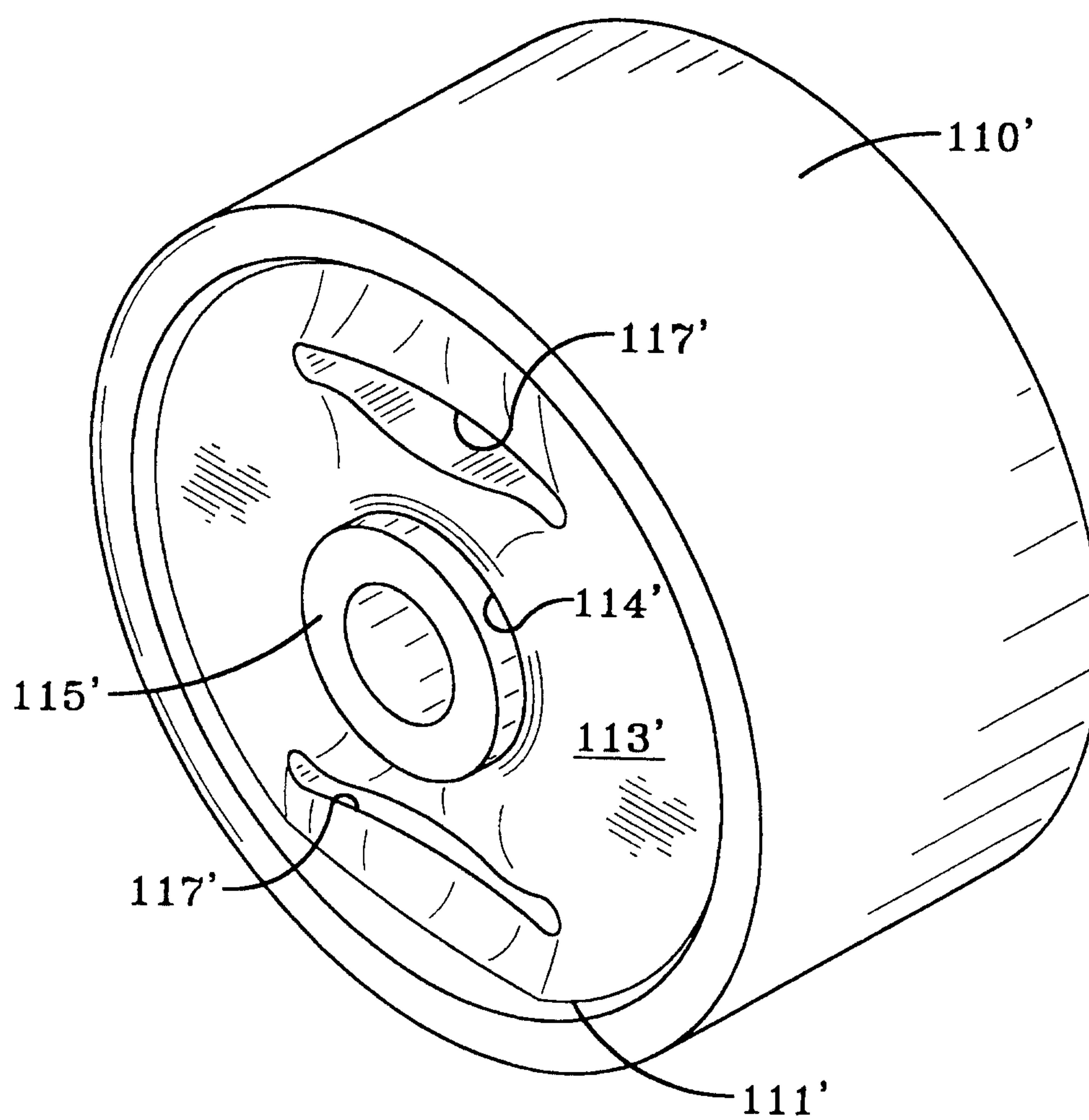


FIG-37

