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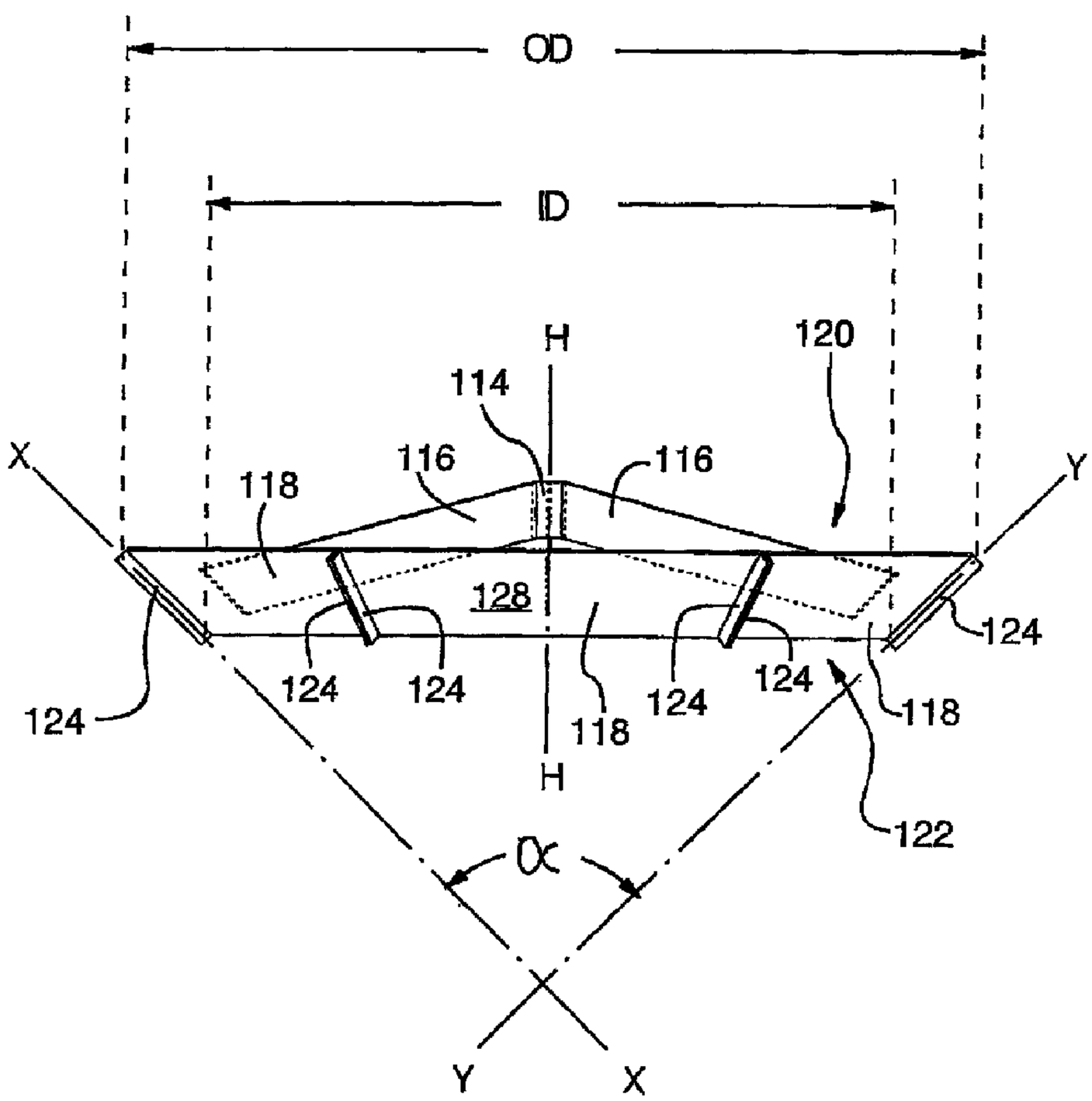
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(57) Abrégé/Abstract:
A mixer apparatus for use with a vessel centered about a longitudinal axis is disclosed. The mixer has a tubular blade which: defines a central head axis; has a first end and a second end spaced from the first end along the head axis; and tapers from the first

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(57) Abrégé(suite)/Abstract(continued):
end to the second end. The outer surface of the blade and the second end define an inside blade diameter "ID" and the outer surface of the blade and the first end define an outside blade diameter "OD". The blade is positioned within and coaxial to the vessel. A scotch yoke, operatively connected to the blade by a shaft, effects reciprocating longitudinal movement of the blade through a stroke "S", with a duration "T" for each stroke, wherein $175 \leq 0.36 \times OD^2/ID^2 \times S/T \leq 250$ when OD, ID and S are expressed in inches, and T is expressed in minutes.

MIXING BLADE

ABSTRACT OF THE DISCLOSURE

A mixer apparatus for use with a vessel centered about a longitudinal axis is disclosed. The mixer has a tubular blade which: defines a central head axis; has a first end and a second end spaced from the first end along the head axis; and tapers from the first end to the second end. The outer surface of the blade and the second end define an inside blade diameter "ID" and the outer surface of the blade and the first end define an outside blade diameter "OD". The blade is positioned within and coaxial to the vessel. A scotch yoke, operatively connected to the blade by a shaft, effects reciprocating longitudinal movement of the blade through a stroke "S", with a duration "T" for each stroke, wherein $175 \leq 0.36 \times OD^2/ID^2 \times S/T \leq 250$ when OD, ID and S are expressed in inches, and T is expressed in minutes.

MIXING BLADE

TECHNICAL FIELD

The present invention generally relates to the field of mineral ore processing, and more particularly, to a mixing apparatus and to uses thereof in the separation of minerals from mineral-bearing ores.

BACKGROUND OF THE ART

Processes are known in the prior art which provide for the separation of minerals from mineral-bearing ores.

For example, in known processes used for the separation of copper from copper-bearing ores, illustrated diagrammatically in Figure 1, non-oxidized ores 20 (which might contain as little as 0.5% copper, and typically contain iron sulfides) are processed in a crusher 22, with water 24, to form a slurry 26. The slurry 26 is then transferred to a flotation cell 28, and subjected to physical action, specifically, air sparging and mixing. As a result of the physical action, a substantial portion of the copper value in the slurry 26 rises to the surface of the flotation cell 28 as a froth 30, and is skimmed therefrom by a paddle mechanism 32, while the waste rock 33 ("gangue") remains in the bulk, and is ultimately passed from the cell 28 to a dryer 34 and discharged as tailings 36. This process of "froth separation" results from differences in wettability of copper as compared to other minerals, and is typically aided by chemical frothing and collector agents 38 added to the slurry 26, such that the froth 30 from such flotation contains 27 to 36% copper. Methylisobutyl carbonal (MIBC) is a typical frothing agent, and sodium xanthate, fuel oil, and VS M8 (a proprietary formulation) are typical collector agents.

The froth 30 is then fed to an oxygen smelter 40, and the copper and iron sulfides are oxidized at high temperature resulting in impure molten metal 42 (97 - 99%, copper, with significant amounts of iron oxide) and gaseous sulfur dioxide 44. The impure metal 42 is then transferred to an electrolytic purification unit 46, which separates the impure metal 42 into 99.99% purity copper material 48 and slag 50.

The gaseous sulfur dioxide 44 is collected in a reactor 52 wherein it is scrubber and mixed with water 24 to form sulphuric acid 54. The sulphuric acid 54 is suitably blended with water 24 and used to leach oxidized ores, typically by "heap leaching" an ore pile 56. The resultant copper-bearing acid 58 is known as "pregnant leach solution". Pregnant leach solution 58 is also obtained by mixing solutions of sulphuric acid 54, in vats 60, with the tailings 36 discharged from flotation operations, to dissolve the trace amounts of copper remaining therein.

The copper is "extracted" from the pregnant leachate 58 by mixing therewith, in a primary extraction step 62, organic solvent 64 (often kerosene) in which copper metal preferentially dissolves. Organic chemical chelators 66, which bind solubilized copper but not impurity metals, such as iron, are also often provided with the organic solvent, to further drive the migration of copper. Hydroxyoximes are exemplary in this regard.

In the primary extraction step 62, the copper is preferentially extracted into the organic phase according to the formula:

$$[CuSO_4]_{aqueous} + [2\ HR]_{organic} \rightarrow [CuR_2]_{organic} + [H_2SO_4]_{aqueous}$$

where HR = copper extractant (chelator)

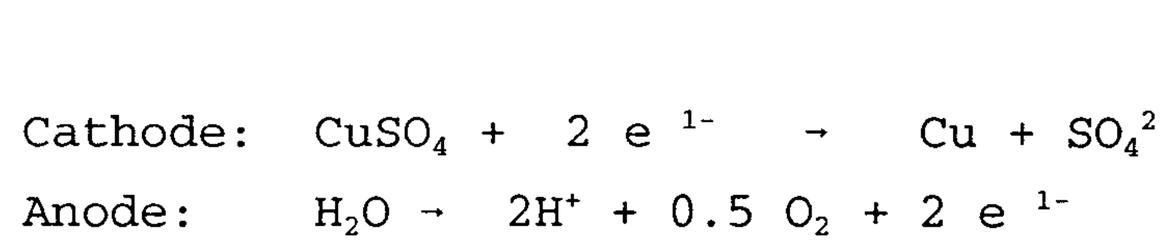
The mixed phases are permitted to separate, into a copper-laden organic solvent 68 and a depleted leachate 70.

The depleted leachate 70 is then contacted with additional organic solvent 72 in a secondary extraction step 74, in the manner previously discussed, and allowed to settle, whereupon the phases separate into a lightly-loaded organic (which is recycled as solvent 64 in the primary extraction step) and a barren leachate or raffinate 76.

The barren leachate 76 is delivered to a coalescer 78 to remove therefrom entrained organics 80, which are recycled into the system; the thus-conditioned leachate 82 is then suitable for recycling into the leaching system.

The pregnant organic mixture 68 (produced in the primary extraction step 62) is stripped of its copper in a stripping operation 84 by the addition of an aqueous stripping solution of higher acidity 86 (to reverse the previous equation); after phase separation, a loaded electrolytic solution 88 ("rich electrolyte") remains, as well as an organic solvent, the latter being recycled as solvent 72 in the secondary extraction 74.

The rich electrolyte 88 is directed to an electrowinning unit 90. Electrowinning consists of the plating of solubilized copper onto the cathode and the evolution of oxygen at the anode. The chemical reactions involved with these processes are shown below



This process results in copper metal 92, and a lean (copper-poor) electrolyte, which is recycled as stripping solution 86.

The combination of leaching, combined with extraction and electrowinning, is commonly known in the art as solvent extraction electrowinning, hereinafter referred to in this specification and in the claims as "SXEW".

In a known application of the described SXEW process, in both the primary 62 and secondary 74 extraction steps, the combined organic and aqueous phases are delivered through a series of mixing vessels (primary P, second S and tertiary T), and then to a settling tank ST, the primary mixing vessel P being about 8 feet in diameter and 12 feet in height, and stirred by a rotary mixer driven by a 20 horsepower motor, and each of the secondary S and tertiary T mixing vessels being about 12 feet in diameter and height, and stirred by a rotary mixer driven by a 7.5 horsepower motor. (The system of primary P, secondary S and tertiary T mixers, and settling tank ST, is replicated to meet volume flow requirements, with each system processing about 10,000 gpm). This provides a mixing regime wherein the organic and aqueous phases are intimately mixed for a period of time sufficient to allow copper exchange (to maximize copper recovery), yet relatively quickly separate substantially into organic and aqueous phases.

In a known application of the froth flotation process, a plurality of flotation cells 28, each being approximately 5 feet square and 4 feet high, are utilized, with pairs of cells sharing a 50 horsepower motor driving respecting rotary mixers (not shown). This provides a mixing regime sufficient to allow the air bubbles to carry the copper value to the surface.

Various modifications can be made to the rotary mixers in the extractors and in the flotation tanks of the foregoing process. However, the general configurations noted above have been found to provide relatively economical results, and significant variations therefrom can impact adversely upon economies.

For example, an attempt to reduce energy costs by scaling-down the motors for the mixers would have consequent impacts either upon the copper recovery efficiency, or upon available process throughputs.

Specifically, the relatively large motors employed are required to drive the sturdy (and therefore heavy) rotary mixers and shafts that are needed to withstand the torques caused by rotation; lower power motors would demand either lower blade speed or smaller blades, with consequent impacts upon mixing and transfer efficiency.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a novel mixing apparatus.

This object is met by the present invention which comprises a mixing apparatus. The mixing apparatus is advantageously used with a vessel having a contiguous sidewall centered about and defining a longitudinal axis.

As one aspect of the present invention, the mixing apparatus comprises a mixing head having a tubular blade portion centered about and defining a head axis and having a first tube end and a second tube end spaced-apart from one another therealong.

The blade portion tapers from the first tube end to the second tube end with the inner surface of the blade portion and the second end defining an inside blade diameter "ID" and the outer surface of the blade portion and the first end defining an outer blade diameter "OD". The mixing apparatus further comprises mounting means for mounting the mixing head substantially coaxial to and within the vessel for longitudinal movement relative thereto. Also provided is a reciprocating means for effecting said longitudinal relative movement of the mixing head in a reciprocating manner through a stroke length "S", with a duration "T" for each cycle, wherein $175 \leq 0.36 \times OD^2/ID^2 \times S/T \leq 250$ when OD, ID and S are each expressed in inches, and T is expressed in minutes.

