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(54) Title: LIQUID REMOVAL

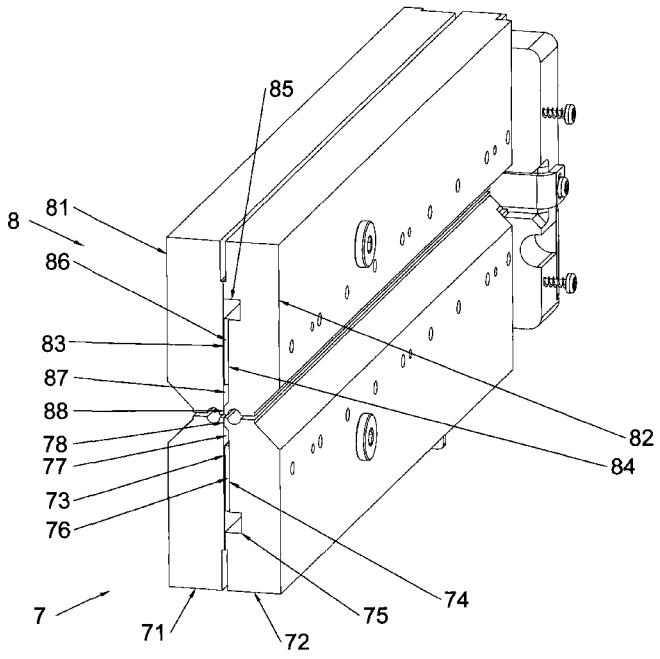

FIGURE 4

(57) Abstract: Liquid removal apparatus comprising air knives (5, 6). Each air knife (5, 6) is comprised of four parts, up- and downstream parts (71, 72) fixed together as a lower member (7) and like parts (81, 82) fixed together as an upper member (8). The upstream parts (71, 81) have plain mating faces (73, 83); whilst the downstream parts (72, 82) have machined faces (74, 84) providing air supply plenum chambers (75, 85), air supply slots (76, 86), inner plenum chambers (77, 87) and air knife slits (78, 88) or a linear array of apertures. At least one elongate groove (91, 92) or rebate (2065) is provided in at least one of the opposed surfaces of the pair of opposed members (7, 8), the groove (91, 92) or rebate (2065) being up- or downstream, in respect of the passage direction, of the respective slit (78, 88) or linear array of apertures.

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LIQUID REMOVAL

The present invention relates to apparatus for removal of liquid from a web and in particular, but not exclusively, for containment of a liquid within a process station and avoidance of it being carried by the web from the process station.

I refer to such containment and avoidance of carrying as "isolation" by analogy with an isolating valve.

By removal of liquid, I intend removal of bulk liquid and/or droplets of liquid, that is superficial dryness. I would not normally expect removal of bulk and droplet liquid to result in complete dryness. A substance may remain damp or wetted or carrying microscopic liquid despite being superficially dry. Accordingly references to "isolation" include superficial isolation and are not limited to isolation to the greatest extent possible as in a hospital isolation ward.

It is known to process webs through tanks for their treatment by chemicals in solution. For instance it is known to plate electrodelessly copper onto polymer webs for uses such as in touch screens. The web may require to be passed from a tank having a solution of one chemical to another such, in which case it is important for the one chemical not to be carried from its tank to a second chemical's tank. In other words, the liquid having the one chemical should be isolated from that of the other. Further, where wash tanks are provided between the chemical tanks, the chemical liquids should be isolated from the wash liquids.

Carry-over of chemicals can be obviated by use of web dryers between tanks. However whereas I have used in my British patent application No GB 2,500,564 a number of superposed air bearing type drying guides, a transfer station can be bulky, and indeed involve risk of uneven drying. Uneven drying can result in uneven contact with plating liquid, for instance, and hence uneven plating.

I have used air knives in many applications from solder levelling to board drying. However, I have not felt confident in use of a standard air knife for web drying.

By "air knife" in the present context, I mean:

A pair of opposed members having opposed surfaces, each having a slit or a linear array of apertures through which air can be blown, for blowing a liquid from the opposite surfaces of a board, sheet or web ("web" alone being used on occasion to include any of these) passing between the opposed members, in a passage direction.

Normally the slit or apertures will be angled to direct air flow oppositely to the direction of travel of the web, whereby the liquid will be blown back to towards the region where the web was treated with the liquid and whence the web is travelling, carrying residual liquid.

The object of the present invention is to provide improved apparatus for liquid removal.

According to the invention there is provided liquid removal apparatus comprising an air knife with at least one elongate groove or rebate in at least one of the opposed surfaces of the pair of opposed members, the groove or rebate being up- or down-stream, in respect of the passage direction, of the respective slit or linear array of apertures.

Normally the web will be longer in the passage direction than its transverse width. The air knife will have a length transversely of the passage direction longer than the web's width, but narrow in its passage direction compared with its length.

As such, the or each elongate groove or rebate will be at least substantially parallel to the respective slit or linear array of apertures.

In the case of one or more groove, the or each opposed surface extends beyond the groove at least substantially flush with itself at the respective slit or linear array of apertures.

Conveniently, the grooves will be provided as pairs, one in one opposed surface, the other in the other. Preferably such grooves will be aligned opposite each

other, to keep a web between them centralised between the opposed surfaces. However the grooves can be staggered.

Normally I expect to provide single opposed elongate pairs of grooves as against multiple pairs of opposed grooves. There may be a single pair upstream or a single pair downstream of the slits or apertures. In unusual arrangements, I envisage use of an upstream and/or a downstream groove opposite a plain opposed member.

In the case of one or more rebate, the or each rebate extends outwards remotely from the respective slit or linear array of apertures to an edge of the rebated opposed member. The rebate may be of constant depth or of varying depth across its width. The width of the rebate can be greater than the extent of the opposed surface between the rebate and the slit or linear array of apertures.

Normally the presence of a groove or rebate on one of the opposed surfaces of one of the opposed members will be mirrored by the presence of the same in like position in the opposed surface of the other opposed member whereby the web will be acted on similarly on both sides.

Again normally the opposed surfaces will be

- chamfered at their remote edges and/or
- at least substantially planar.

Further, separation of the opposed surfaces is greater outwards of the or each groove than inwards thereof, whereby air flow is slower in use outwards of the groove(s) than inwards, between the groove(s) the slit or aperture line.

That said, where one opposed member is curved, preferably at least partially circularly cylindrically, it can be plain with neither rebate nor groove, particularly where the curved member is a bearing member inside the curvature of a web passing over it. In such case, the other opposed member can be complementarily curved, but need not be.

In a particular curved bearing member embodiment, the inner opposed member has a central slit or aperture array for air to provide isolation of liquid on either side, with further apertures for respective liquids up- and down-stream of the air slit or array.

In speaking of opposed members, I include the situation where two parts have been machined at opposed surfaces to provide a slit and the parts have been fixed together to provide a single member of a pair of opposed members.

I envisage use of the liquid removal apparatus between two liquids. Accordingly, I should emphasise that I use "isolation" as in isolation of liquid on opposite sides of a liquid removal air knife to refer to the situation where there are two liquids, one on one side and the other on the other, which are maintained isolated by removal of the up-stream liquid from flowing into the air knife as the web moves into it and prevention of the downstream liquid from flowing back up-stream from the downstream side of the air knife. In other words the liquid removal provides their isolation from each other.

I should also emphasise that grooved air knives and rebated air knives, or indeed grooved sides of an air knife and a rebated side of an air knife will normally be used in different circumstances; that is to say where liquid is in contact with a side of the air knife, that side will have a groove, whereas where liquid is not in contact with that side, it will have a rebate.

Where an air knife side is in contact with liquid flowing from above with a web moving up or down, or in contact with liquid below being below a free surface level again with the web moving up or down, or indeed contact with liquid on either or both sides below a free surface level with the web moving horizontally; then in any of these circumstances, and in particular where the direction of web movement is such as to carry liquid into the air knife, my observations are that despite the liquid having to pass between the opposed members against air flow outside the grooves, some liquid can pass into the grooves. However, the groove acts to isolate the central region the air knife from the liquid. The air flow into the groove expels any liquid getting into the groove and returns it whence it came.

The airflow will normally be symmetrical on both sides of the web and on the upstream and downstream side of the air knife. It therefore tends to support the web centrally of itself, with the central portion of the air knife functioning as an air bearing. Outboard of the grooves, the liquid contributes to the bearing support of the web centrally of the opposed members. The liquid tends to enter and be expelled again and in the process assists in keeping the web spaced from the opposed members.

I have discovered that where the web is coming from a liquidless region or passing to a liquidless region, in either of which situations there are not two liquids present requiring isolation from each other, incorporation of grooves into the opposed surfaces can allow the web to flutter into contact with the opposed members. In such situations, it is preferable to use the rebated air knives or a rebated side of the air knife. The rebated opposed members provide less opportunity at their edges for the web to flutter into contact with the opposed members.