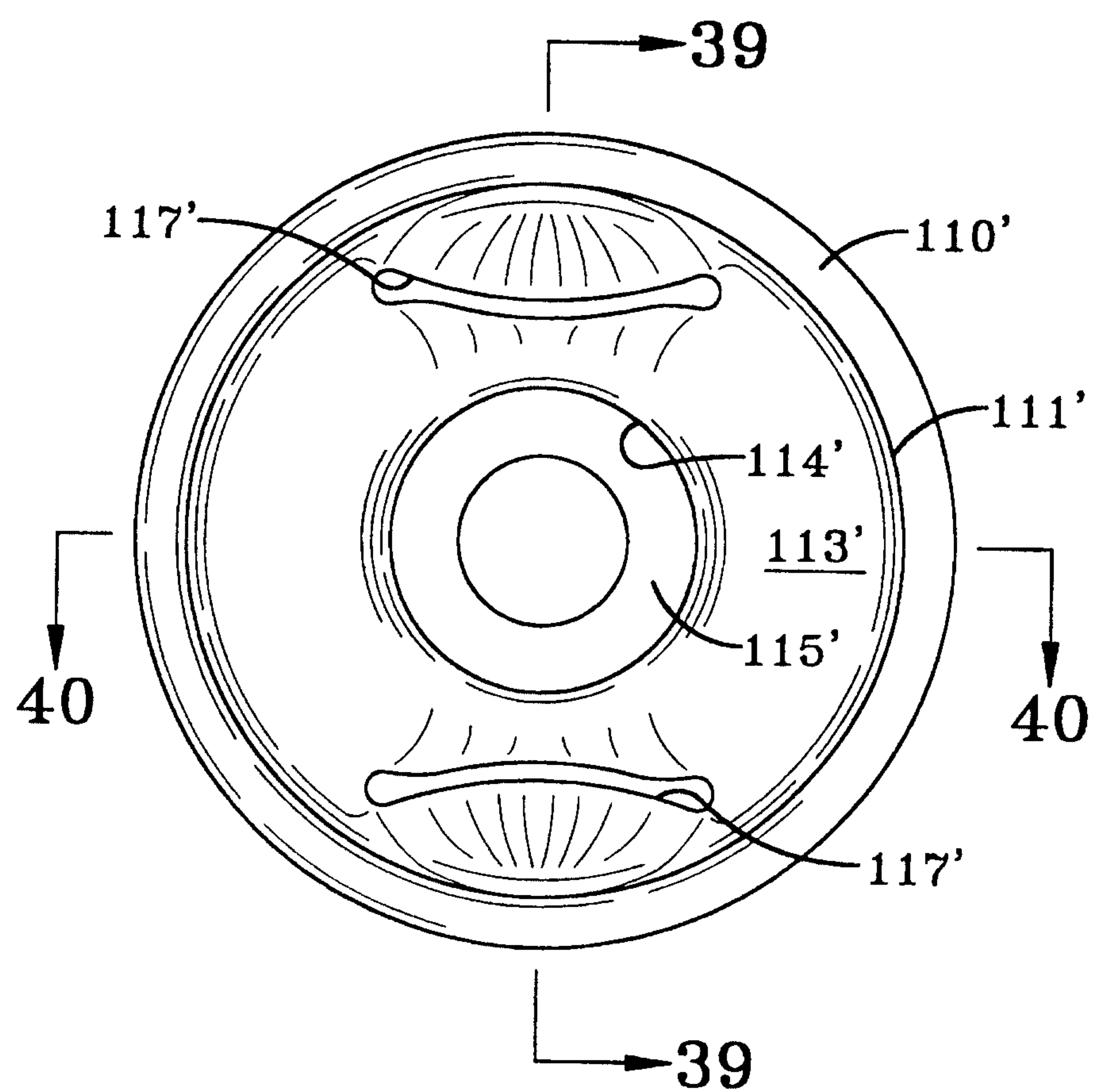


FIG-38

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