As other aspects of the invention, the blade portion preferably tapers in a substantially frustoconical manner from the first tube end to the second tube end, and an angle α, defined by the angle between the pair of axes defined by and coincident with the intersections of the outer surface of the blade portion and a plane coincident with the head axis, preferably lies between 90° and 180°.

As other aspects of the present invention, the mounting means preferably comprises a shaft. The shaft has a bottom end operatively rigidly connected to the mixing head by a hub member rigidly connected to the bottom end of the shaft and a plurality of support webs extending between and connecting the hub member and the blade portion, and extends from said bottom end, substantially parallel to the head axis, to a top end which is disposed above the vessel in use.

As yet another aspect of the present invention, the reciprocating means preferably comprises shaft gripping means for gripping the shaft adjacent the top end thereof and effects longitudinal reciprocating movement of the shaft gripping means through stroke length "S" with duration "T" for each cycle, thereby to effect longitudinal movement of the mixing head in said reciprocating manner.

As another aspect of the present invention, a housing, positionable above said vessel, is preferably provided, and the reciprocating means preferably comprises a flywheel, a crank member, and a yoke.

The flywheel is mounted to the housing for rotation about a rotational axis which is normal to the longitudinal axis.

The crank member projects from the flywheel in a direction parallel to the rotational axis and is connected to the flywheel for rotation therewith.

The yoke is displaced from the flywheel in the direction of the crank member and has a substantially linear race formed therein which is in receipt of the crank member and is adapted to permit relative translational movement of the crank member and the yoke.

The yoke is positioned with the race arranged normal to the rotation axis and bisected thereby and is mounted to the housing in a manner which constrains movement of the yoke otherwise than along an axis parallel to the longitudinal axis and normal to the rotational axis, such that during rotation of the flywheel, the crank member imparts longitudinal reciprocating movement to the yoke.

As yet another aspect of the invention, the shaft gripping means is preferably operatively rigidly connected to the yoke for longitudinal reciprocating movement therewith.

As another aspect of the present invention, the mounting means is preferably adapted to mount the mixing head within the vessel with the first tube end disposed above the second tube end.

The invention also comprises use of the mixing apparatus as a mixer for a vessel in an SXEW extractor unit, and as a mixer for the vessel in a froth flotation cell.

Other advantages, features and characteristics of the present invention, as well as methods of operation and functions of the related elements of the structure, and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following detailed description and the appended claims with reference to the accompanying drawings, the latter of which is briefly described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagrammatic representation of processes for copper extraction of the prior art.

Figure 2 is a front, top, left side perspective view of a mixing apparatus according to a preferred embodiment of the present invention, in a preferred use.

Figure 3 is a left side cross-sectional view of the structure of Figure 2.

Figure 4 is a front, top right side perspective view of the reciprocating means and mounting means of the mixing apparatus of Figure 2.

Figure 5 is an exploded perspective view of a part of the structure of Figure 4.

Figure 6A is a front elevational view of the structure of Figure 4, with the mixer shaft and shaft gripping means removed for clarity.

Figure 6B is a view similar to Figure 6A, with, *inter alia*, the flywheel displaced 90° counter-clockwise relative to its position in Figure 6A.

Figure 6C is a view similar to Figure 6A, with, *inter alia*, the flywheel displaced 90° counter-clockwise relative to its position in Figure 6B.

Figure 6D is a view similar to Figure 6A, with, *inter alia*, the flywheel displaced 90° counter-clockwise relative to its position in Figure 6C.

Figure 7 is a front, top, left side perspective view of the mixing head of the structure of Figure 2.

Figure 8 is a rear, bottom, right side perspective view of the mixing head of the structure of Figure 2.

Figure 9 is a bottom view of the mixing head of Figure 2.

Figure 10 is a left side view of the mixing head of Figure 2.

Figure 11 is a view of an alternate embodiment of the support webs of the invention, which view corresponds to the area circumscribed by circle 11 in Figure 7.

Figure 12 is a view of an alternate embodiment of the blade portion of the present invention, which view corresponds to the area circumscribed by circle 12 in Figure 7.

Figure 13 is a view similar to Figure 12, showing a further embodiment of the blade portion of the invention.

Figure 14 is a front, top, left side perspective view of a mixing apparatus according to the preferred embodiment of the invention in an alternate use.

Figure 15 is a left side cross-sectional view of the structure of Figure 14.

Figure 16 is a view similar to Figure 3, illustrating the mixing apparatus according to an alternative embodiment in a further alternative use.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to Figure 2 of the drawings, a mixing apparatus, according to a preferred embodiment of the present invention and designated with general reference numeral 100, is shown in use, in a manner fully described in following paragraphs, with a vessel 102 having a contiguous sidewall 104 centered about and defining a longitudinal axis A-A.

Full details of the preferred mixing apparatus of the present invention will be set out in following paragraphs. However, for greater clarity, it should firstly be understood, generally, that the mixing apparatus 100 comprises a mixing head 106 having a head axis H-H (illustrated in Figures 3, 7 and 8); mounting means for mounting the mixing head 106 substantially coaxial to and within the vessel 102 for longitudinal movement relative to the head axis H-H, said mounting means being designated with general reference numeral 108 in Figure 2; and reciprocating means, designated with general reference numeral 110, for effecting said longitudinal relative movement of the mixing head 106 in a reciprocating manner.

The various parts of this preferred mixing apparatus will now be described with more particularity.

With reference to Figure 7, the mixing head 106 will be seen to include a blade portion 112, a hub member 114 and a plurality of support webs 116.

The blade portion 112, as shown, is constructed from six arcuate segments 118. The segments 118 are arranged in tubular relation so as to form a first tube end 120 and a second tube end 122, illustrated in Figure 10, and are secured, by bolts (not shown), to one another through flanges 124 (see Figures 7, 8 and 9) provided at the ends of each segment 118 for this purpose.

The tubular blade portion 112 defines and is centered about the head axis H-H, such that the first tube end 120 and the second tube end 122 of the blade portion 112 are spaced-apart from one another therealong, and the blade portion 112 tapers in a substantially frustoconical manner from the first tube end 120 to the second tube end 122.

The rate of taper is such that the angle α, defined by the angle between the pair of axes X,X and Y,Y, which axes are defined by and coincident with the intersections of the outer surface 128 of the blade portion 112 and a plane P-P coincident with the head axis, is greater than or equal to 90° and less than 180° ($90° \leq \alpha < 180°$), as indicated in Figure 9 and Figure 10.

The hub member 114 is also tubular, and is centrally disposed adjacent to the blade portion 112.

The plurality of, specifically, three, support webs 116 each extend between and connect the hub member 114 and the blade portion 112. Such connection is effected by rivets or bolts (not shown).

With reference now to Figure 3, the preferred mounting means 108 will be seen to comprise a mixer shaft 130 and a linear bearing 132.

The mixer shaft 130 has a bottom end 134 operatively rigidly connected to the mixing head 106 and extends from said bottom end 134, substantially coincident with the head axis H-H, to a top end 136 which is disposed above the vessel 102 in use. Such rigid connection of the mixer shaft 130 and the mixing head 106 may be effected by, for example, threading the exterior of the bottom end of the mixer shaft, and providing a corresponding thread on the interior of the hub member (not shown).

The linear bearing 132 supports the mixer shaft 130 for longitudinal movement; this is effected in the preferred embodiment by mounting the bearing 132 to a housing 138 which is itself mounted, as illustrated in Figure 2, to a

frame 140 which, in the preferred embodiment shown, spans over the vessel 102.

As best illustrated in Figure 4, the reciprocating means 110 comprises a shaft gripping means, designated with the general reference numeral 142, for gripping the mixer shaft 130 adjacent its top end 136 and for effecting longitudinal reciprocating movement of the shaft gripping means 142 through stroke length "S" with duration "T" for each cycle, thereby to effect coincident longitudinal movement of the mixing head 106 in said reciprocating manner through the same stroke length "S", as indicated in Figure 3, wherein the mixing head 106 is shown in blackline in a starting position, and in phantom outline, at a position longitudinally displaced from the starting position through a distance "S".

Such reciprocating movement is effected through a scotch yoke apparatus 144, comprising a flywheel 146, a drive means 148, a crank member 150 and a yoke 152, illustrated in Figure 4 and in Figure 5.

The flywheel 146 is mounted to the housing 138 for rotation about a rotational axis R-R (illustrated in Figure 4) which is normal to the longitudinal axis A-A.

The drive means 148 is for driving rotation of the flywheel 146 and, in the preferred embodiment illustrated, comprises an explosion-proof electric motor, operatively connected by its drive shaft (not shown) to the flywheel 146.

The crank member 150 projects from the flywheel 146 in a direction parallel to the rotational axis R-R and is connected to the flywheel 146 for rotation therewith.

The yoke 152 is displaced from the flywheel 146 in the direction of the crank member 150 and has formed therein a substantially linear race 154 which is in receipt of the crank member 150 and is adapted to permit relative translational movement of the crank member 150 and the yoke 152 as the flywheel 146 rotates.

The yoke 152 has threaded, coaxial bores 156 disposed on its upper and lower surfaces to receive respective threaded guide shafts 158. Corresponding guide bearings 160 are provided on the housing 138. When the yoke 152 is operatively mounted with the guide shafts 158 disposed within the guide bearings 160, the yoke 152 is positioned with the race 154 arranged normal to the rotation axis R-R and bisected thereby, and is mounted to the housing 138 in a manner which constrains movement of yoke 152 otherwise than along an axis B-B parallel to the longitudinal axis A-A and normal to the rotational axis R-R (best indicated in Figure 4), such that during rotation of the flywheel 146, the crank member 150 imparts longitudinal reciprocating movement to the yoke 152, as indicated by the sequence of Figures 6A-6D.

The length of the resultant stroke may be selected by suitable adjustment to the radial position of the crank member 150 (that is, the distance between the crank member 150 and the rotation axis R-R); for this reason, the crank member 150 is threaded, and a plurality of threaded sockets 162 are provided in a radial array on the face of the flywheel 146, as illustrated in Figure 5. The duration of each stroke may be selected by suitable adjustment to the rotational speed of the electric motor 148.

In the preferred embodiment, the yoke moves through a stroke length "S", with a duration "T" for each cycle, wherein $175 \leq 0.36 \times OD^2/ID^2 \times S/T \leq 250$ when T is expressed in minutes, S is expressed in inches, "ID" is an inside blade diameter, expressed in inches and defined by the outer surface 128 of the blade portion 112 and the second tube end 122, and "OD" is an outside blade diameter, expressed in inches and defined by the outer surface 128 of the blade portion 112 and the first tube end 120, as indicated in Figure 10.

Returning to Figures 4 and 5, the shaft gripping means 142 preferably comprises a clamp 163, specifically, a pair of mating clamping blocks 164, each having a concave groove 166 of semi-circular cross-section formed therein to grippingly receive the mixer shaft 130. Clamp 163 is selectively rigidly affixed, by bolts 168, to the yoke 152, such that longitudinal reciprocating movement is imparted to the shaft gripping means 142 by said longitudinal reciprocating movement of the yoke 152. This clamp arrangement permits the relative depth of the mixing head 106 in the vessel 102 to be conveniently adjusted from above; the clamp 162 need only be loosed, by disengaging the associated bolts 168, whereupon mixer shaft 130 can be raised or lowered as desired, and bolts 168 re-engaged.

The mixer shaft 130 is itself preferably constructed of a plurality of tube segments 170, threaded at their ends and joined to one-another in end-to-end relation by threaded couplings 172, so that segments 170 can be added or removed as desired, thereby to permit the aforementioned adjustment feature to be more conveniently and fully exploited.

With general reference to Figure 4 and Figure 5, stresses created on the yoke 152, by virtue of its carriage of the shaft gripping means 142, are preferably countered by the provision of a balancing shaft 174, rigidly connected to the housing 138 to extend substantially parallel to longitudinal axis A-A, and by a pair of mating linear bearing blocks 176, each having a respective groove 178 of semi-circular cross-section formed therein sheathed with a self-lubricating material such as polytetrafluorethylene , which are mounted to the yoke 152 by bolts 180 and slidably receive the balancing shaft 174 therethrough.

It has been found that the present invention can be used to great advantage as a mixer for a vessel in a SXEW extractor unit, as illustrated in Figures 2 and 3.

EXAMPLE 1

In the known application of the SXEW process previously described, samples were taken from the outfall of each of the primary vessel; secondary vessel; tertiary vessel and settling tank of a respective secondary extraction unit (A) and permitted to separate.

In a parallel secondary extraction unit (B) (ie processing a pregnant leachate of substantially identical composition), a mixing apparatus in accordance with the present invention (OD=60; ID=40; α=120°; S=10; T=.0333, driven by a 2hp motor) was substituted for the rotary mixer in the secondary mixing vessel, and samples were again taken from the outfall from each of the primary, second and tertiary mixing vessels, and from the settling tank, and permitted to separate.

