(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 October 2014 (16.10.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/167366 A1

(51) International Patent Classification:
C25D 17/00 (2006.01) *C25D 7/10* (2006.01)
C25D 5/02 (2006.01) *C25D 17/06* (2006.01)
C25D 5/08 (2006.01) *F16C 33/00* (2006.01)
C25D 7/04 (2006.01)

(21) International Application Number:
PCT/GB2014/051166

(22) International Filing Date:
14 April 2014 (14.04.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1306710.3 12 April 2013 (12.04.2013) GB

(71) Applicants: **MAHLE INTERNATIONAL GMBH** [DE/DE]; Pragstrasse 26-46, 70376 Stuttgart (DE). **MAHLE ENGINE SYSTEMS UK LTD** [GB/GB]; 2 Central Park Drive, Rugby, Warwickshire CV23 0WE (GB).

(72) Inventors: **FORDER, Jon**; 16 Acacia Road, Rugby, Warwickshire CV21 2QT (GB). **CAREY, John**; 77 Little Meadow, Great Oakley, Corby, Northamptonshire NN18 8JP (GB).

(74) Agent: **HARRISON GODDARD FOOTE LLP**; Belgrave Hall, Belgrave Street, Leeds, Yorkshire LS2 8DD (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: ELECTROPLATING RACK

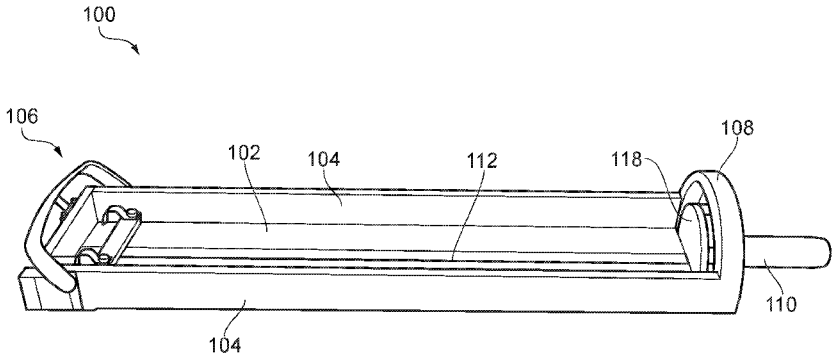

FIG. 1A

(57) Abstract: An electroplating rack for holding a plurality of sliding bearing shells whilst a coating is electroplated onto their concave inner surfaces, comprising an end bracket, wherein the end bracket comprises a liquid supply conduit for receiving a flow of liquid into the plating rack along the concave inner faces of the bearing shells; and, an electroplating bath for such an electroplating rack.

WO 2014/167366 A1

ELECTROPLATING RACK

The present invention relates to an electroplating rack and electroplating bath for use in electroplating the concave surfaces of hollow cylindrical and part-cylindrical sliding bearing lining shells, and in particular half bearing shells and plain bushes.

BACKGROUND

Half bearing lining shells are commonly used in crankshaft journal bearings of internal combustion engines, are substantially semi-cylindrical in shape, and may be provided with one or more generally semi-annular thrust flanges at the axial ends of the bearing shell before being assembled into the bearing of an engine. Plain bushes are hollow cylindrical bearing linings. In use, a pair of half bearing lining shells, or a plain bush, are used to support the journal of a shaft (e.g. a rotatable engine crankshaft).

The concave bearing surfaces of sliding bearings generally have a layered construction. The layered construction frequently comprises: a strong backing material, for example steel, of a thickness in the region of about 1 mm or more; a layer of a first bearing material (the "lining layer"), for example a copper-based material (e.g. bronze) or aluminium-based material, which is adhered to the backing and of a thickness generally in the range from about 0.1 to 0.5 mm (e.g. 300 μm of copper-based alloy of 8 %wt Sn, 1 %wt Ni, and balance of Cu, apart from incidentally impurities); and, a layer of a second bearing material (the "overlay layer") of a metallic or polymer-based bearing material adhered to the surface of the lining layer.