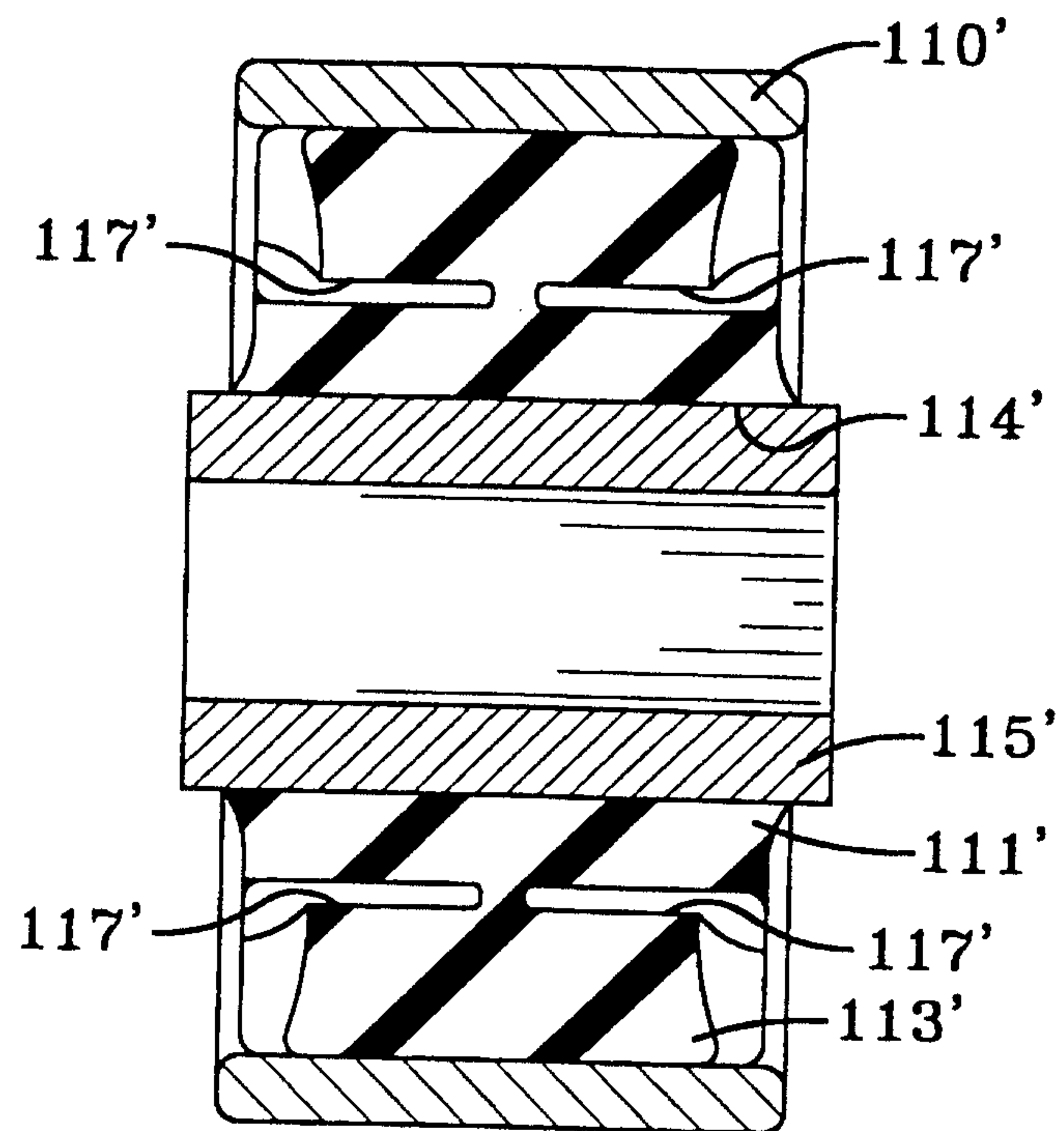