Copper concentration (g/l) was measured in the organic component of each sample, as follows:

	(A) Cu(g/l)	(B)[30cpm] Cu (g/l)
Primary mixing vessel	2.01	2.01
Secondary mixing vessel	2.06	2.06
Tertiary mixing vessel	2.12	2.13
Settling tank	2.14	2.13

As would be expected, copper concentration from the primary mixing vessel in each of the A and B lines is similar (because to that point in the process, mixing is provided by identical rotary mixers). However, unexpectedly, copper concentrations in the outfall from the secondary mixers also remained identical, and copper concentration in the outfall from the settling tanks remained quite similar, despite the almost 75% reduction in energy input (2 hp drive motor for the reciprocating mixer, as compared to the 7.5 hp motor driving the rotary mixer).

Without intending to be bound by theory, it is believed the mixing apparatus of the present invention provides mixing currents which [at least in the context of the liquids utilized in SXEW copper extraction, in a vessel having an internal diameter D and a height H, wherein OD:D is between about 1:2.5 to 1:4, OD:ID is greater than 1.0 and smaller than or equal to about 1.5; and D:H is approximately 1:1] create a dispersion characterized by consistent-sized droplets, uniformly distributed throughout the mixing vessel, whereas in a rotary mixer, there is a wide variation in drop sizes, and in the distribution of said drops, (perhaps due to the fact that the blade in a rotary mixer moves at different speeds along its length). This uniform dispersion is believed to provide an environment amenable to efficient mass transfer between phases, while at the same time providing for substantial disengagement of the mixed phases within a relatively short time frame.

Whereas the illustrations depict an embodiment of the present invention which is preferred, various modifications are contemplated.

For example, whereas in the preferred embodiment, a scotch yoke apparatus is utilized to provide a linear reciprocating movement, it will be evident that other mechanisms, such as crank shafts, cam and cam follower mechanisms, and swash plates are possible substituents therefor.

It should also be noted that, while in the preferred embodiment illustrated, the head axis H-H and the longitudinal axis A-A are coincident, this need not be the case.

As well, whereas in the preferred embodiment illustrated, the mixing head tapers uniformly along its length, so as to take on a substantially frustoconical shape, and the mounting means is adapted to mount the mixing head to the vessel with the first tube end disposed above the second tube end, it is possible for the mixing head to assume non-frustoconical form, wherein the rates of taper differ at the top and bottom ends, and also for the mixing head to be disposed with the second tube end disposed above the first tube end, as illustrated in Figure 16. Flow baffles 184 can also be disposed within the vessel, as indicated also in Figure 16.

Additionally, whereas the preferred blade portion and support webs are substantially smooth, it is contemplated that the blade portion 112 can be formed with a plurality of perforations 186 each extending between the inner surface 126 and the outer surface 128, as illustrated in Figure 12, and that the support webs 116 may be provided with a plurality of perforations 188, as well as a plurality of tabs 190 each substantially overlying a respective perforation 188 and being connected to the support web 116 at one edge of said respective perforation 188 to form a gill, as illustrated in Figure 11. In this manner, the characteristics of the mixing currents produced by the blade portion in motion can be finely tuned to control the droplet size of the dispersion, and hence, the mixing efficiency of the device, which feature is not available in prior art mixers.

As a further alternative, illustrated in Figure 13, the blade portion 112 may be provided with a plurality of dimples 192 projecting outwardly from the outer surface 128 and inwardly from the inner surface 126. Similarly, this allows fine tuning of the mixing device of the present invention in a manner not taught by the prior art.

For the purpose of minimizing friction, the preferred crank member 150 is of two-part construction, including an inner axle portion 182 which is fixedly connected to the flywheel 156 and an outer roller portion 184 which is rotatably mounted by bearings (not shown) on the axle portion 182 (best illustrated in Figure 5). However, this is not necessary.

Of course, whereas the detailed description herein pertains specifically to the recovery of copper from copper bearing ores, it should also be understood that the present invention may be utilized in other applications wherein SXEW processes are utilized, such as, for example, in the recovery of zinc, nickel, platinum and molybdenum.

Moreover, it will be evident that the invention may have advantageous utility even outside the SXEW process, in other mixing applications, such as in the context of a froth flotation cell, illustrated in Figures 14 and 15, wherein the mixing apparatus is used to agitate a slurry to form a froth, and a paddle mechanism 32 is operatively mounted to the vessel 102 to scour froths produced thereby.

It will, of course, also be understood that various other modifications and alterations may be used in the design and manufacture of the mixing apparatus according to the present invention without departing from its spirit and scope. Accordingly, the scope of the present invention should be understood as limited only by the accompanying claims, purposively construed.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE RIGHT OR PRIVILEGE IS CLAIMED IS DEFINED AS FOLLOWS:

1. A mixing blade for use in a vertical reciprocating mixer of the type used to mix fluids in a vessel, the mixing blade comprising:

a blade body having a first end, an opposed second end disposed in spaced relation thereto along a longitudinal axis, and a passageway extending longitudinally between the first and second ends; the passageway tapering from the first end to the second end;

the blade body having an inner surface and an outer surface, the outer surface of the blade body defining an inside blade diameter ID at the second end, and an outside blade diameter OD at the first end;

the intersections of the outer surface of the blade body and a plane coincident with the longitudinal axis defining a pair of axes, the axes defining therebetween an angle α;

wherein the angle α is between 90° and 120°, and OD:ID is between 1.25 and 1.5.

2. A mixing blade according to claim 1, wherein the OD:ID is 1.5.

3. A mixing blade according to claim 2, wherein the angle α is 90°.

4. A mixing blade according to claim 2, wherein the angle α is 120°.

5. A mixing blade according to claim 1, wherein the passageway tapers in a substantially frustoconical manner from the first end to the second end.

6. A mixing blade according to claim 1, wherein the passageway tapers uniformly from the first end to the second end.

7. A mixing blade according to claim 1, wherein the passageway tapers in a non-uniform fashion from the first end to the second end.

8. A mixing blade according to claim 1, further comprising a hub member for mounting to a shaft and a plurality of support webs extending radially from the hub member to join the blade body.

9. A mixing blade according to claim 8, wherein the support web members extend from the hub member in a downwardly canted fashion.

10. A mixing blade according to claim 8, wherein the mixing blade includes three support webs.

11. A mixing blade according to claim 8, wherein the outer and inner surfaces of the blade body are substantially smooth.

12. A mixing blade according to claim 8, wherein the blade body has a plurality of dimples projecting from at least one of the outer and inner surfaces thereof.

13. A mixing blade according to claim 12, wherein the plurality of dimples project outwardly from the outer surface of the blade body.

14. A mixing blade according to claim 12, wherein the plurality of dimples project inwardly from the inner surface of the blade body.

15. A mixing blade according to claim 8, wherein at least one of the blade body and the support webs has a plurality of perforations formed therein.

16. A mixing blade according to claim 15, wherein each of the blade body and the support webs has a plurality of perforations formed therein.

17. A mixing blade according to claim 15, wherein the support webs have a plurality of perforations formed therein and a plurality of tabs, each tab substantially overlying a respective one of the plurality of perforations and being connected to the support web at one edge of said respective one of the plurality of perforations to form a gill.