Such metallic layers are commonly deposited by electroplating coatings, in which a plurality of half bearing shells are held on a frame-like plating rack, before being immersed in a bath of electroplating solution (electrolyte). The plating rack has an electrically insulating front plate with an elongate slot running along its length, and the half bearing shells are loaded along the length of the insulating plate, by standing their circumferential end faces (parting faces) onto the insulating plate, equally spaced to either side of the slot, before being clamped into place by a bearing clamping mechanism. Such a plating rack is disclosed in US3779890, and a related rack for a single bearing shell is disclosed in US2500206.

When submerged in the electroplating solution, the bearing shells are electrically connected as a cathode, and at least one elongate anode is provided parallel to, and spaced apart from, the elongate slot, most or all of which is submerged in the plating solution. An electric

field is provided between the anode and the cathodic bearing shells, with the electric field established in the plating solution and passing through the elongate slot, such that the elongate slot may be regarded as a virtual anode, that is substantially at an equipotential along its submerged length, apart from at the ends. The bearing shells are aligned on the insulating plate symmetrically with their semicircular axial edges in abutment, with the bearing shells being curved about a common axis of curvature, which is approximately collinear with the centre-line of the elongate slot, which provides an electric field that is substantially uniform across their concave inner surfaces to facilitate a uniform electroplating deposition rate.

At high current densities, the rate at which electroplating ions are deposited is limited by the rate at which the ions are replenished in the electroplating solution adjacent the deposition surface. To enhance the rate of replenishment against the plating surface, it is known to agitate the electroplating solution or to cause relative movement of the bearing shells and the solution. A uniform rate of replenishment is required to all parts of the concave inner surface of the bearing shells to avoid inhomogeneous rates of deposition on the surface. However, known approaches provide only a limited and/or inhomogeneous enhancement of the replenishment of the solution against the plating surface. In one approach, a plurality of plating racks are each suspended from a carousel-like mechanism, and drawn around within a large tank of solution: such an arrangement has a large footprint, requires a large volume of solution, and is expensive. In another approach, a plating rack is rotated about the axis of the sliding bearings. In further approaches, the solution in the bath is agitated around the plating rack by pumping the solution to cause circulation, or by bubbling gas through the solution. In a yet further approach, the plating rack is moved axially through a few centimetres with a reciprocating motion.

SUMMARY OF THE DISCLOSURE

According to the present invention there is provided
an electroplating rack for holding a plurality of sliding bearing shells whilst a coating is electroplated onto their concave inner surfaces, comprising
an end bracket,
wherein the end bracket comprises a liquid supply conduit for receiving a flow of liquid into the plating rack along the concave inner faces of the bearing shells.

According to a second aspect of the present invention, there is provided

an electroplating bath for receiving an electroplating rack according to the first aspect, comprising

a bath for containing electroplating solution and having a liquid supply outlet configured to mate with the liquid supply conduit of the rack, and

a pump configured to pump electroplating solution out through the liquid supply outlet.

Advantageously, the liquid supply conduit enables a complete exchange of the electroplating solution within the plating rack, as fresh electroplating solution enters through the end bracket, flows generally axially along the concave inner faces of the bearing shells, and exits through the elongate slot. This may enable an enhanced replenishment rate, and so enable an enhanced rate of deposition. Further, the liquid supply conduit may enable an enhanced uniformity of replenishment compared with known methods.

The liquid inlet may comprise a coupling pipe that projects from the end bracket, for docking with a liquid supply outlet of an electroplating bath. Advantageously the coupling pipe enables the plating rack to be conveniently engaged with a supply of electroplating solution, by engaging with a corresponding supply outlet in the electroplating bath.

The coupling pipe has a terminal region with an open end and the terminal region may have an external profile that tapers down in width towards the open end. Advantageously a coupling pipe having a tapered profile can form a good fluid connection with a correspondingly tapered feature within the supply outlet, and facilitates alignment of the coupling pipe when it is received into the supply outlet.

The end bracket may comprise an internal face, and the liquid supply conduit may have an internal port that is level with the internal face. Advantageously, an abrupt end to the liquid supply conduit induces turbulent flow in the electroplating solution entering into the plating rack, preventing the formation of a vorticular flow (i.e. a screw-like flow) at the inlet, which could establish an inhomogeneous pattern of replenishment of plating solution across the deposition surface, producing inhomogeneous deposition rates. Further, the abrupt inner end of the liquid supply conduit enhances mixing of the electroplating solution within the plating rack.