Where, as is preferred, the air is supplied in the air knives to the web via slits, it travels up and down stream of the web movement along the web on both sides. For symmetrical bearing support of the web, the gap between the opposed surfaces, less the thickness of the web, is substantially equal to the width of the slits supplying the air. This travels to the web and then splits in two, on each side of the web, and in doing so requires only half the cross-sectional flow area to maintain similar flow conditions. This is provided by the half the same sized gap being available on opposite sides of the web.

Despite the tendency of the liquid outwards of the grooves to damp the lateral movement of the web, nevertheless the opposed surfaces at the lands outwards of the grooves is preferably greater than at the inwards lands.

Where a grooved arrangement is provided up- or down-stream and a rebated arrangement down- or up-stream respectively, the length of land from the slit to the groove and from the slit to the rebate is preferably substantially the same, whereby the

bearing support of the web is similar up- and down-stream without a tendency for the web to touch the opposed surfaces.

In contrast to my earlier use of air knives for solder levelling, where the air slits are staggered to clear the solder from one direction and then the other, in particular from through holes through the tinned boards, in my liquid isolating air knives, I prefer to place the air slits directly opposite each other so that they act to centre the web between the opposed surfaces.

Whilst I have given alternatives of the grooves and the rebates above, and indeed for other features of the liquid removal apparatus, the provision of the slits or aperture line can have alternatives. In particular, one or each opposed surface can have two, or even more, slits or aperture lines. Conveniently plain surface portions are provided between slits or aperture lines, whereby the air flow from the respective slits / aperture lines being directed respectively outwards to ensure even airflow both up- and down-stream. The groove(s) / rebate(s) are provided outwards of the two slits / aperture lines.

The opposed members can be each comprised of three parts, complementarily machined at joint faces and fixed together to provide one of the opposed members,

- with a plain central one of the parts and two grooved or rebated ones of the parts, the parts being machined at their joints to provide one said slit between the central part and one of the grooved or rebated parts and another said slit between the central part and the other of the grooved or rebated parts and
- the central part being flush with the other parts between the slits.

Alternatively, the opposed members can be each comprised of one part or three parts, complementarily machined at joint faces and fixed together to provide one of the opposed members,

- with a plain central strip of the one or a central one of the parts where three are provided, between the two lines of apertures and two grooved or rebated outer regions and
- the central strip being flush with the outer regions.

To help understanding of the invention, specific embodiments thereof will now be described by way of example and with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional side view of web processing apparatus including air knives in accordance with the invention;

Figure 2 is a similar view on a larger scale of a washing tank of the apparatus with the air knives up- and down-stream of it;

Figure 3 is a similar view again on a larger scale still of the downstream air knife;

Figure 4 is a perspective cross-sectional view of one of air knives per se;

Figure 5 is a scrap view of the air knife of Figure 4 showing grooves in accordance with the invention;

Figure 6 is a cross-sectional diagram of another embodiment of a treatment bath and wash tank incorporating liquid removal apparatus of the invention;

Figure 7 is a scrap view of a liquid removal and isolation air knife included in the embodiment of Figure 6;

Figure 8 is a similar view of a combined air knife and liquid bearing;

Figure 9 is a view similar to Figure 6 of a horizontal arrangement of wash stations including air knives of the invention;

Figure 10 is a view similar to Figure 4 of another variant air knife; and

Figure 11 is a view similar to Figure 8 of a further variant air knife.

Referring to the drawings, web treatment apparatus 1 has two process tanks 2,3, each with respective upper and lower bearing fluid bearings 21,22; 31,32. In use, a web 4 passes sinuously around them for treatment with chemical solution 23 in tank 2 and washing with water 33 in tank 3. Respective air knives 5,6 are provided at the outlet from tank 2 / inlet to tanks 3 and at the outlet from tank 3. Despite being oriented differently, they are substantially identical and one only will be describe in detail. The web 4 is passed around a plurality of other fluid bearings 10, which guide it in and out of the tanks.

Each air knife is comprised of four parts, up- and down-stream parts 71,72 fixed together as a lower member 7 and like parts 81,82 fixed together as an upper

member 8. The up-stream parts 71,81 have plain mating faces 73,83; whilst the down-stream parts 72,82 have machined faces 74,84 providing air supply plenum chambers 75,85 air supply slots 76,86, inner plenum chambers 77,87 and air knife slits 78,88. Non-shown means is provided for supply of air to the plenum chambers 75,85 whereby extended air jets exit the slits 78,88 towards each other. They impinge on the web when between the air knife members.

From the slits, the air flows along the top and bottom 41,42 faces of the web. In the absence of the grooves 9, about to be described as being in accordance with the invention, the air flow exits the air knife in the up- and down-stream direction, passing out from between opposed faces 79,89 of the knife members. In doing so the air blows away any droplets tending to be drawn in between the members.

I would have expected the effect of the air knives to be adequate in drying the web. However I have experienced effects which appear to result from uneven drying in the absence of the grooves 9.

The grooves comprise up- and down-stream, opposed semi-circular grooves 91,92 in the opposed faces 79,89. I believe that they operate as plenum chambers thoroughly equalising the pressure and flow of the air over the faces 41, 42 of the web 4 outwards of them.

In addition, the opposed faces are slightly relieved outwards of the grooves, where their separation 101 is greater than it 102 is inwards of the grooves. Thus not only is the flow rendered even, it is also slowed. Again, this is surprising but is effective.

Turning now to Figures 6 to 8, another web processing apparatus has a process tank 202, with an inlet air bearing 210 with an array of air nozzles 211 over its surface guiding the web 204 passing over it into the process tank. The bearing is supplied with filtered air pressurised somewhat above atmospheric pressure. The air can be processed to the standard known as CDA air, Clean, Dry Compressed Air. It issues from the nozzles creating an air bearing layer enabling the web to pass over the bearing without contacting it.

The tank has respective upper and lower liquid bearing bearings 221,222. These are supplied with liquid 223 with which the web is being processed in the tank through like nozzles (not shown), the supplied liquid being under pressure and creating a bearing film for passage of the web along a serpentine path around the bearings, without touching them.

Exiting vertically from the process tank, the web 204 passes to a liquid isolating air knife 206. In contrast to the air knife 6 above, its arrangements above and below its air knife slits 2061 differ. Above the slits, its opposed members 2062 have opposed grooves 2063 in their opposed faces 20641,20642. The grooves act to steady the flow of CDA air upwards such that wash liquid 233 present above the air knife does not penetrate between the opposed members 2062 of the air knife. Below the slits, the opposed surfaces are relieved, forming rebates 2065. These open downwardly such that any process liquid drawn out of the tank on the web is blown back by the air issuing from the rebates and, if any passes into the rebates, by the air as it issues from the narrow air gap between the unrelieved strips 2066 of the opposed faces 2064 below the slits.

Typical dimensions that I have found to be satisfactory, for supply of air to the slits and 0.5 bar with the web being 0.1mm thick are:

Width of slits 2061	0.1mm
Gap at opposed faces 20641	0.2 to 0.3mm
Gap at opposed faces 20642	0.4mm
Diameter of grooves 2063	5mm
Slit to groove at face 20641	1.5mm
Groove to chamfer at face 20642	5.5mm
Slit to rebate at face 2066	2.5mm

Insofar as these are dimension are practical I would expect that respective halving to doubling them would also be practical

Above and to one side of the air knife 206, two wash liquid transfer bearings 2031 are provided up-stream of a wash tank 203. Wash liquid 233, typically de-ionised water, is pumped to the bearings, forming bearing films over them. Some of

the liquid runs back down the web to the air knife 206, where it runs around the edges of the web to begin washing the other side of the web.

From the transfer bearings, the web passes into a first portion 2032 of the wash tank 203. Here it passes around another bearing 2034 provided with the wash liquid, above the normal depth 2036 of the wash water in the tank. Thence the web passes up to a compound bearing and air knife 207. This has a bearing cylinder 2071, divided internally into two wash liquid passages 20721, 20722 with a central air passage 2073 between them. Each has bearing nozzles 2074. Above the cylinder 2071 is arranged an air knife opposed member 2075 having a central air knife slit 2076 and up- and down-stream rebates 2077.

With the web passing over the bearing cylinder and air supplied to the slit 2076 and the central passage and wash liquid supplied to the passages 20721,20722, the air flow isolates the wash liquids of the respective portions 2032,2033 of the wash tank 203. Any wash liquid carried up by the web on to the top of the web on the cylinder 2071 is blown back at the up-stream rebate 2077. Equally whilst the same liquid is pumped to the up-stream passaged 20721 and out through its nozzles, the air from the central passage 2073 blows this liquid back preventing it passing the slit 2074.