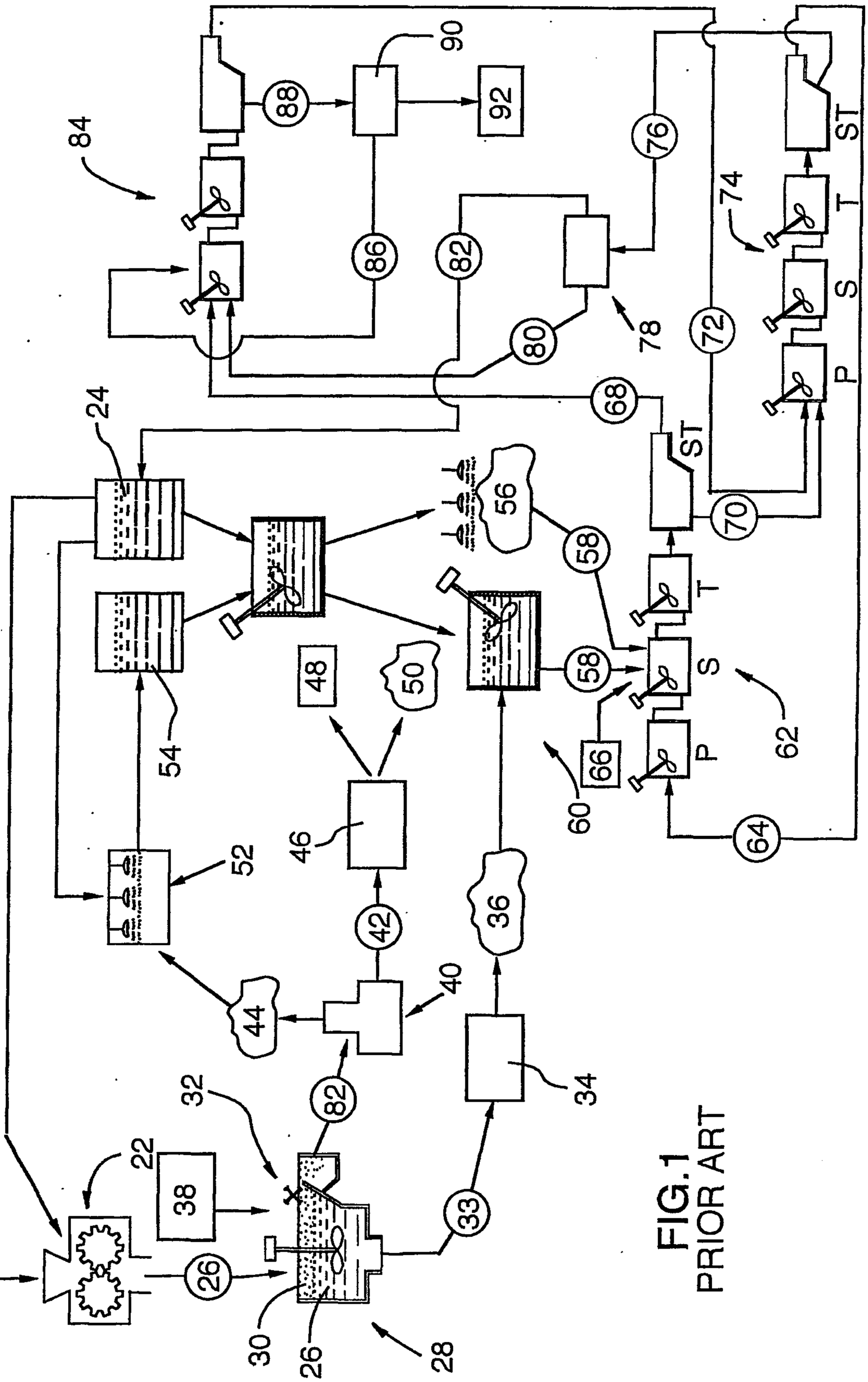


FIG.1
PRIOR ART

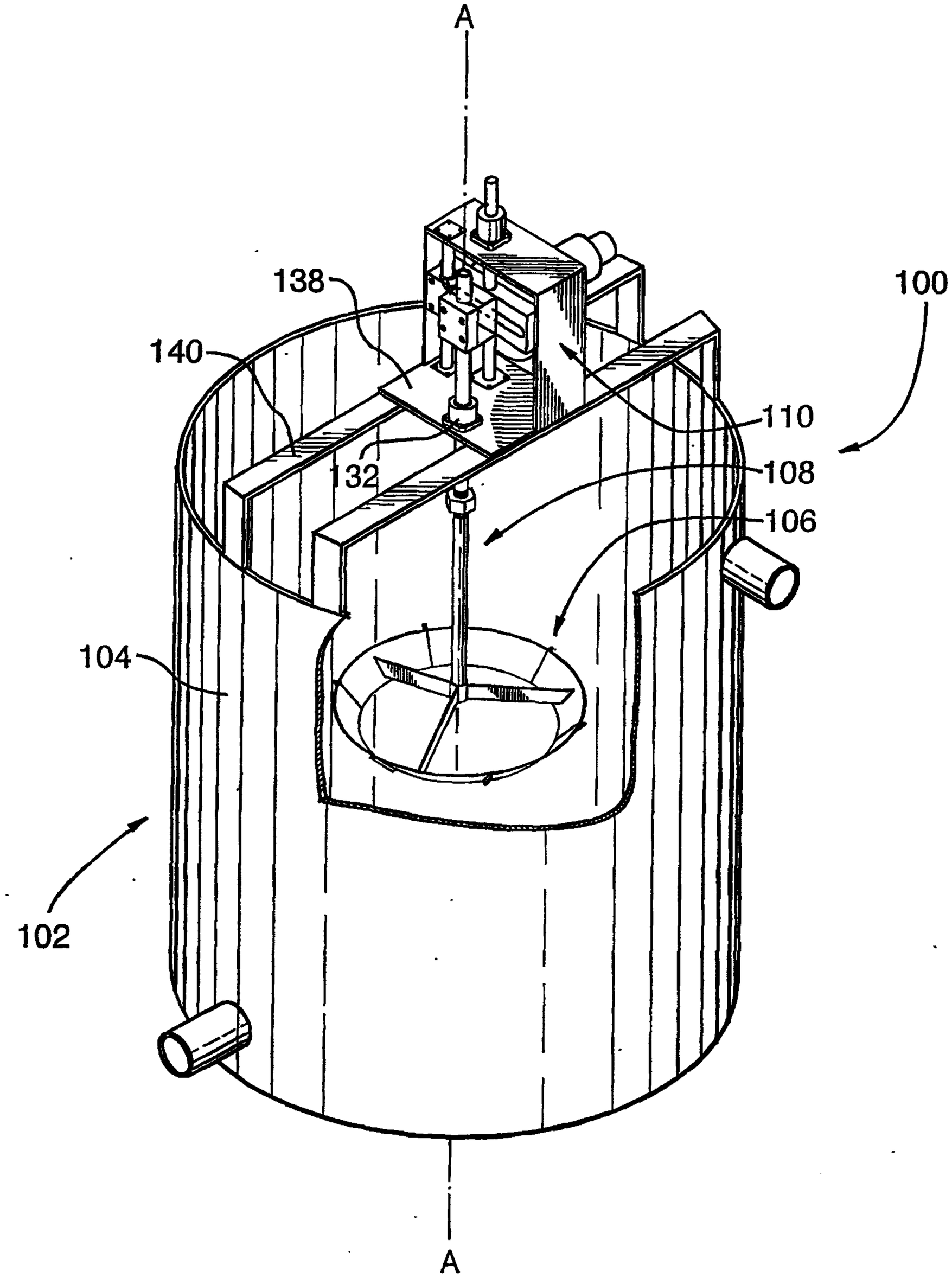


FIG.2

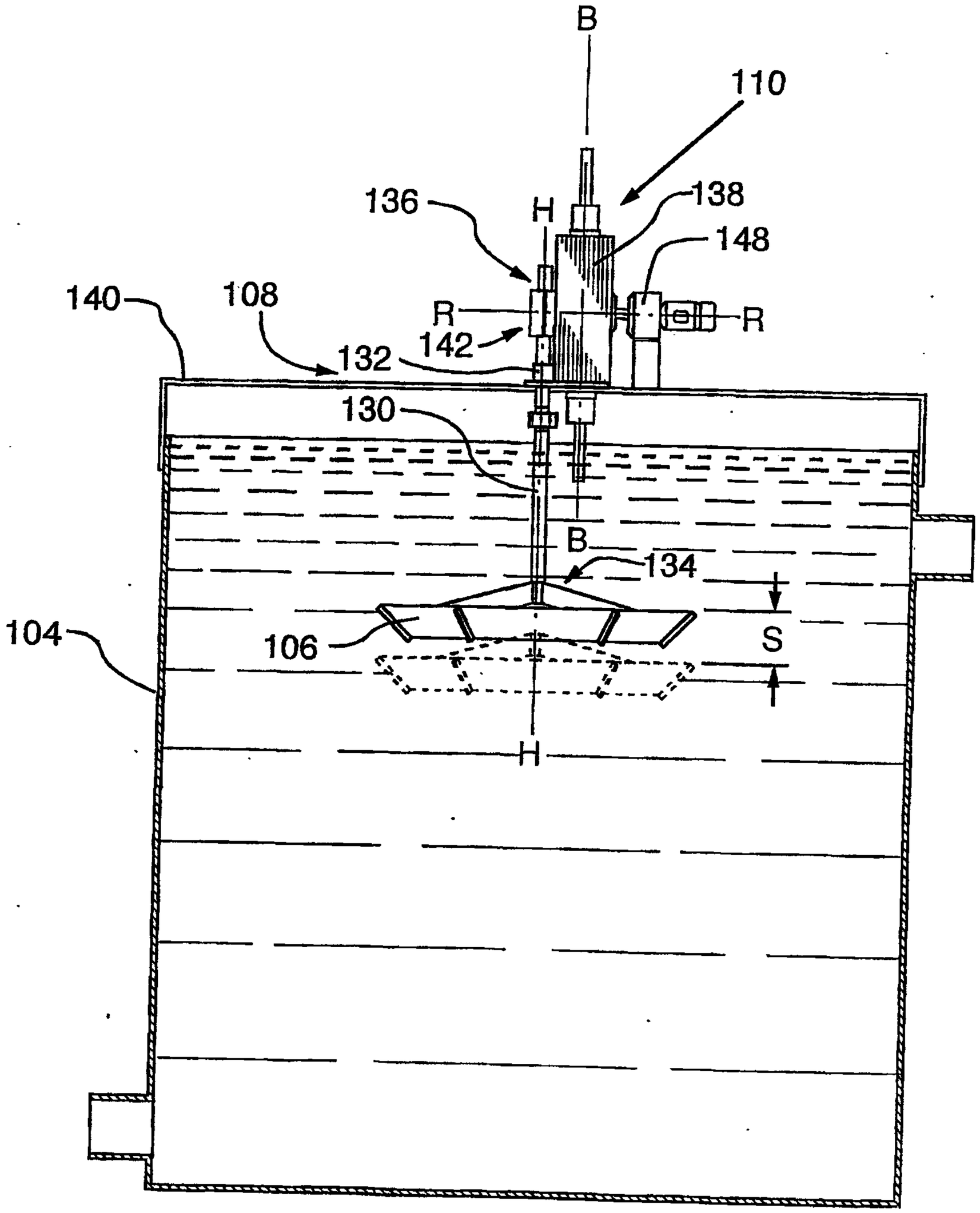


FIG.3

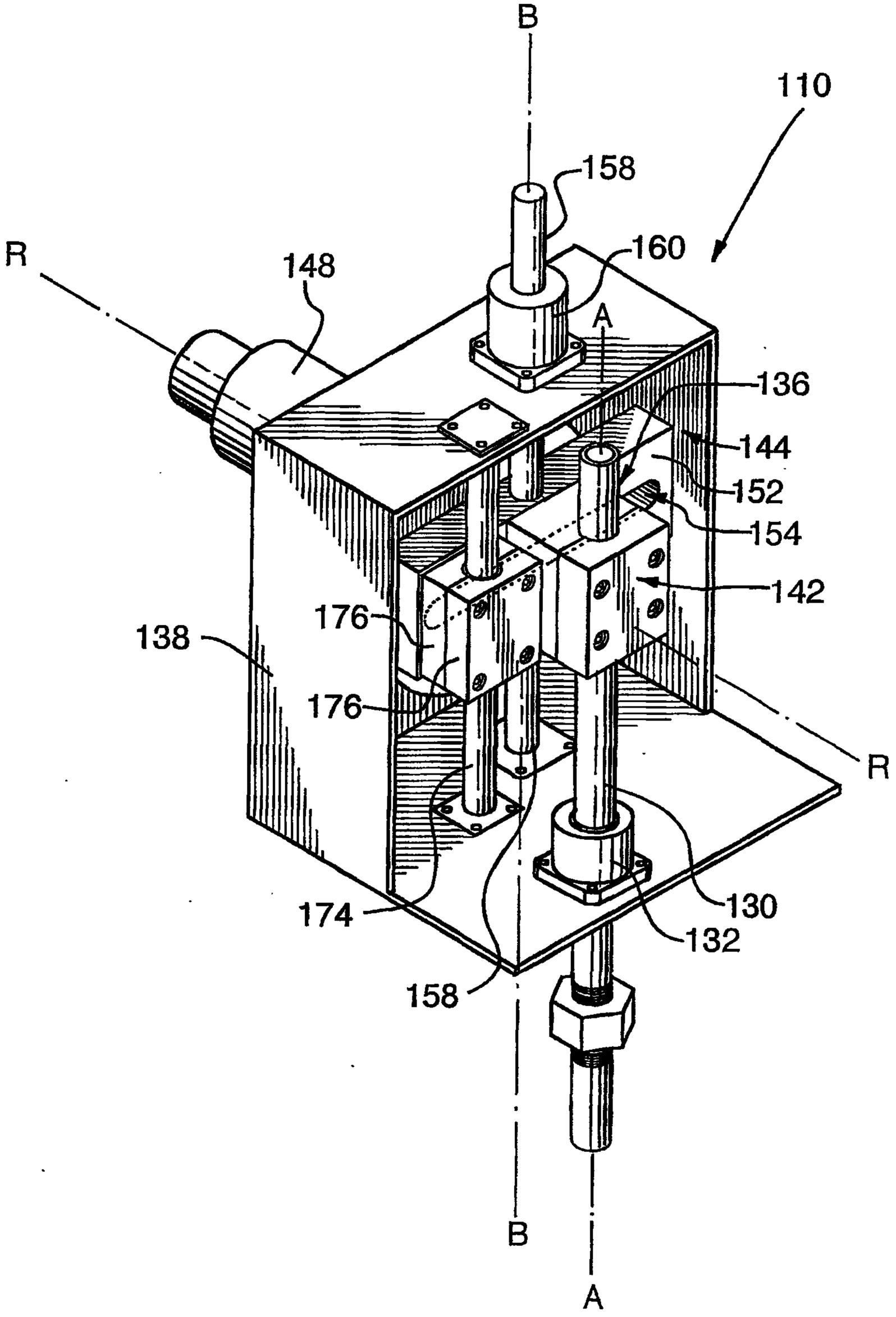

B
110
158
160
R
148
A
136
144
152
154
142
176
C
138
176
174
130
132
158
B
A

FIG.4

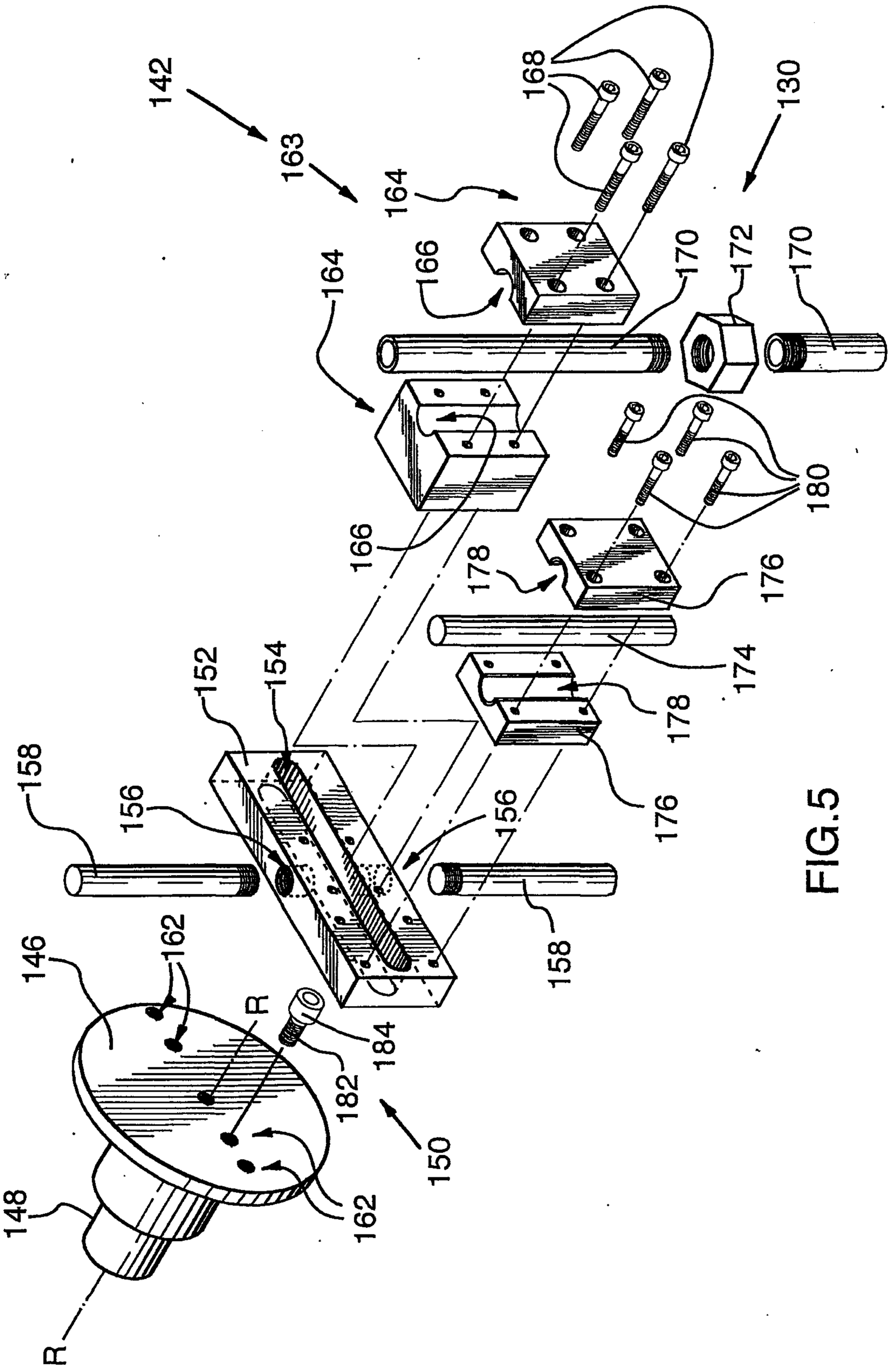

142
163
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166
180
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174
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154
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156
158
146
162
R
184
182
150
148
162
R