The rack may comprise a bearing clamping mechanism configured to clamp a stack of bearing shells against the end bracket, with the axial edges of adjacent bearing shells in abutment.

The electroplating rack may comprise an electrically insulating plate having an elongate slot extending along the plate, wherein the rack is configured to hold a plurality of hollow semi-cylindrical sliding bearing shells symmetrically arrayed along the insulating plate with circumferential end faces of each bearing shell contacting the insulating plate on opposite sides of the elongate slot, wherein the liquid supply conduit is configured for receiving a flow of liquid into the plating rack between concave inner faces of the bearing shells and the insulating plate. Advantageously, this arrangement enables a rapid and relatively uniform replenishment of the solution adjacent the plating surface, as the plating solution exits the plating rack through the elongate slot.

The electroplating rack may be configured to hold a plurality of substantially cylindrical sliding bearing shells axially arrayed along the rack, wherein the end section is connected to a further end section, and the further end section comprises a liquid overflow aperture for receiving a flow of liquid out of the plating rack. Advantageously, this arrangement enables a rapid and relatively uniform replenishment of the solution adjacent the plating surface, with the plating solution exiting through the upper end of the stack of cylindrical bearing shells.

The electroplating bath may comprise a support for supporting the plating rack, which comprises a rack clamp, for clamping the liquid supply conduit into the liquid supply outlet. Advantageously, the provision of the rack clamp enables a higher pressure liquid supply to be connected to the liquid supply conduit, without the plating rack becoming detached from the liquid supply outlet.

The electroplating bath may comprise a plating rack according to the first aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

- Figure 1A shows a plating rack according to the present invention, for use in electroplating half bearing shells;
- Figure 1B shows an enlarged view of an end of the plating rack of Figure 1A;
- Figure 1C shows a cross-sectional view of the plating rack of Figure 1A in use;
- Figures 2A and 2B show schematic front and side views of the plating bath according to the present invention;
- Figure 2C shows the top of a plating bath according to the present invention;

- Figure 2D shows a view down into the bottom of the bath of Figure 2C, when empty of electroplating solution; and
- Figure 3 shows a plating rack according to the present invention, for use in electroplating plain bushes.

DETAILED DESCRIPTION

In the described embodiments, like features have been identified with like numerals, albeit in some cases having increments of integer multiples of 100. For example, in different figures, 100 and 300 have been used to indicate a plating rack.

Figure 1A shows a plating rack according to the present invention, Figure 1B shows an enlarged view of the lower end section, and Figure 1C shows a cross-sectional view of the plating rack in use perpendicular to the elongate slot.

The plating rack 100 comprises an electrically insulating front plate 102, sides 104, an upper end section, a bearing clamping mechanism 106 at the upper end, a semicircular lower end section 108, and a coupling pipe 110 (e.g. liquid supply conduit). The insulating plate 102 has an elongate slot 112 running centrally along its length.

In use, semi-cylindrical bearing shells 114 are loaded along the length of the plating rack 100, with their circumferential end faces 116 contacting the front plate 102, symmetrically arranged on either side of the elongate slot 112, and between the sides 104. The stack of bearing shells 114 is held in place on the rack 100 with the bearing clamping mechanism 106, which clamps the bearing shells against the lower end section 108, and provides electrical contact to the stack of bearing shells. Once loaded, the plating rack 100 is lowered into an electroplating bath to submerge the bearing shells in electroplating solution, and the stack of bearing shells 114 are electrically connected as a cathode.

The coupling pipe 110 projects from the end section 108, and in use is coupled to a supply of plating solution (e.g. a solution of tin ions), which flows into the interior of the plating rack 100. The coupling pipe 110 is close to the common axis of the bearing shells 114 and the elongate slot 112, so that plating solution flowing into the plating rack 100 through the coupling pipe is away from the surface of the bearing shells and induces a generally axial flow within the plating rack. The end 118 of the coupling pipe 110 furthest from the end section 108 is conically tapered (i.e. reducing in width towards the open end), to facilitate connection of a supply pipe. On the inner surface (internal face) 120 of the end section 108,

the coupling pipe ends abruptly, i.e. level with the inner surface (not shown in Figure 1A), such that plating solution flowing into the plating rack 100 induces turbulence in the solution within the plating rack. The inner surface 120 is substantially perpendicular to the major axis of the bearing shells 114. The turbulence prevents a stable flow pattern in the solution within the plating rack (e.g. a vorticular flow) which could cause inhomogeneous replenishment, and also enhances mixing of the electroplating solution within the plating rack. As fresh electroplating solution flows into the plating rack 100 through the coupling pipe 110, displaced solution flows out of the plating rack through the elongate slot 112.