Whilst the same wash liquid can be pumped to the passage 20722, this can also be kept separate, in the compound bearing and air knife 207 and indeed in the second portion 2033 of the wash tank, improving the washing. In like manner, the air from the central passage tends to blow back any liquid from the second passage 20722, which might tend to flow back past the central air nozzles 2074. The bearing liquid from the passage 20722 and its nozzles 2074 passes into the second tank portion 2033.

In this tank portion, the web passes around another wet bearing 2037 and up to an air knife 208. It will be noted that the washing occurs at the bearings, where the wash liquid is flowing as a hydrodynamic bearing film with respect to the web, as opposed to by immersion in the liquid in the tank portions 2032, 2033.

The air knife 208 has upper and lower rebates 2081 analogous to the rebates 2065. Thence the web passes to an air bearing 209 and on to a subsequent treatment station or to a reeling station (neither shown).

Turing on to Figure 9, fluid isolating air knives can be used where the web or board being treated is travelling horizontally as well as at the various angles described above. Figure 9 shows a pair of washing stations with a 301,302, such as shown in my British patent No 2,459,055, each having upper and lower, up- and down-stream flow path defining plates 3011,3012,3013,3014; 3021,3022,3023,3024, with double, staggered wash liquid slits 3015;3025. The web 304 passes between the plates and the jets. Air knives 305; 306; 307 are arranged up-stream of between and down-stream of the washing stations.

The air knife 306 between the stations 301,302 has grooves 3061, 3062 in its opposed members and chamfered up- and down-stream edges 3063. The arrangement is such that the edges of the wash station plates are close to the air knife members so that wash liquid flows onto the top of the top plates and is held from running freely from beneath the web, whereby web is exposed to the wash liquid for as long as possible. Thus the chamfers of the air knives have the wash liquid between them and the web. Despite this the grooves set in from the chamfers are effective in providing a uniform air flow from between the opposed members, whereby the liquid does not flow into the air knives past the chamfers.

The air knives 305,307 have similar grooves at their sides facing the wash station plates. At their outer sides, they have rebates, such as the rebates 2065, 2077, 2081. The lands between them and the central air knife slits as between the grooves and the air knife slits, whereby the air flow from the slits is divided to flow both up-stream and down-stream.

Two further variants are shown in Figures 10 and 11. The air knife 17 of Figure 10 is of three part construction as opposed to the two part construction shown in Figure 4. In description of this variant, the upper and lower parts will not be described separately, since they are practically identical to each other. The outer parts 171,172 with the grooves 192 are the same, except being mirror images of each other,

in that each has a machined faces 174 providing an air supply plenum chamber 175, air supply slots 176, an inner plenum chamber 177 and an air knife slit 78. These outer parts but against a plain innermost part 190. Thus two air knife slits are provided, supplied with the same air. The innermost part and the outer parts are flush across the slits and the inner most part is plain at the web passage. Insofar as no air can flow inwards from the slits, the flow is outwards with an expectation of closely similar flow in both the up- and down-stream directions. Should the pitch between slits must be significantly wider than the outer air-bearing surface a groove (or rebate) can be provided to guard against contact between the innermost part and the web.

Figure 11 shows a two slit arrangement incorporated into combined air knife and bearing similar to that in Figure 8. A central plate 501 performs the same function as the innermost part 190. However it has a grooved passage surface 502. This is to guard against contact between the web and the central plate. Two mirror image outer parts 503,504, conveniently 3D printed, are formed with a plenum space 505 against each side the central plate, slit formations 506 and outer grooves 507. Air is supplied to the plenum spaces in use to separate liquid supplied to outer passages 508,509 and providing bearing action via nozzles 510.

CLAIMS:

1. Liquid removal apparatus comprising
   - an air knife having:
     - a pair of opposed members having opposed surfaces, each having at least one slit or linear array of apertures through which air can be blown, for blowing a liquid from the opposite surfaces of a board, sheet or web passing between the opposed members, in a passage direction;

wherein there is provided:

   - at least one elongate groove or rebate in at least one of the opposed surfaces of the pair of opposed members, the groove or rebate being up- or down-stream, in respect of the passage direction, of the respective slit or linear array of apertures.

2. Liquid removal apparatus as claimed in claim 1, wherein:
   - the air knife has a length transversely of the passage direction and is narrow in the passage direction compared with its length and
   - the or each elongate groove or rebate is at least substantially parallel to the respective slit or linear array of apertures.

3. Liquid removal apparatus as claimed in claim 1 or claim 2, wherein the said at least one elongate groove is provided and the respective opposed surface extends beyond the groove at least substantially flush with itself at the respective slit or linear array of apertures.

4. Liquid removal apparatus as claimed in claim 1 or claim 2 or claim 3, wherein the at least one elongate groove is provided as an upstream and/or a downstream groove opposite a plain opposed member.

5. Liquid removal apparatus as claimed in claim 1 or claim 2 or claim 3, wherein the at least one elongate groove is provided as a single pair upstream or a single pair downstream of the slits or apertures.

6. Liquid removal apparatus as claimed in claim 1 or claim 2 or claim 3, wherein the at least one elongate groove is provided as single opposed elongate pairs of grooves both upstream and downstream of the slits or apertures.

7. Liquid removal apparatus as claimed in claim 1 or claim 2 or claim 3, wherein the at least one elongate groove is provided as multiple pairs of opposed grooves both upstream and downstream of the slits or apertures.

8. Liquid removal apparatus as claimed in claim 6 or claim 7, wherein the opposed pairs are aligned opposite each other.

9. Liquid removal apparatus as claimed in claim 6 or claim 7, wherein the opposed pairs are staggered opposite each other.

10. Liquid removal apparatus as claimed in in anyone of claims 1 to 9, wherein separation of the opposed surfaces is greater outwards of the or each groove than inwards thereof, whereby air flow is slower in use outwards of the groove(s) than inwards, between the groove(s) the slit or aperture line.

11. Liquid removal apparatus as claimed in in anyone of claims 1 to 5, wherein the said at least one elongate rebate is provided and the or each rebate extends outwards remotely from the respective slit or linear array of apertures to an edge of the rebated opposed member.

12. Liquid removal apparatus as claimed in claim 11, wherein the or each rebate is of constant depth or of varying depth across its width.

13. Liquid removal apparatus as claimed in claim 11, wherein the width of the rebate is greater than the extent of the opposed surface between the rebate and or each the slit or linear array of apertures.

14. Liquid removal apparatus as claimed in any preceding claim, wherein the presence of a groove or rebate in one of the opposed surfaces of one of the opposed members is mirrored by the presence of the same in like position in the opposed surface of the other opposed member, whereby in use the web will be acted on similarly on both sides.

15. Liquid removal apparatus as claimed in any preceding claim, wherein the opposed surfaces are chamfered at their remote edges.

16. Liquid removal apparatus as claimed in any preceding claim, wherein the opposed members are at least substantially planar.

17. Liquid removal apparatus as claimed in any one of claims 1 to 15 wherein one opposed member is curved, preferably at least partially circularly cylindrically, and is plain with neither rebate nor groove.

18. Liquid removal apparatus as claimed in any one of claims 1 to 15 wherein one opposed member is curved, preferably at least partially circularly cylindrically, and is plain with a groove on either side of a slit.

19. Liquid removal apparatus as claimed in claim 17 or claim 18, including three passages, one for supplying air to its slit and two for supplying respective liquids to nozzles in the opposed member up- and down-stream of the slit.

20. Liquid removal apparatus as claimed in claim 17, claim 18 or claim 19, wherein the curved member is a bearing member inside the curvature of a web passing over it.

21. Liquid removal apparatus as claimed in any one of claims 17 to 20, wherein the other opposed member is complementarily curved.

22. Liquid removal apparatus as claimed in any preceding claim, wherein the opposed members are each comprised of two parts, complementarily machined at a joint faces to provided their slit and fixed together to provide one of the opposed members.

23. Liquid removal apparatus as claimed in any preceding claim, wherein one or each opposed surface has at least two, slits or aperture lines, preferably with plain surface portions provided between slits or aperture lines, with the said groove(s) / rebate(s) provided outwards of the said at least two slits / aperture lines

24. Liquid removal apparatus as claimed in claims 23, wherein the opposed members are each comprised of three parts, complementarily machined at joint faces and fixed together to provide one of the opposed members,

- with a plain or grooved central one of the parts and two grooved or rebated ones of the parts, the parts being machined at their joints to provide one said slit between the central part and one of the grooved or rebated parts and another said slit between the central part and the other of the grooved or rebated parts and
- the central part being flush with the other parts between the slits.

25. Liquid removal apparatus as claimed in claims 21, wherein the opposed members are each comprised of one part or three parts, complementarily machined at joint faces and fixed together to provide one of the opposed members,

- with a plain or grooved central strip of the one or a central one of the parts where three are provided, between the two lines of apertures and two grooved or rebated outer regions and
- the central strip being flush with the outer regions.