FIG.5

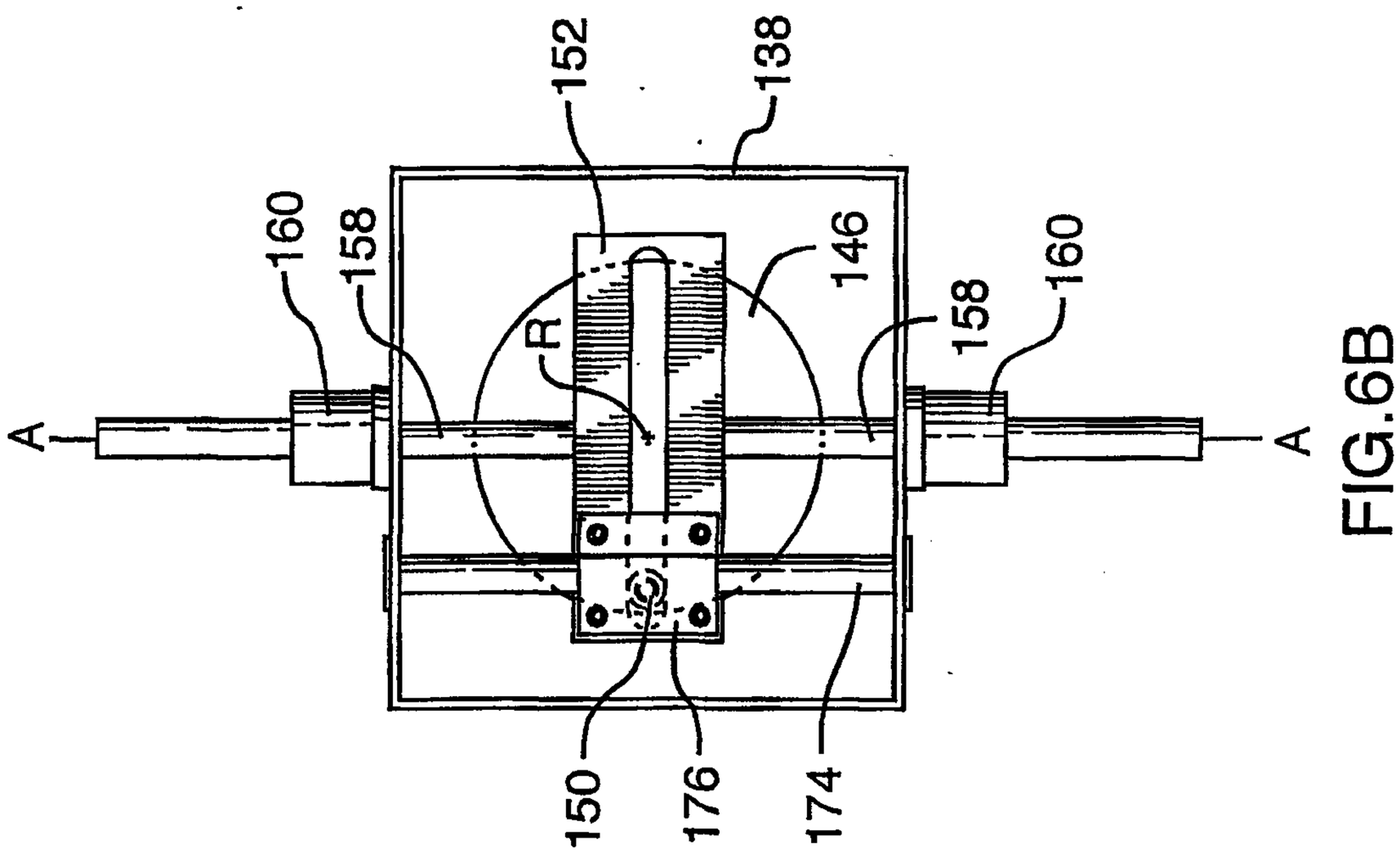

152
138
160
158
146
R
158
160
A
A
150
176
174

FIG.6B

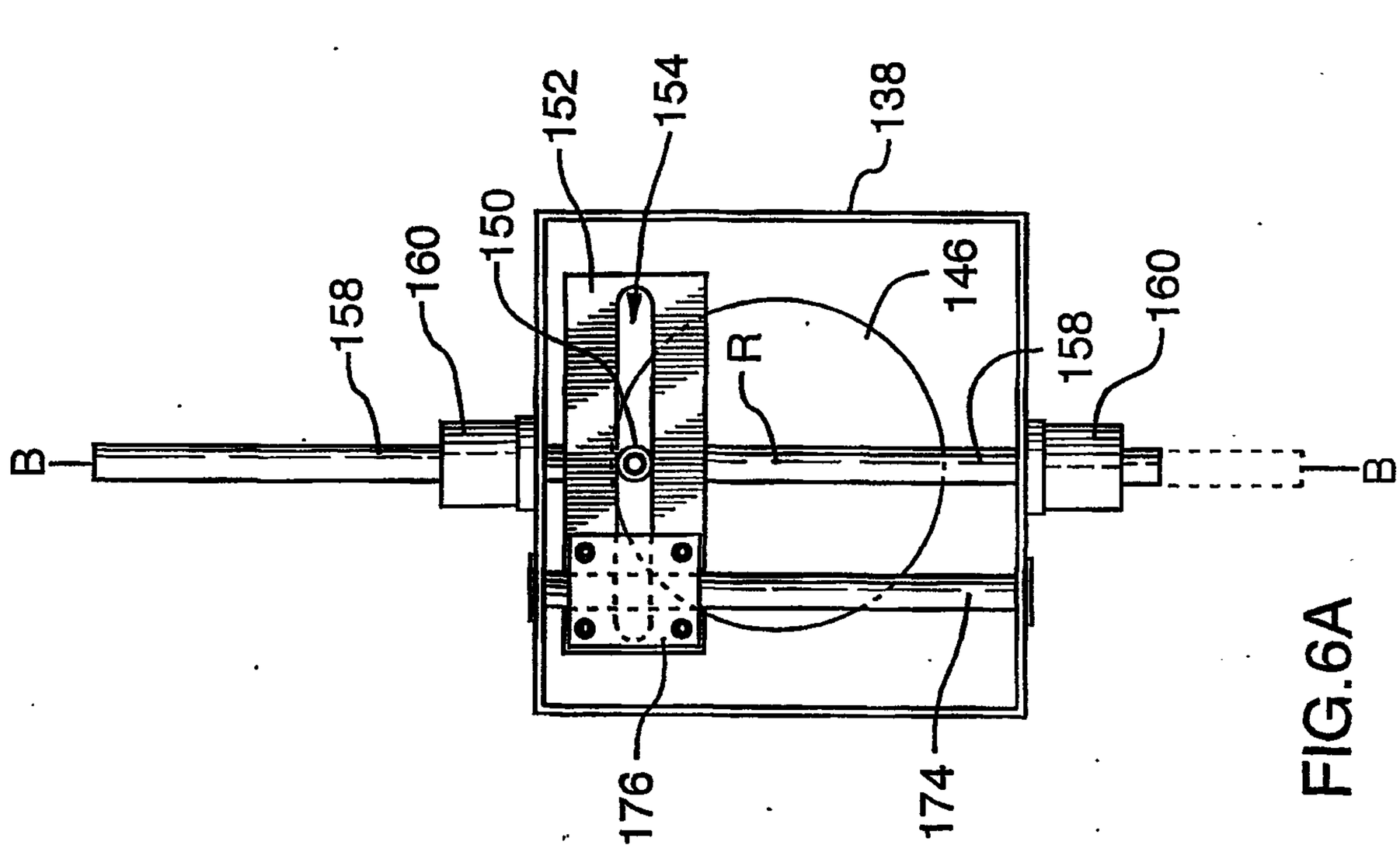

152
154
138
158
160
150
146
R
158
160
B
B
76
74

FIG.6A

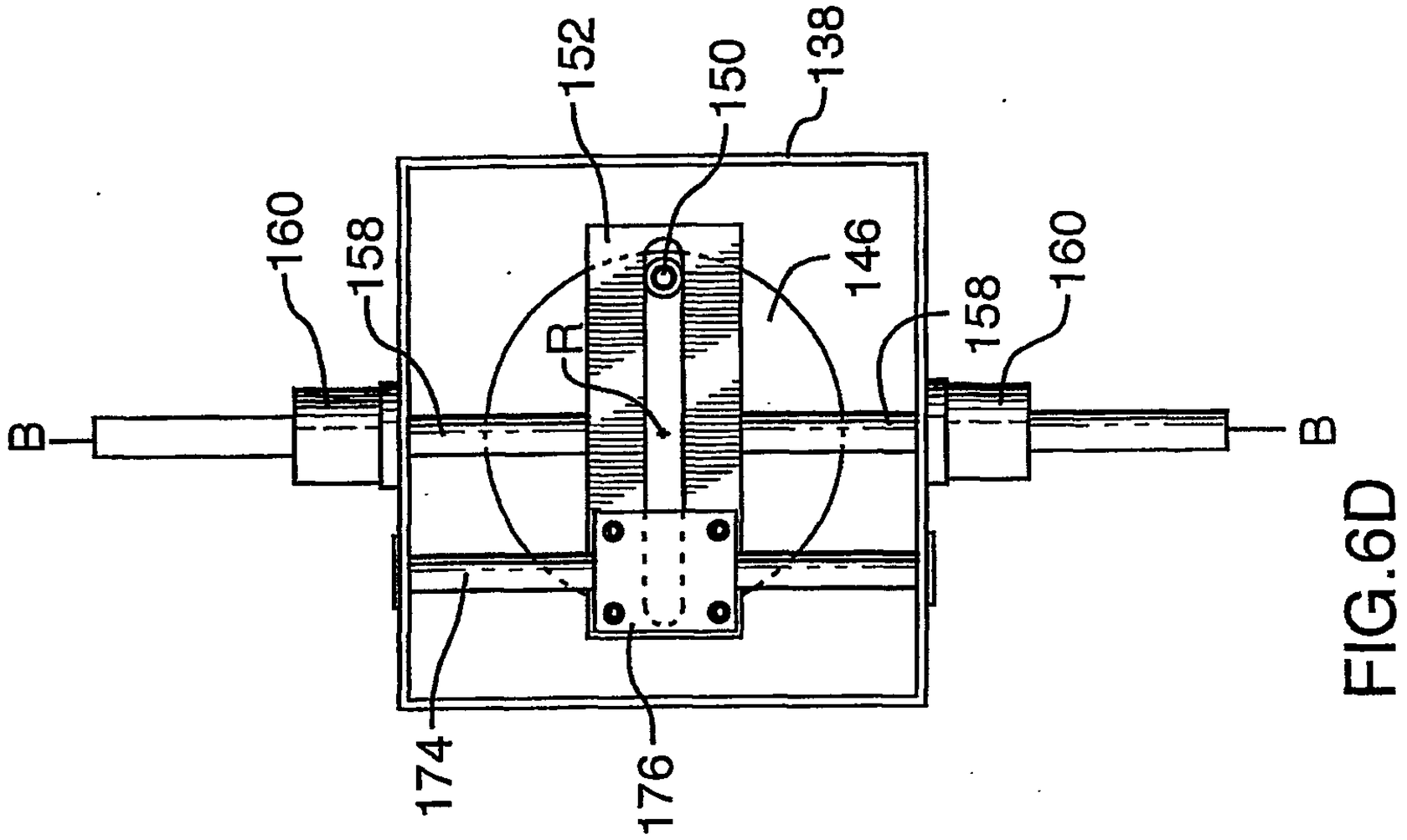

152
150
138
160
158
146
R
158
160
B
B
174
176

FIG.6D

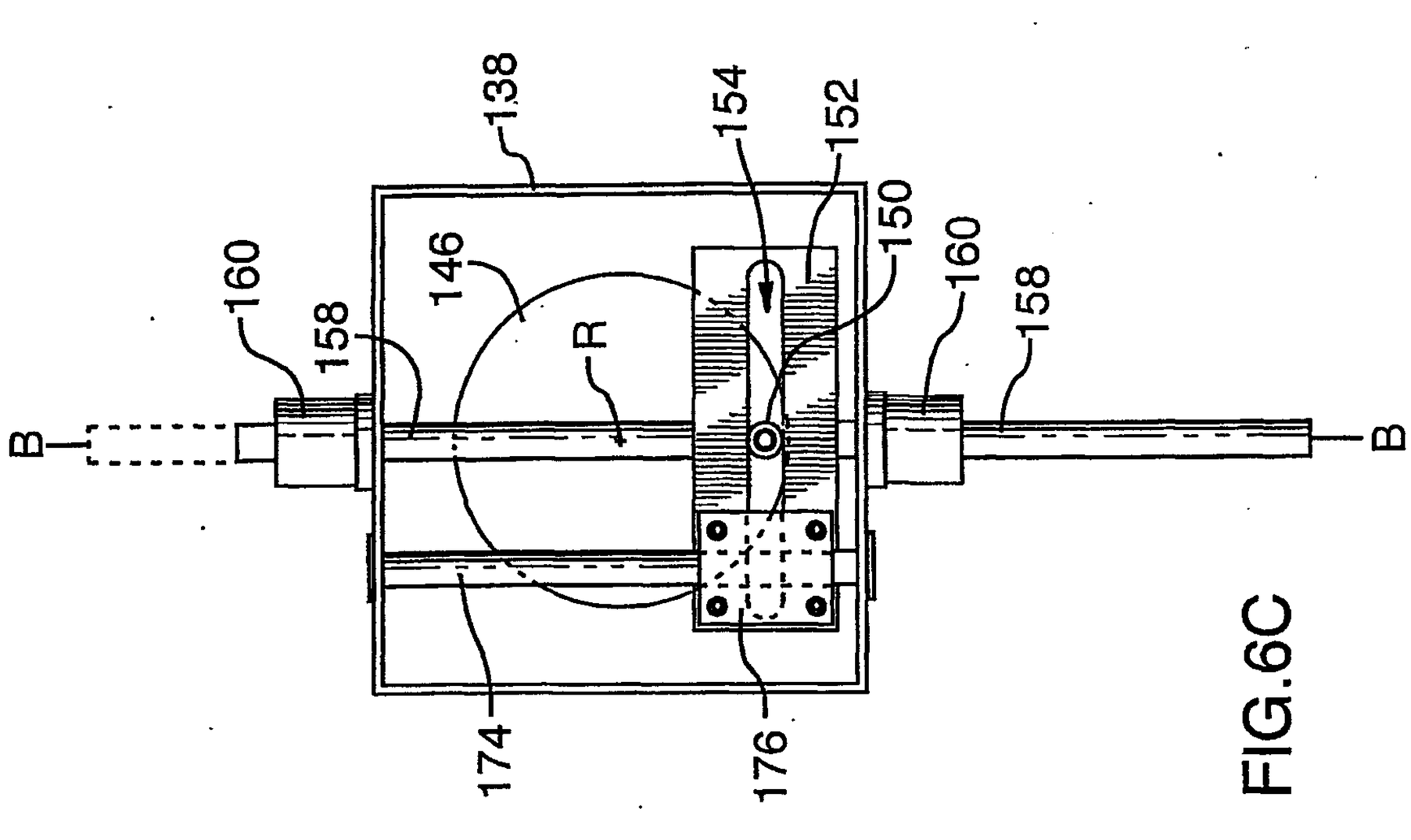

138
154
152
150
160
158
146
R
160
158
B
B
174
176

FIG.6C