The clamped stack of bearing shells 114 are electrically biased as a cathode, and electrodes 122 (sometimes known as "robber electrodes" or "thieving electrodes") are provided behind the bearing shells, also with a negative bias. The robber electrodes 122 prevent, or substantially reduce, unwanted deposition of ions onto the convex outer surface of the bearing shells 114. An anode 224 is provided in front of, and spaced apart from, the elongate slot 112, and as the electric field is channelled through the elongate slot 112, a substantially equal electric field arises across the inner concave surface of the bearing shells 114.

Figures 2A and 2B schematically illustrate front and side views of an electroplating bath 250 into which an electroplating rack 100 has been received; Figure 2C shows the top of such an electroplating plating bath, and Figure 2D shows a view down into the bottom of the bath, when empty of electroplating solution.

The bath 250 comprises an open topped vessel 252 for receiving electroplating solution (electrolyte) 254, a frame 256 for supporting the electroplating rack 100 and incorporating a rack clamping mechanism 258, and an anode 224 (more than one anode may be provided, as shown in Figure 2C). A pumping mechanism (not shown) collects electroplating solution 254 and delivers it through a supply pipe 260 to the supply outlet 262. The supply outlet 262 has a conically tapered opening 264 configured to form a mating fit with the tapered end 118 of the coupling pipe 110 of the plating rack 100. In use, the electroplating rack 100 is lowered into the electroplating solution 254, with the tapered end 118 of the coupling pipe 110 received into the tapered opening 264 of the supply outlet 262. The rack is supported by the frame 256, with the bearing shells 114 submerged in the electroplating solution 254, and the rack being clamped in place by the rack clamping mechanism 258. A supply F1 of electroplating solution 254 is pumped out of the supply pipe 260, into the plating rack 100 through the coupling pipe 110, generating a turbulent, generally axial flow F2 within the rack, which exits F3 through the elongate slot 112 in the insulating front plate 102.

An electrical supply 266 is connected across the anode 224 and the cathodic bearing shells 114, which generates an electrical field arrangement within the plating rack that diverges radially from the elongate slot 112 to the inner concave surface of the sliding bearings 114, with a substantially uniform electric field across the concave inner plating surface. The current density at the inner concave surface governs the deposition rate of ions from the electroplating solution, and may be set to a higher level than in prior plating racks, due to the enhanced rate of replenishment of the electroplating solution that is provided by the axial supply in through the end section 108 and coupling pipe 110.

Although the Figures 1A to 2B illustrate plating racks for use in plating semi-cylindrical sliding bearing shells, the present invention also relates to plating racks for electroplating the concave inner surfaces of hollow cylindrical sliding bearing shells (e.g. plain bushes).

Figure 3 illustrates a plating rack 300 for use in plating a column-like stack of cylindrical bearing shells 314 aligned along a common axis, and clamped in the rack, which may be received into the electroplating bath 250 of Figures 2A to 2D. The plating rack 300 has a frame comprising an upper end section 374, a lower end section 308, and connecting rods 370 connecting between them. The plating rack also comprises a bearing clamping mechanism 306 that is connected to the upper end section 374, a central anode 324, a coupling pipe 310. In use, the stack of bearing shells 314 are clamped between the clamping mechanism 306 and the lower end section 308. The anode 324 is coaxial to the bearing shells 314, being supported at one end by the upper end section 374 and at the other end by the lower end section 308, being supported by a tripod-like frame 372 that is connected to the lower end section. A generally cylindrical cover (not shown) is also provided, which surrounds the bearing shells 314 and provides electrostatic shielding that reduces plating on the concave outer surfaces of the bearing shells, as well as protecting the bearing shells from becoming dislodged during immersion in the plating bath, and subsequent removal.