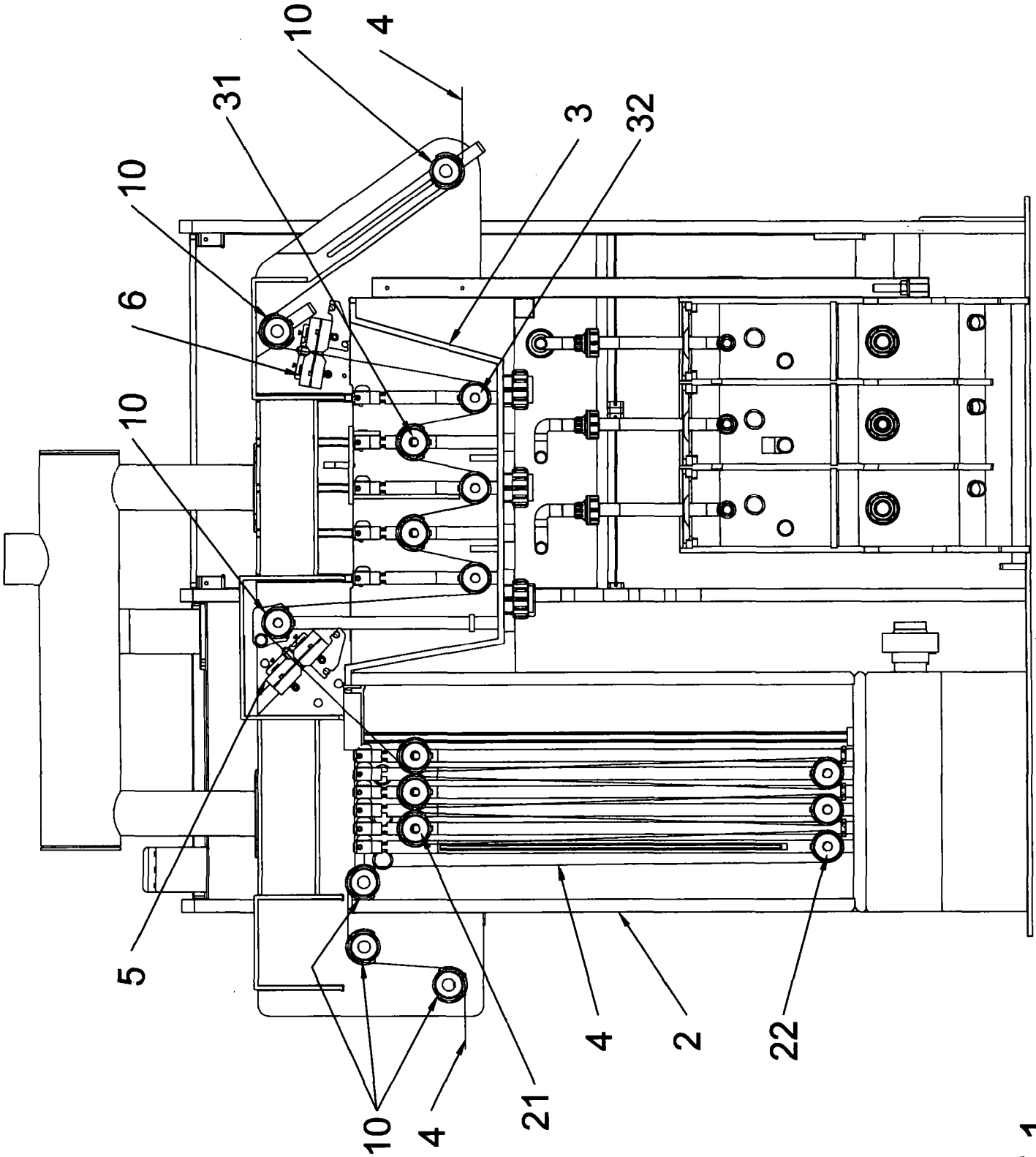

FIGURE 1

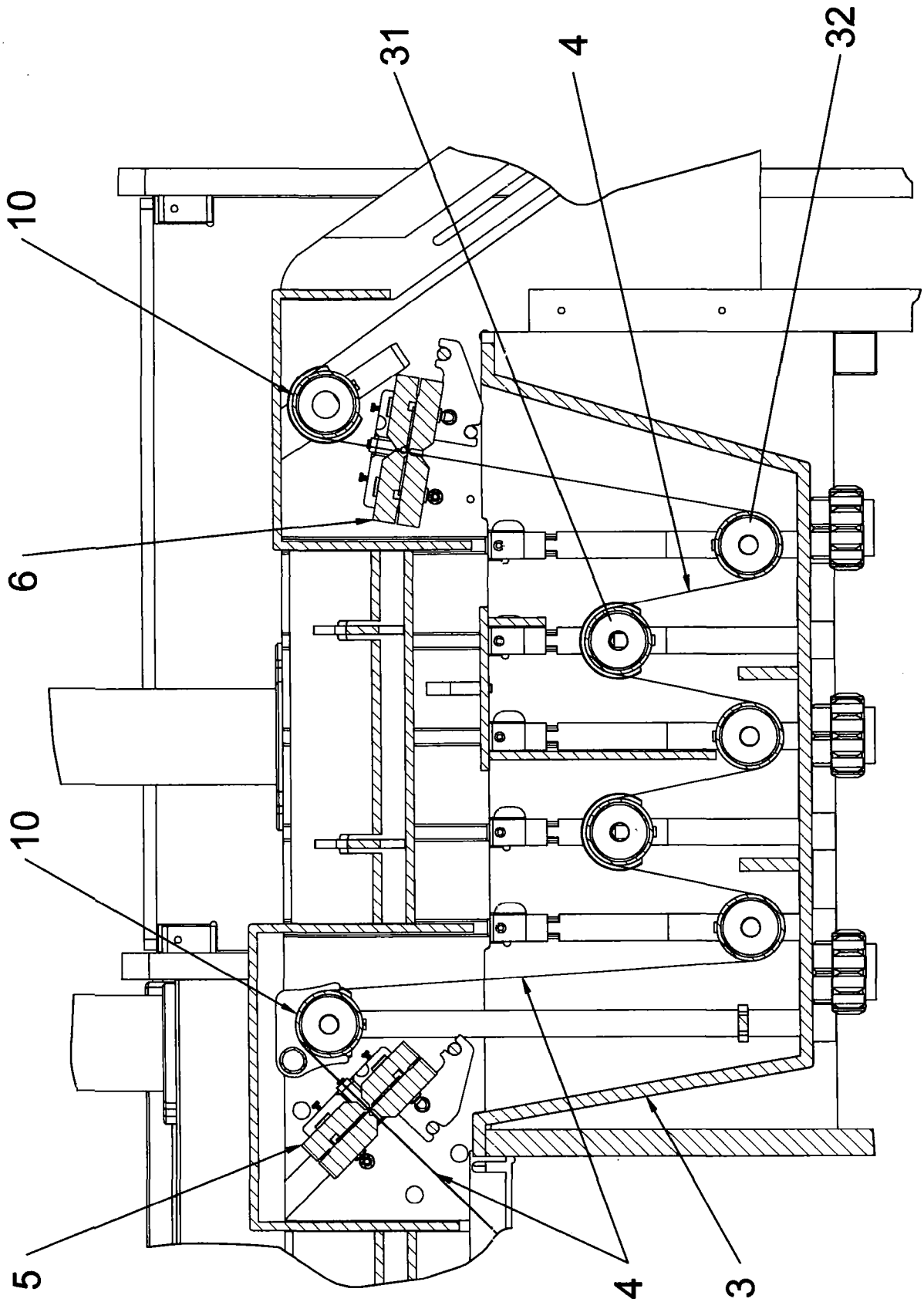

FIGURE 2

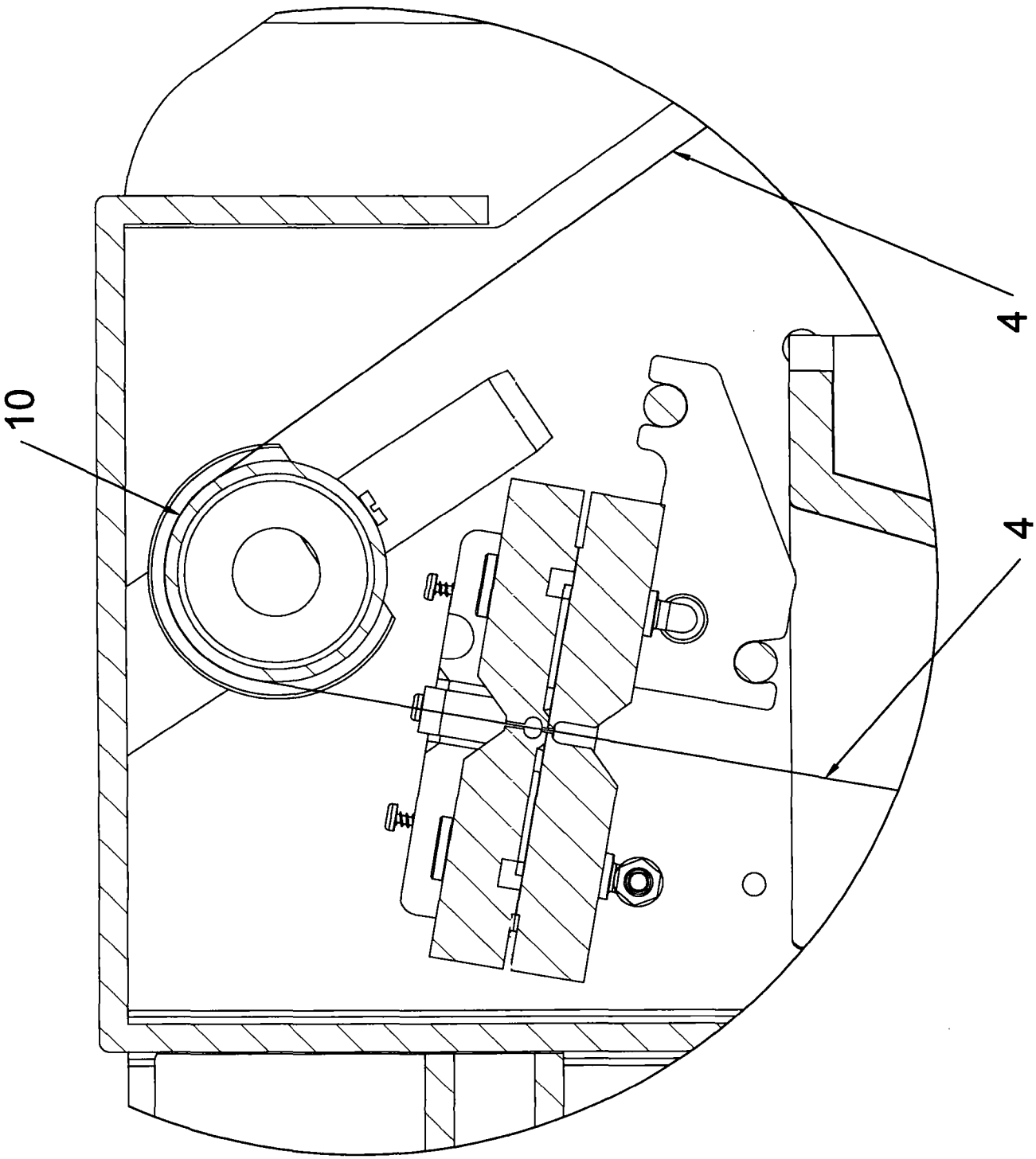

FIGURE 3