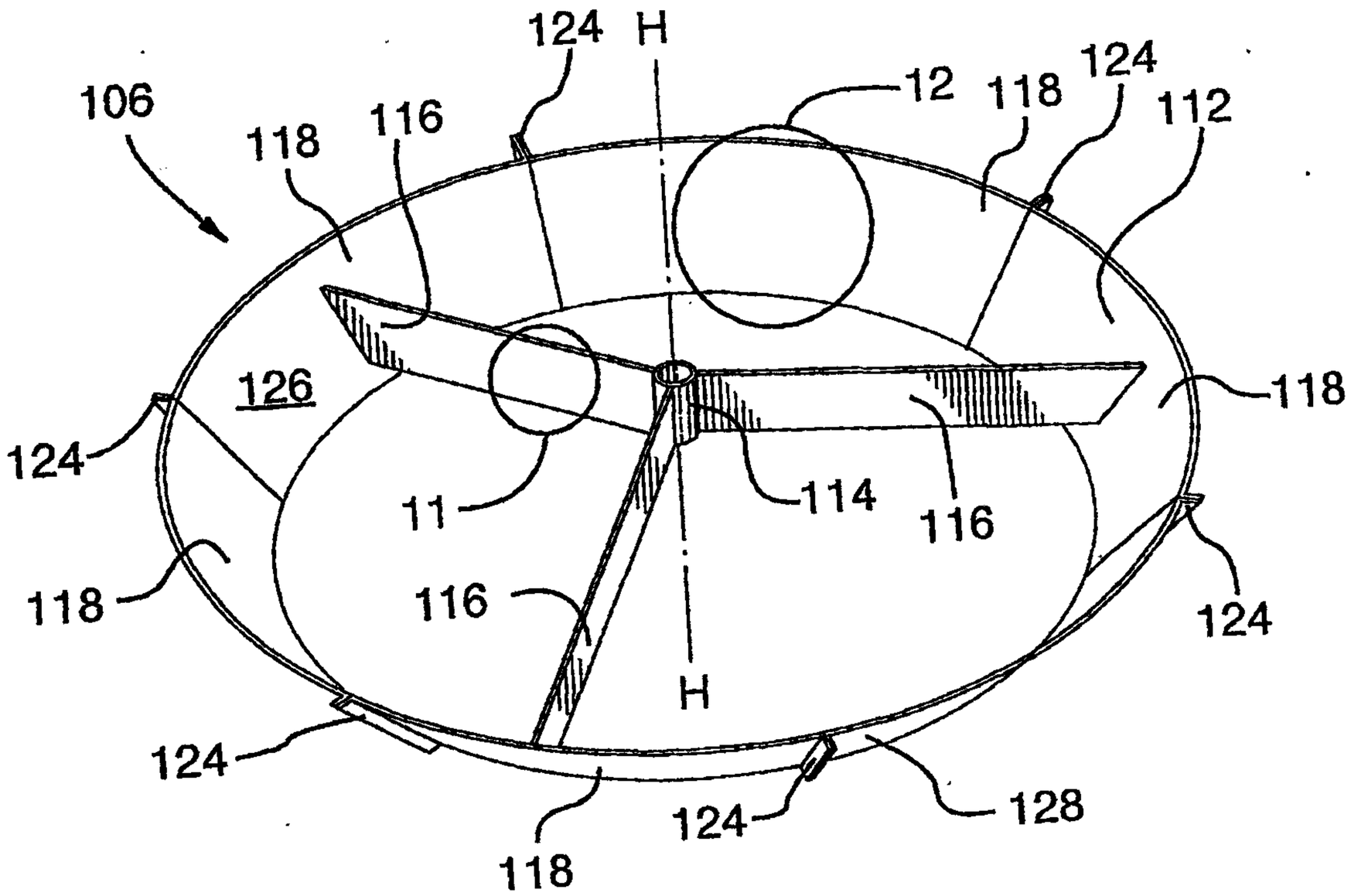

124
H
106
118
116
12
118
124
112
126
124
11
114
116
118
118
116
H
124
124
128
118

FIG.7

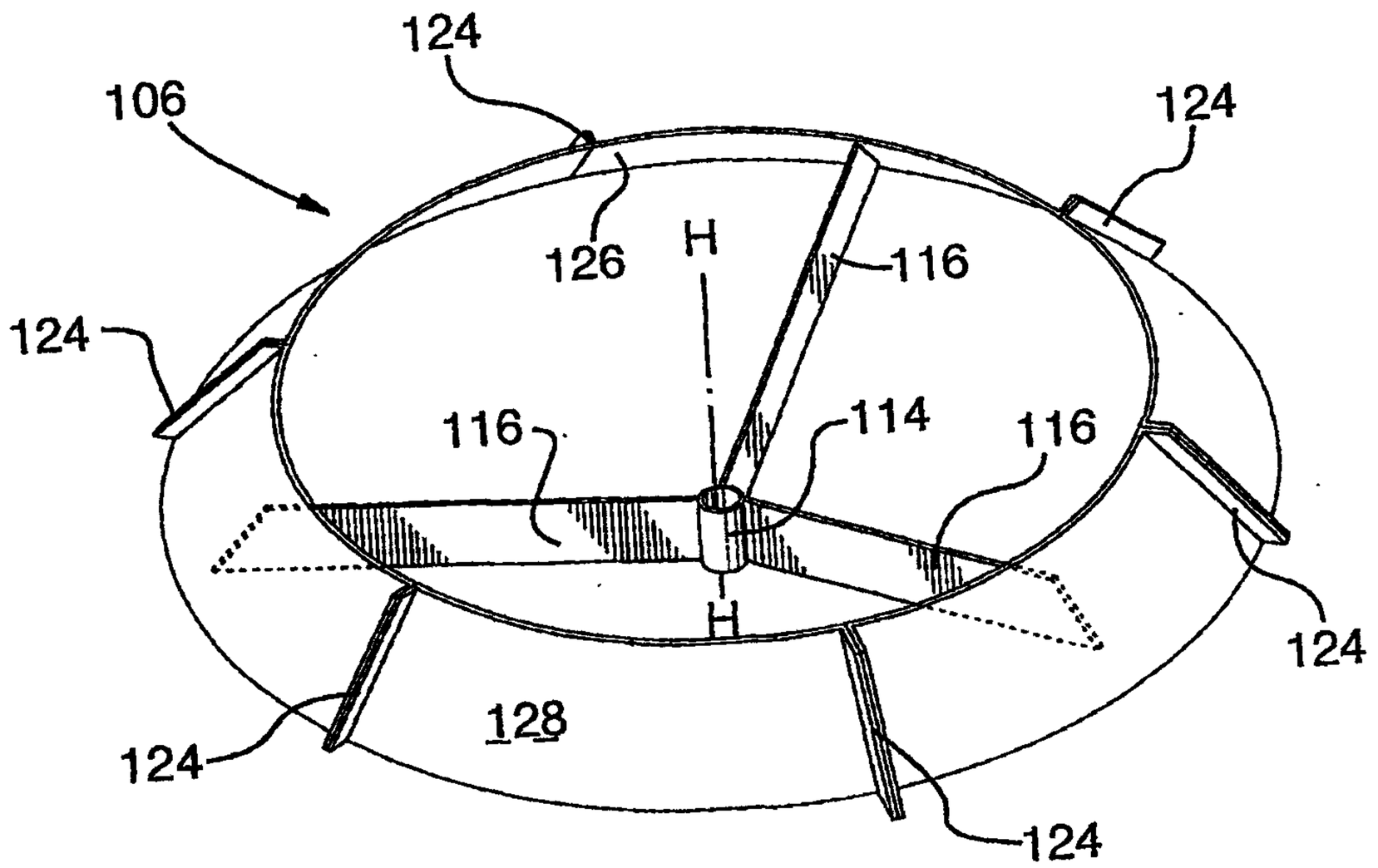

124
106
124
126
H
116
124
116
114
116
H
124
128
124
124

FIG.8

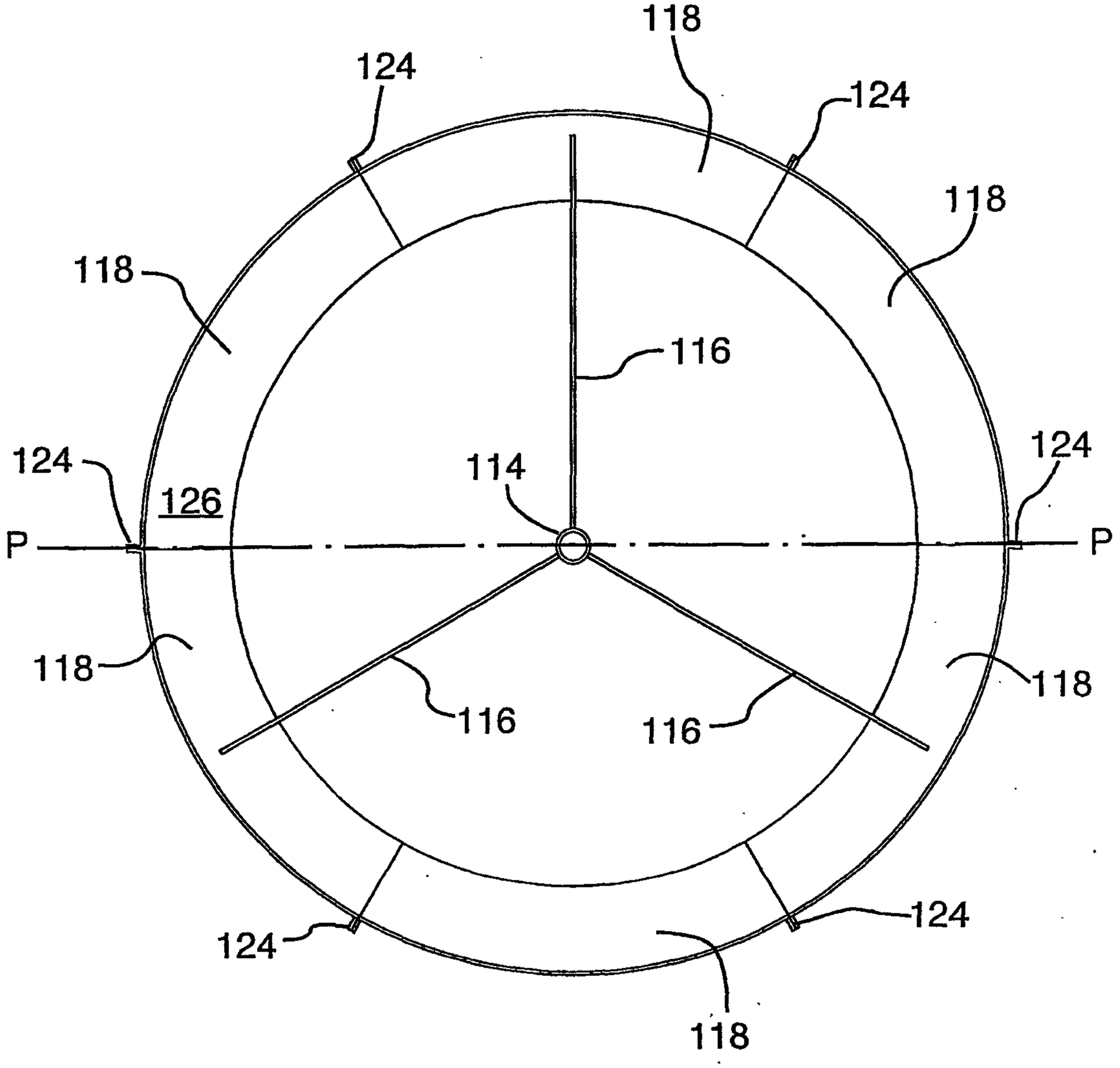

118
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126
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118