FIG-39

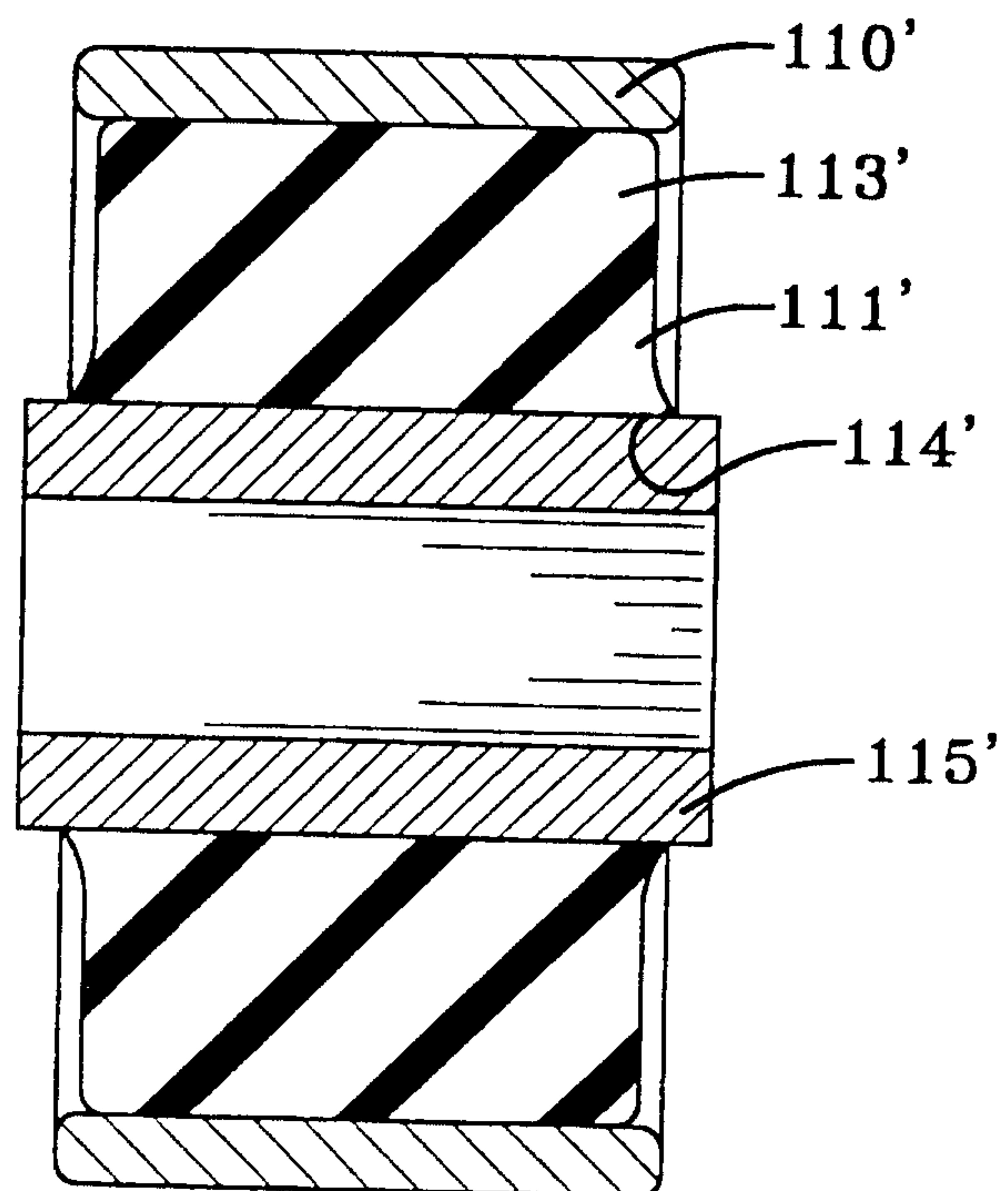


FIG-40