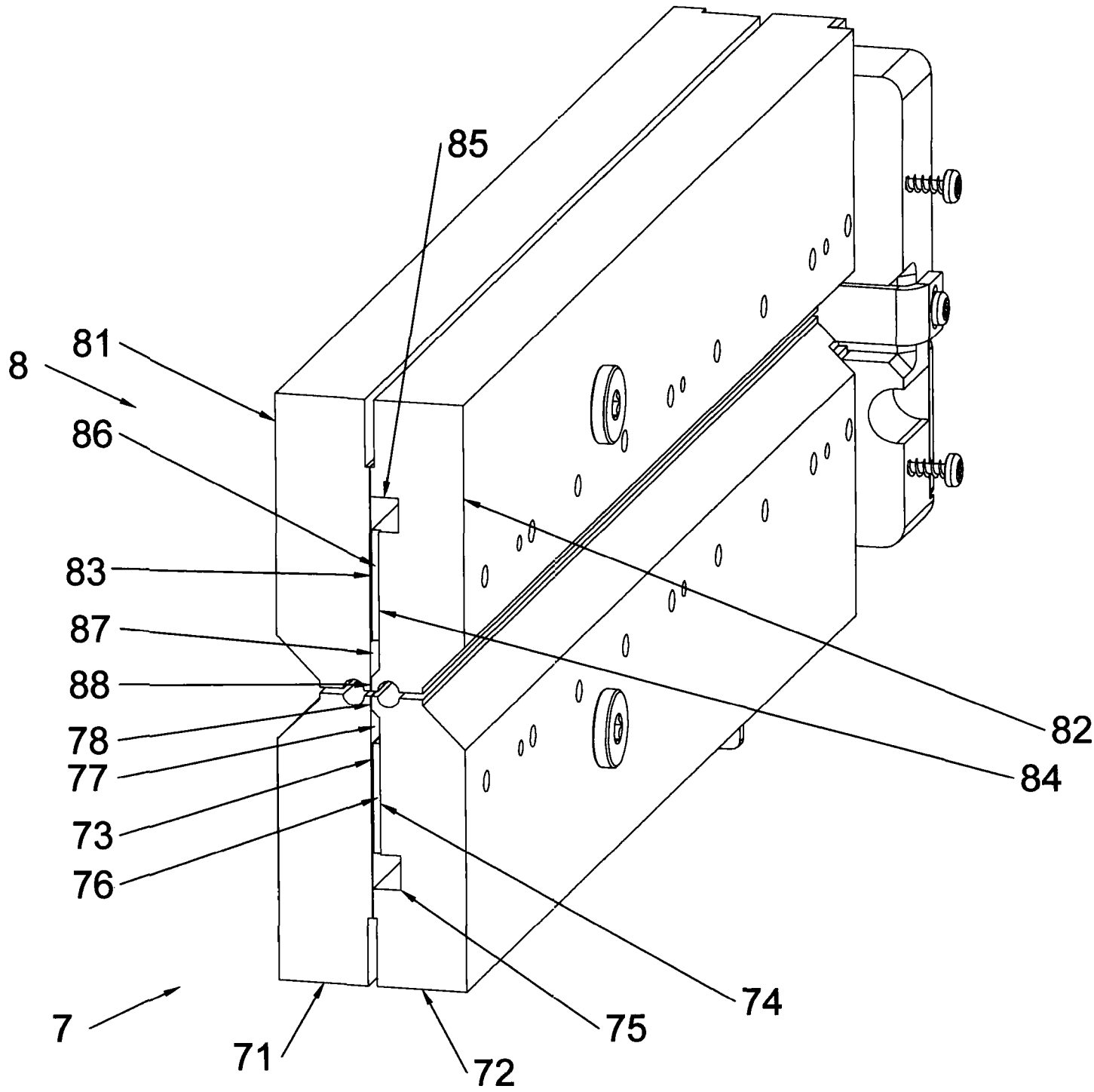

FIGURE 4

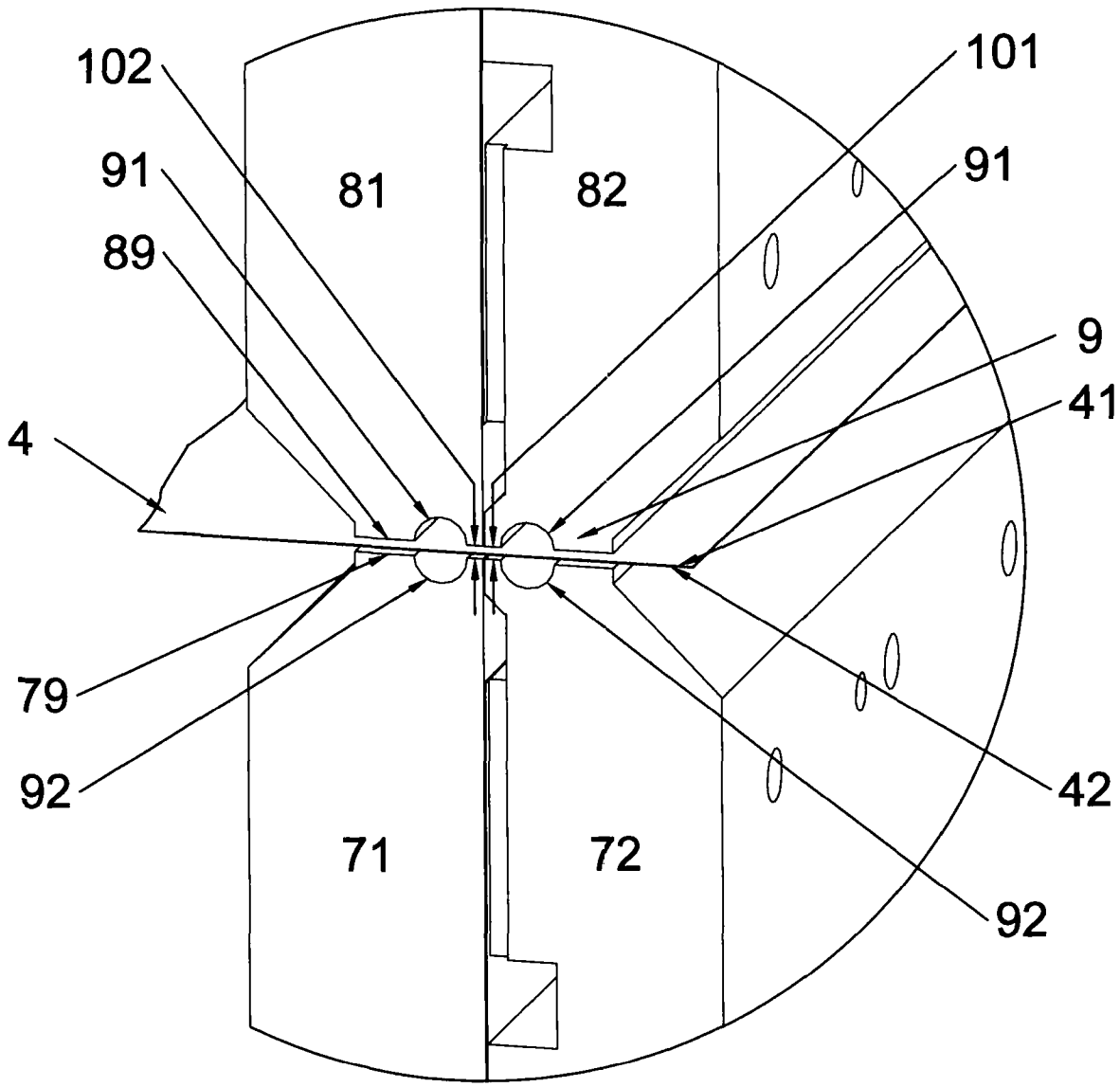

FIGURE 5

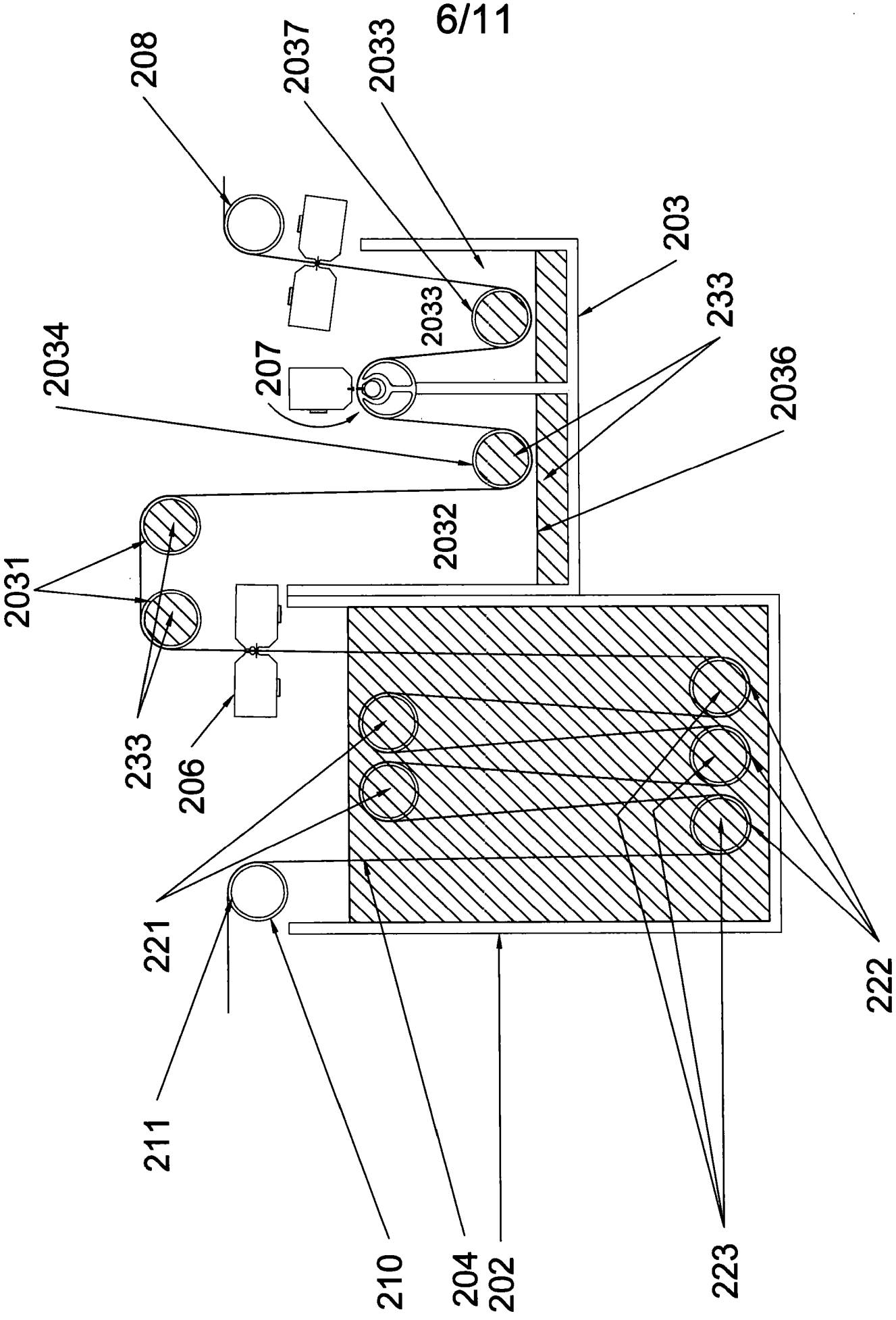