FIG.9

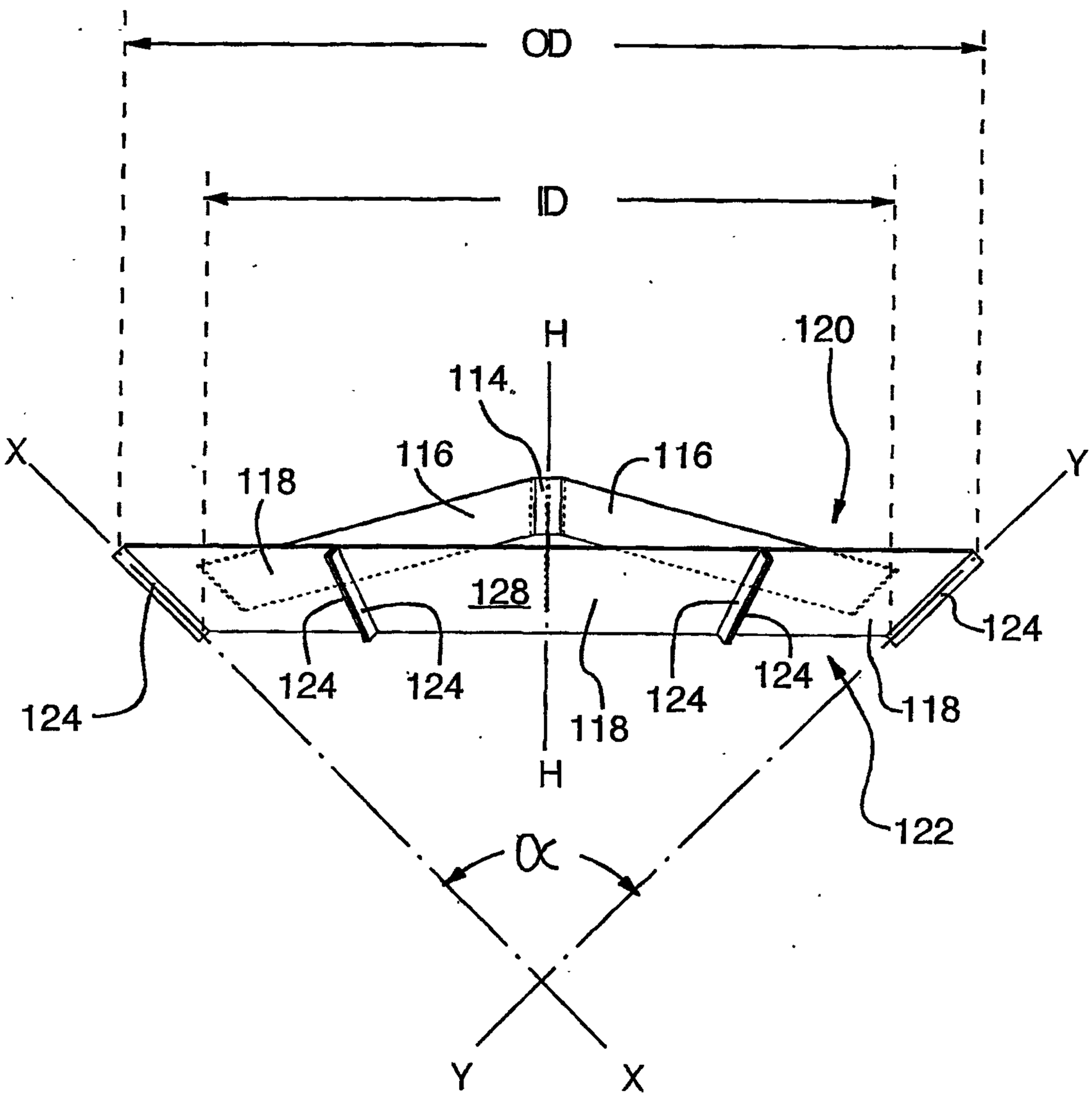

OD
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124
118
118
H
122
α
Y
X

FIG.10

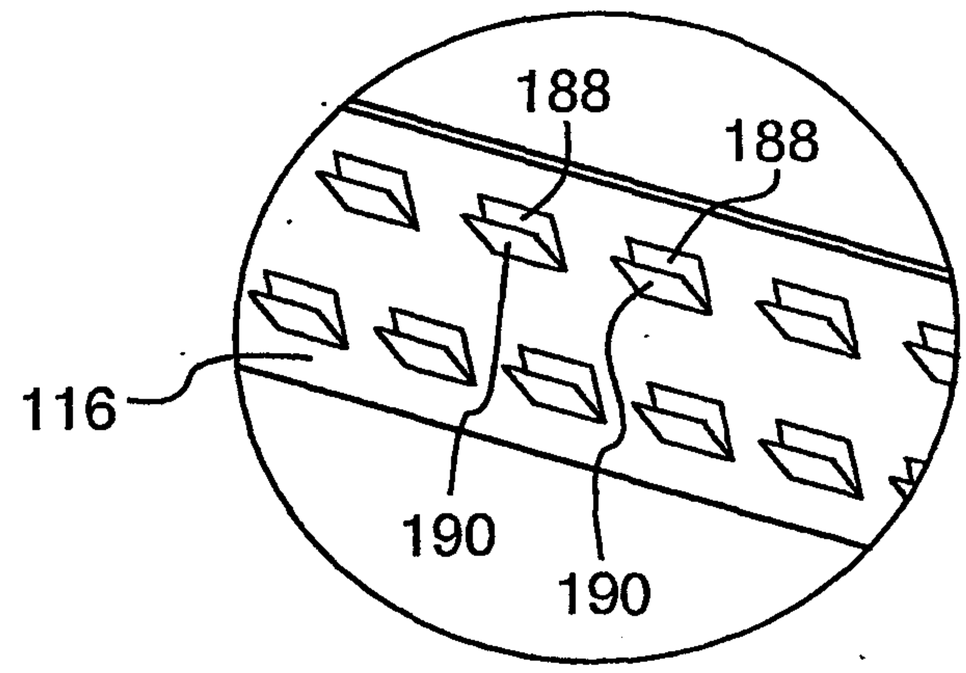


FIG.11

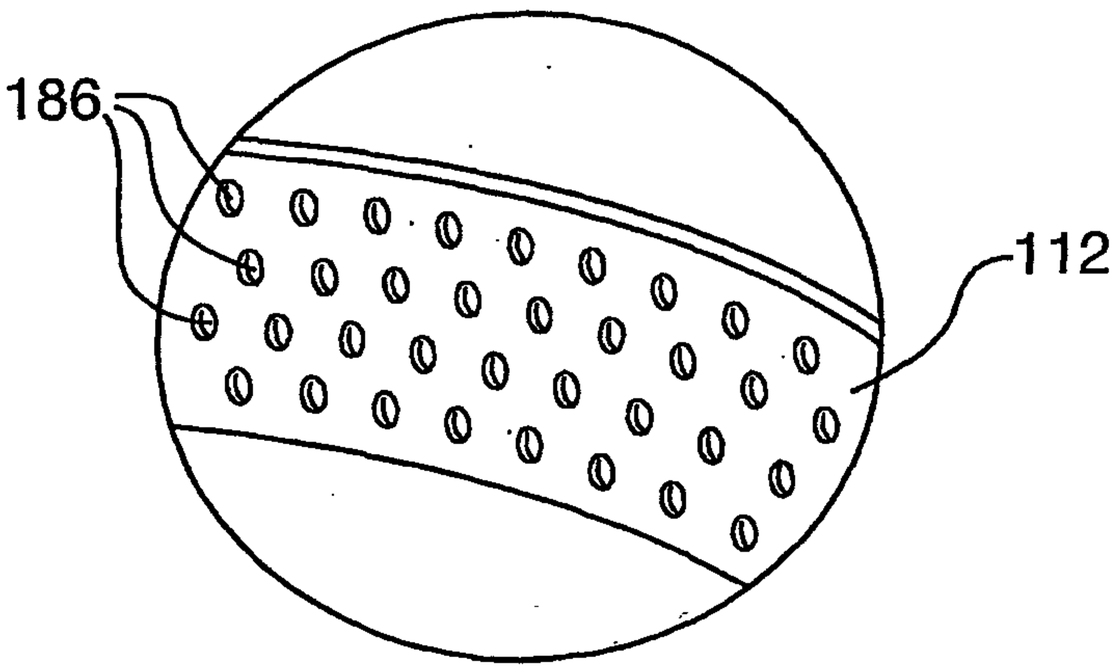


FIG.12

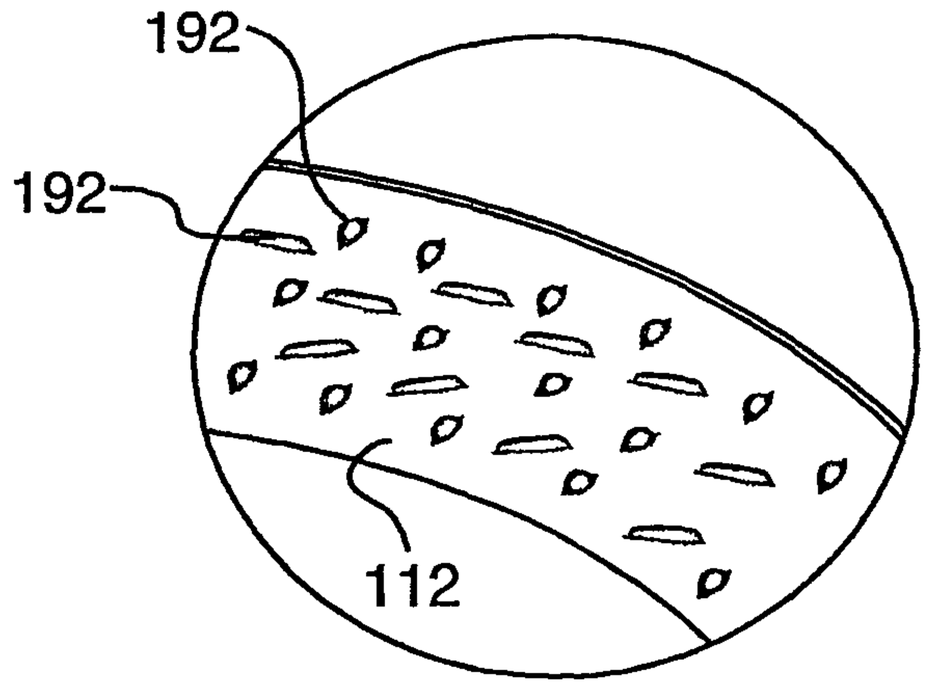


FIG.13