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FIGURE 6

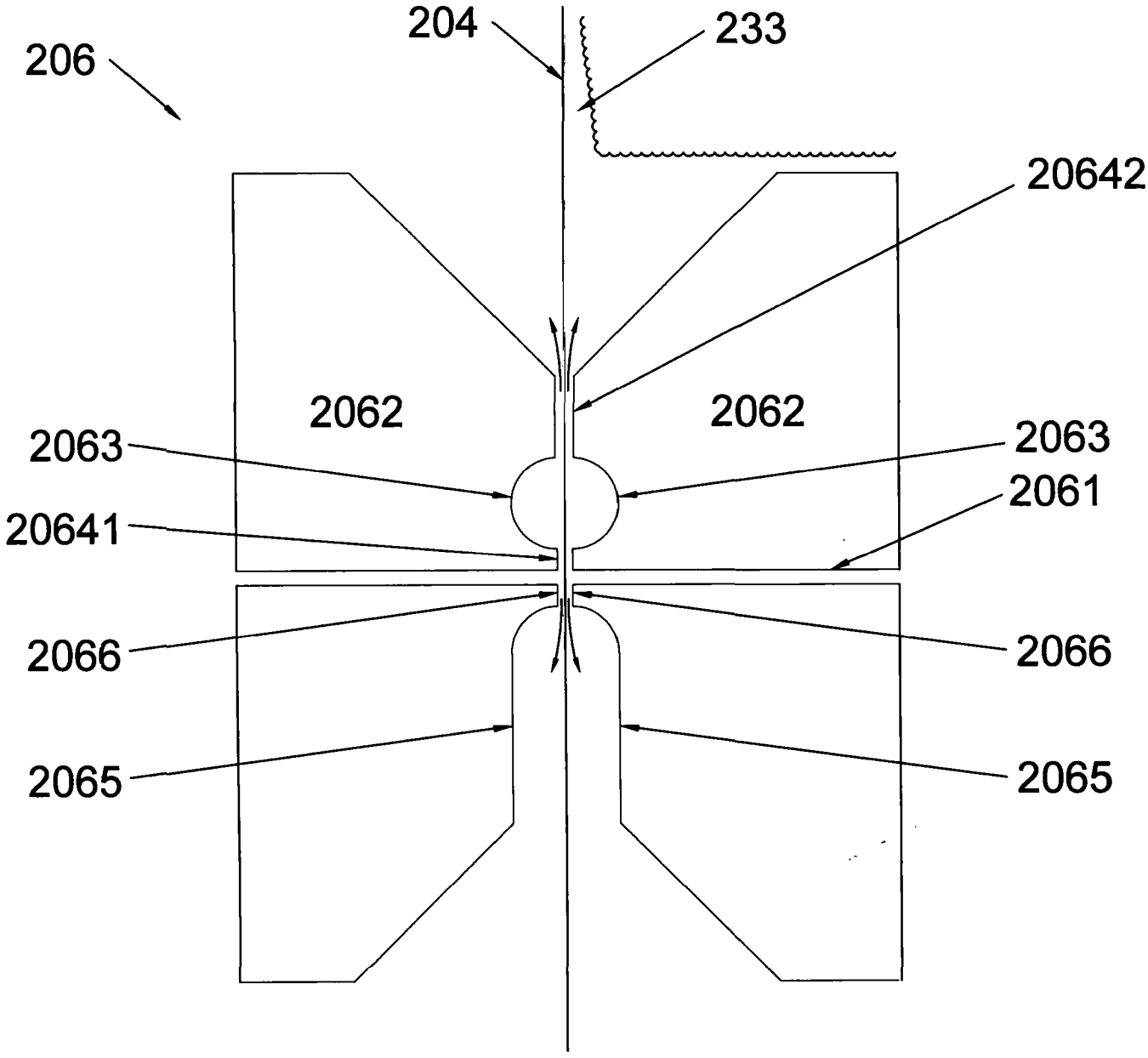
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FIGURE 7