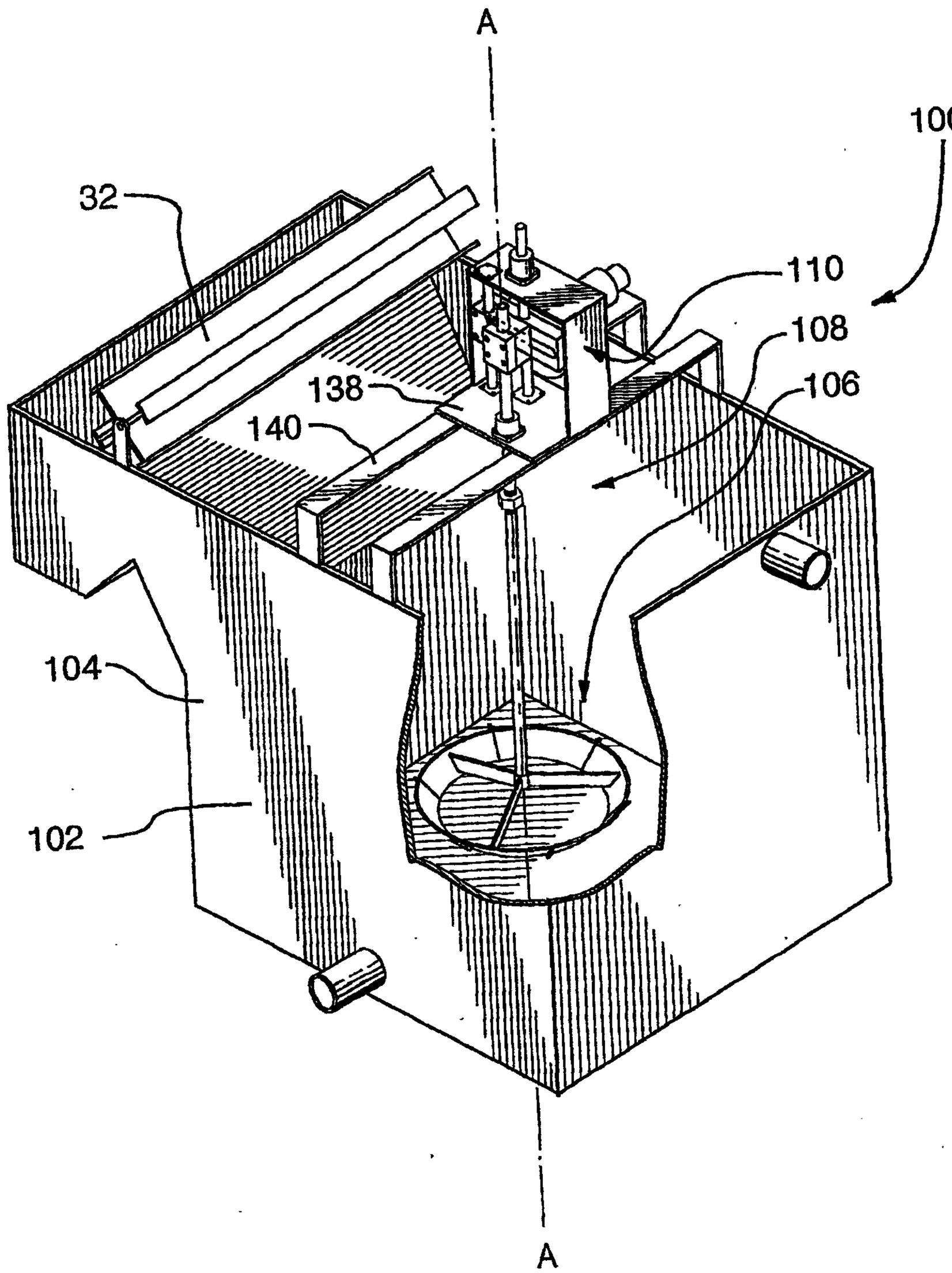


FIG.14

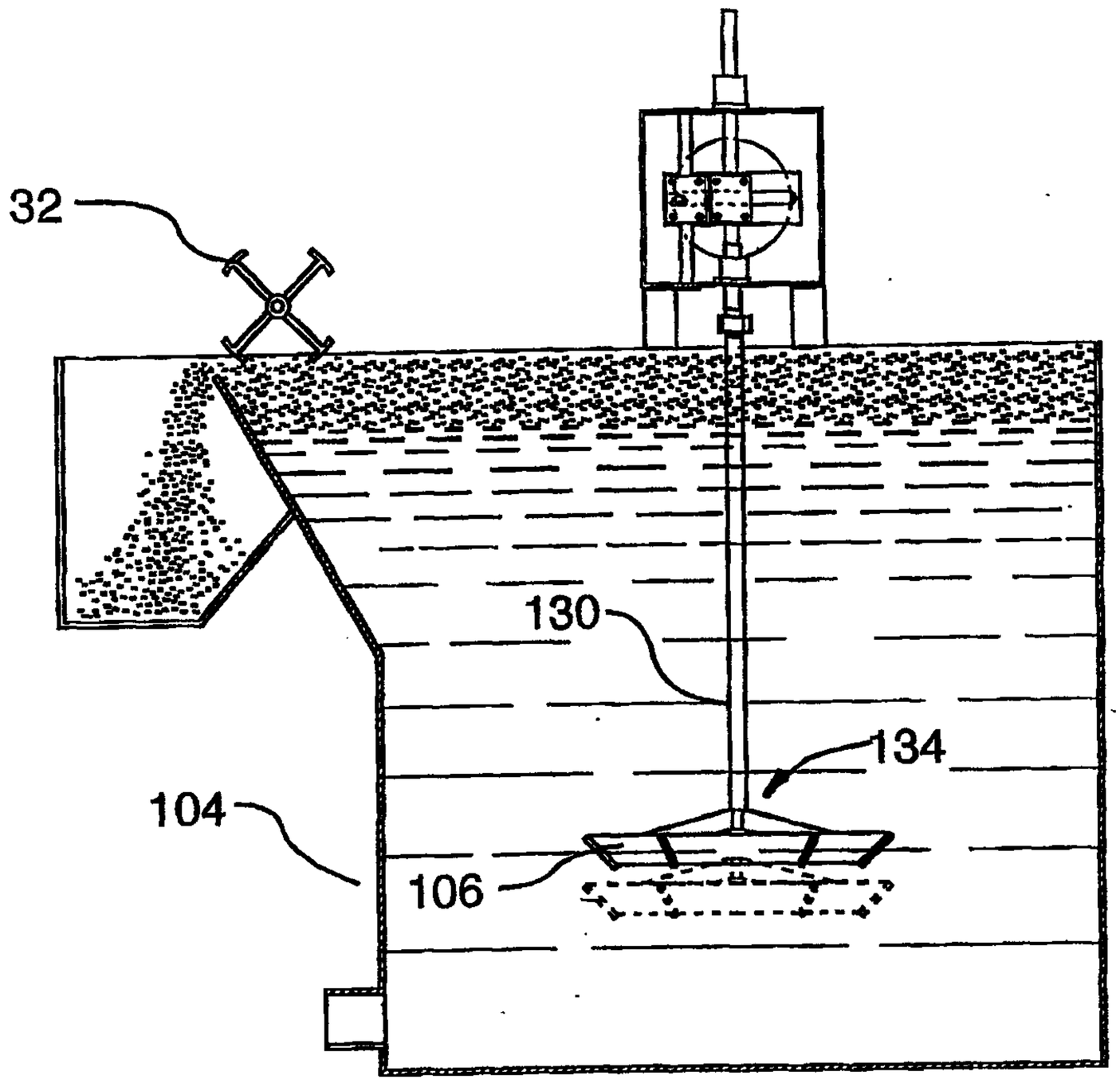


FIG.15

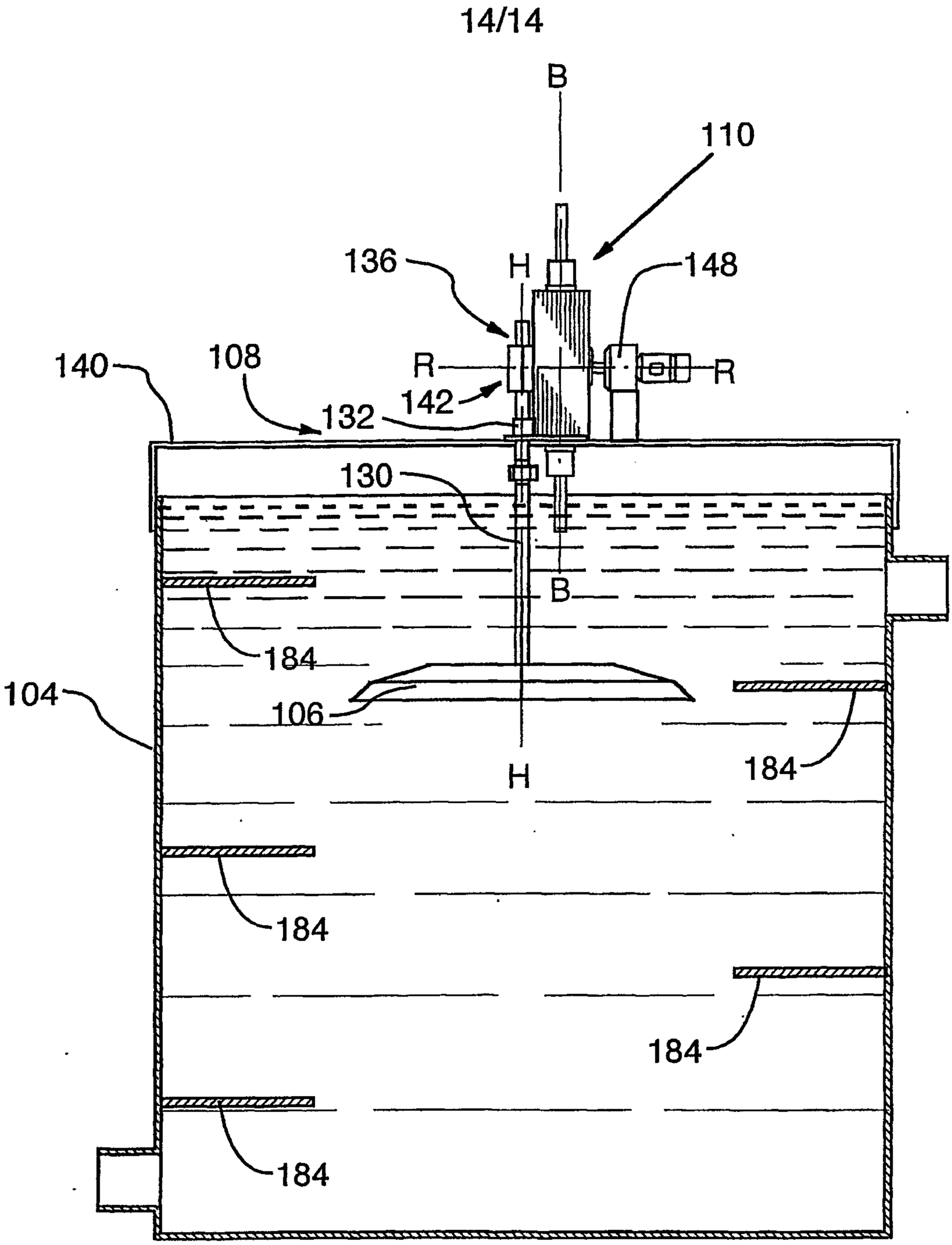
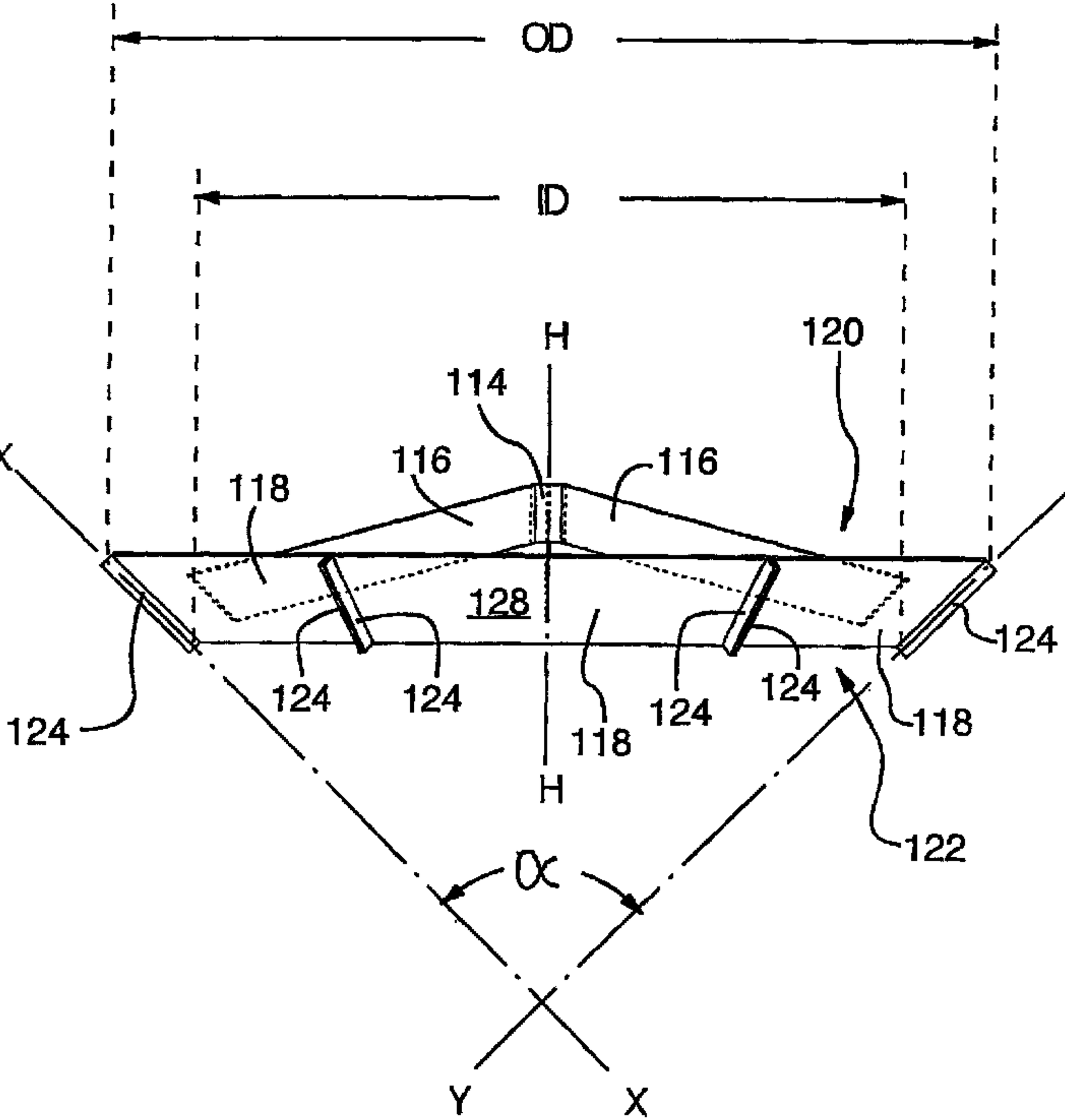

B
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FIG.16


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