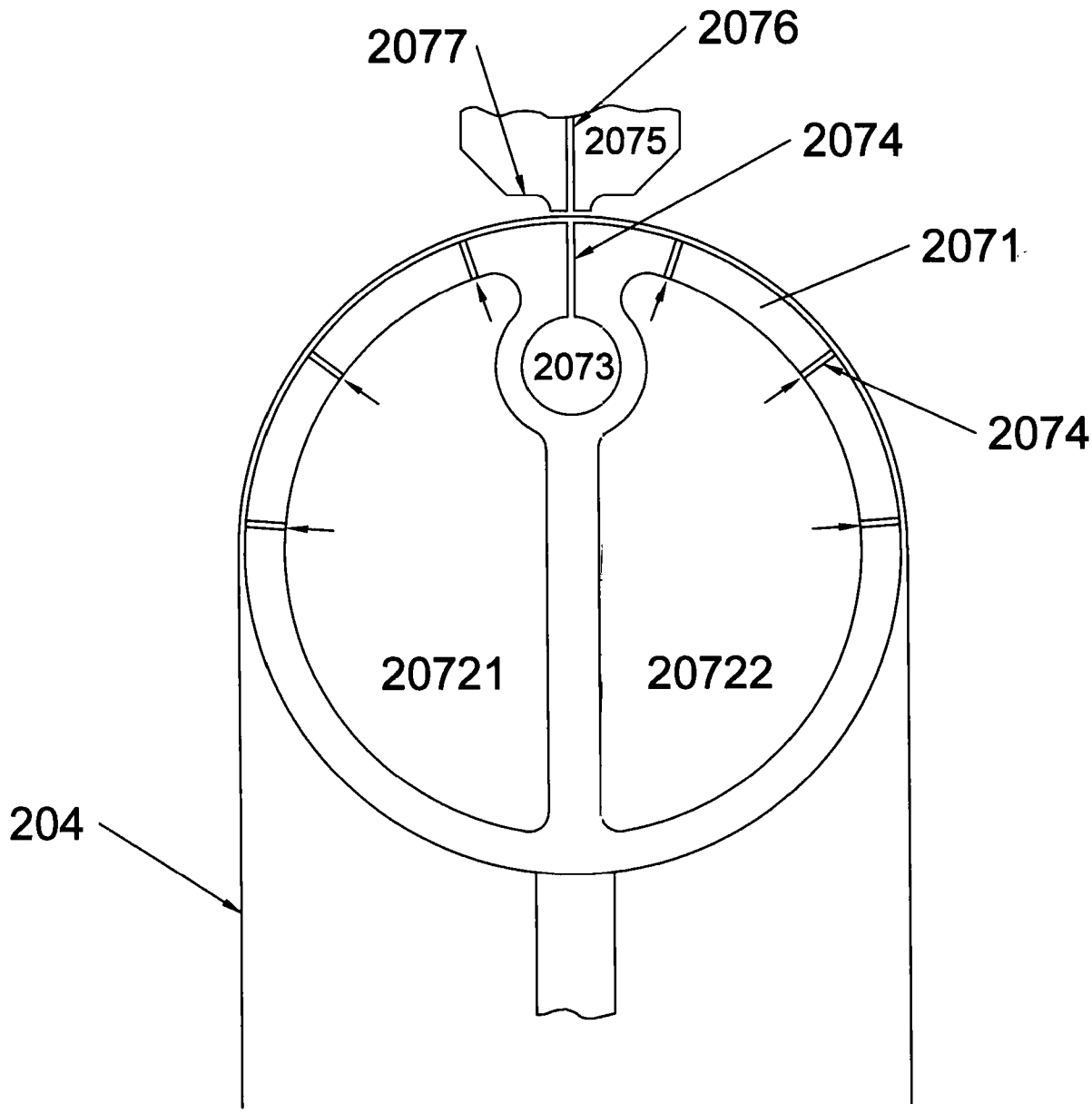

FIGURE 8

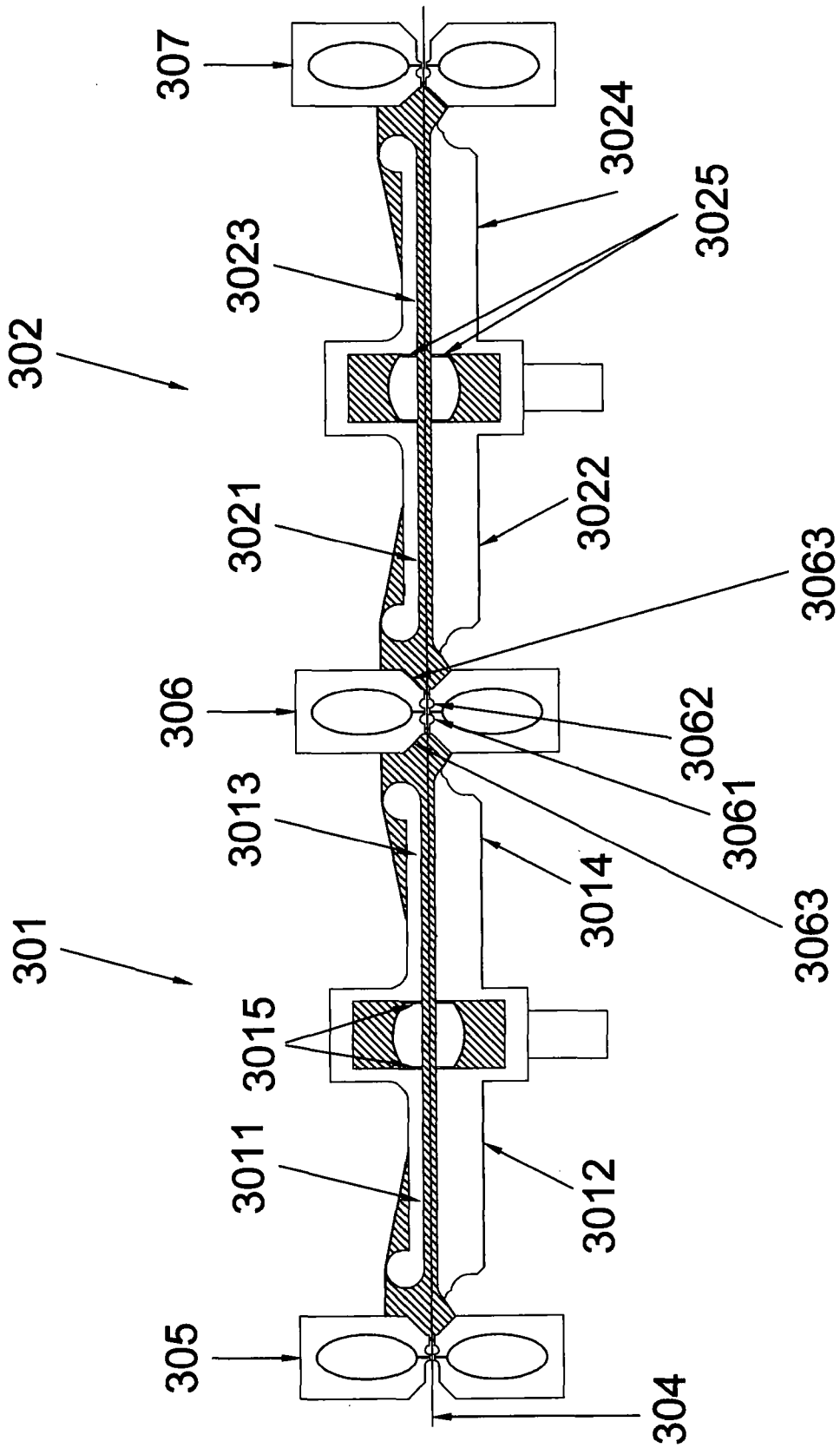
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FIGURE 9

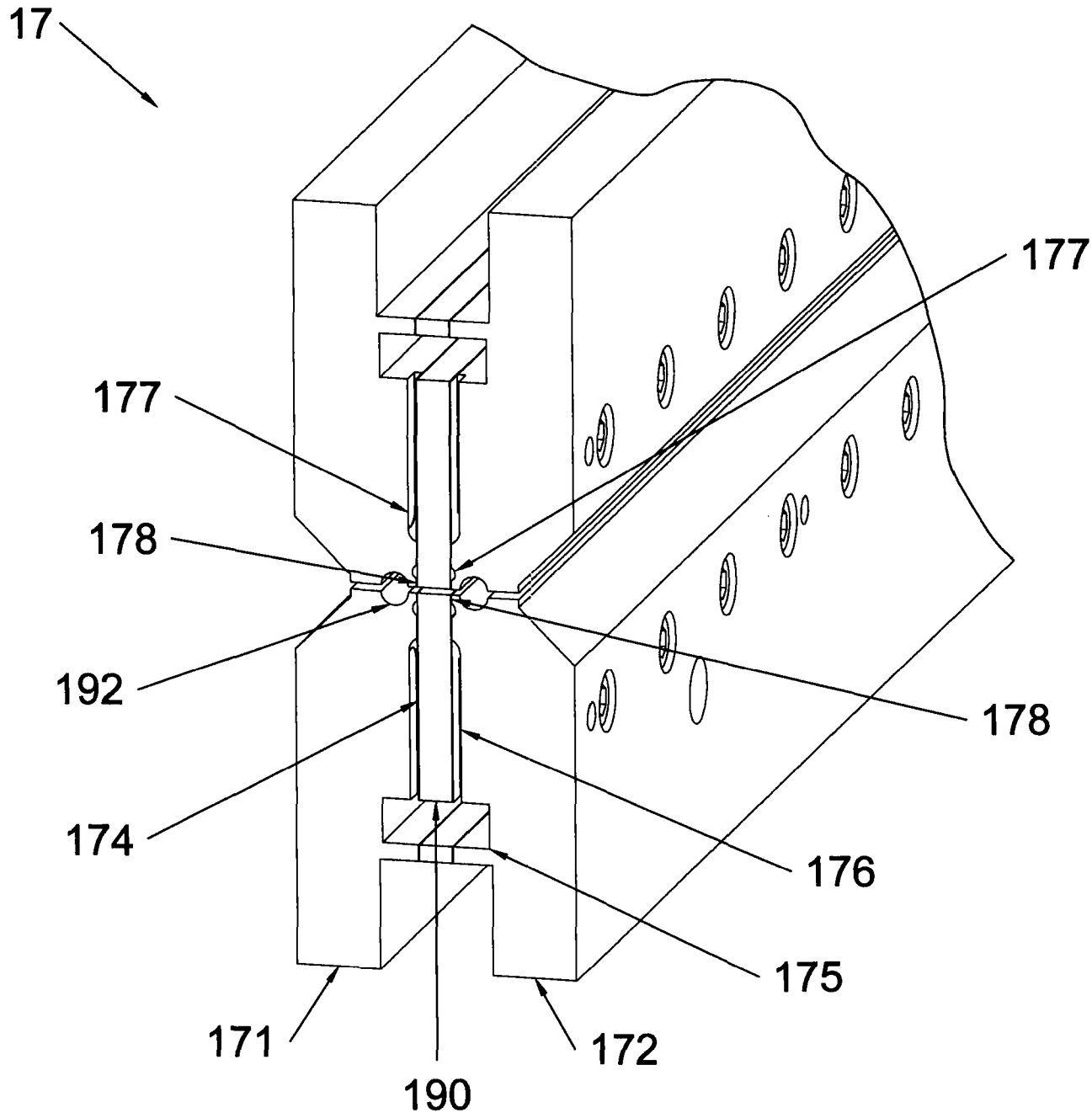

FIGURE 10

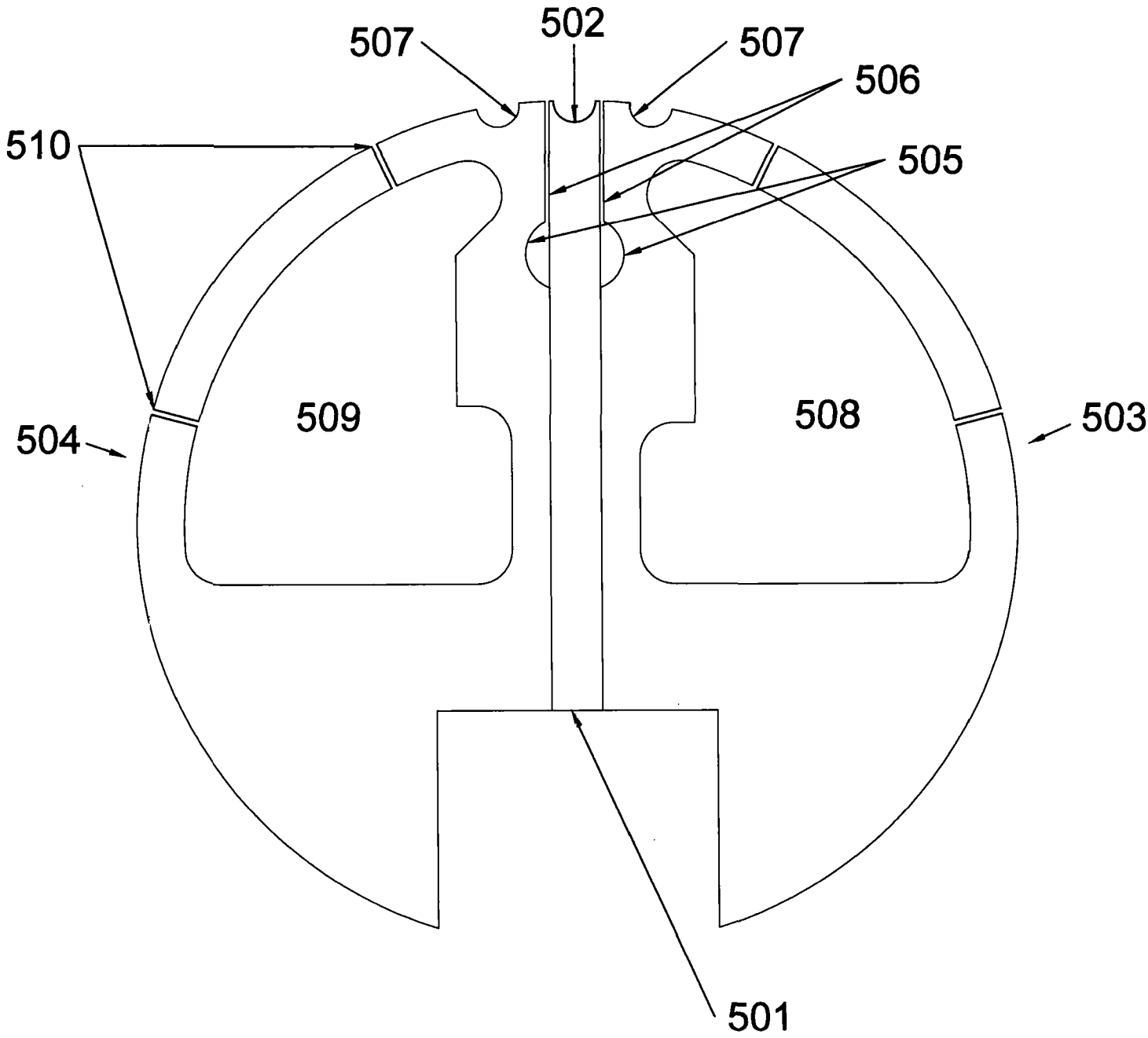

FIGURE 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/053395

A. CLASSIFICATION OF SUBJECT MATTER
INV. B08B5/02 F26B21/00 B05B1/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B08B F26B B05B B65H D21H B21B B05C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 423 768 A (GOFF) 8 July 1947 (1947-07-08) column 1, line 1 - line 12 column 1, line 45 - column 2, line 2 column 2, line 37 - line 50 column 3, line 34 - line 75 claims figures ----- -/--	1-5,8, 10-16, 19,22, 24,25

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 January 2017	13/02/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	van der Zee, Willem

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/244925 A1 (SHIN) 9 October 2008 (2008-10-09) abstract paragraph [0003] paragraph [0040] paragraph [0042] - paragraph [0044] paragraph [0062] - paragraph [0065] claims figures	1-5,7,8, 10-16

X	US 4 551 926 A (AUFDERHAAR) 12 November 1985 (1985-11-12) abstract column 2, line 59 - column 3, line 35 claims figures	1-6,8,9, 14-16

X	CH 687 957 A5 (R. SCHNEIDER CONSULTING DEVELOPMENT) 15 April 1997 (1997-04-15) abstract column 4, line 18 - column 5, line 28 column 7, line 35 - column 8, line 18 claims figures	1,2, 11-18, 20-23

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X	WO 2008/084224 A2 (LYMN) 17 July 2008 (2008-07-17)	1,2, 11-14,16
A	abstract page 13, line 26 - page 14, line 2 claims figures & GB 2 459 055 A (LYMN PETER PHILIP ANDREW [GB]) 14 October 2009 (2009-10-14) cited in the application	15

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International application No
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