The coupling pipe 310 projects from the lower end section 308, and in use is coupled to a supply of plating solution (e.g. a solution of tin ions), which flows into the interior of the plating rack 300, within the bearing shells 314. The coupling pipe 310 is coaxial with the common axis of the bearing shells 314, so that plating solution flowing into the plating rack 300 through the coupling pipe is spaced apart from the surface of the bearing shells and induces a generally axial flow within the plating rack. The end 318 of the coupling pipe 310 furthest from the end section 308 is conically tapered (i.e. reducing in width towards the

open end), to facilitate connection of a supply pipe of the plating bath. On the inner surface 320 of the end section 308, the coupling pipe ends abruptly, such that plating solution flowing into the plating rack 300 induces turbulence in the solution within the plating rack. The turbulence prevents a stable flow pattern in the solution within the plating rack (e.g. a vorticular flow) which could cause inhomogeneous replenishment, and also enhances mixing of the electroplating solution within the plating rack. As fresh electroplating solution flows into the plating rack 300 through the coupling pipe 310, displaced solution flows out of the plating rack through openings 376 in the clamping mechanism 306, above the end of the stack of bearing shells 314.

The figures provided herein are schematic and not to scale.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of them mean "including but not limited to", and they are not intended to (and do not) exclude other moieties, additives, components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

CLAIMS

1. An electroplating rack for holding a plurality of sliding bearing shells whilst a coating is electroplated onto their concave inner surfaces, comprising
an end bracket,
wherein the end bracket comprises a liquid supply conduit for receiving a flow of liquid into the plating rack along the concave inner faces of the bearing shells.

2. An electroplating rack according to claim 1, wherein the liquid inlet comprises a coupling pipe that projects from the end bracket, for docking with a liquid supply outlet of an electroplating bath.

3. An electroplating rack according to claim 2, wherein the coupling pipe has a terminal region with an open end and the terminal region has an external profile that tapers down in width towards the open end.

4. An electroplating rack according to any one of claims 1, 2 or 3, wherein the end bracket comprises an internal face, and the liquid supply conduit has an internal port that is level with the internal face.

5. An electroplating rack according to any preceding claim, wherein the rack comprises a bearing clamping mechanism configured to clamp a stack of bearing shells against the end bracket, with axial edges of adjacent bearing shells in abutment.

6. An electroplating rack according to any preceding claim, wherein the rack comprises an electrically insulating plate having an elongate slot extending along the plate, wherein the rack is configured to hold a plurality of hollow semi-cylindrical sliding bearing shells symmetrically arrayed along the insulating plate with circumferential end faces of each bearing shell contacting the insulating plate on opposite sides of the elongate slot, and wherein the liquid supply conduit is configured for receiving a flow of liquid into the plating rack between concave inner faces of the bearing shells and the insulating plate.

7. An electroplating rack according to any one of claims 1 to 5, wherein the electroplating rack is configured to hold a plurality of substantially cylindrical sliding bearing shells axially arrayed along the rack, wherein the end section is connected to

a further end section, and the further end section comprises a liquid overflow aperture for receiving a flow of liquid out of the plating rack.

8. An electroplating bath for receiving an electroplating rack according to any preceding claim, comprising
a bath for containing electroplating solution and having a liquid supply outlet configured to mate with the liquid supply conduit of the rack, and
a pump configured to pump electroplating solution out through the liquid supply outlet.

9. An electroplating bath according to claim 8, wherein the electroplating bath comprises a support for supporting the plating rack, which comprises a rack clamp, for clamping the liquid supply conduit into the liquid supply outlet.

10. An electroplating bath according to claims 8 or 9, wherein the electroplating bath comprises an electroplating rack according to any one of claims 1 to 7.

11. An electroplating rack substantially as hereinbefore described with reference to the accompanying description and any one of Figures 1A to 2B and 3.

12. An electroplating bath substantially as hereinbefore described with reference to the accompanying description and any one of the Figures 1C to 2D.

13. A method of electroplating a bearing shell substantially as hereinbefore described with reference to the accompanying description and any one of the Figures.

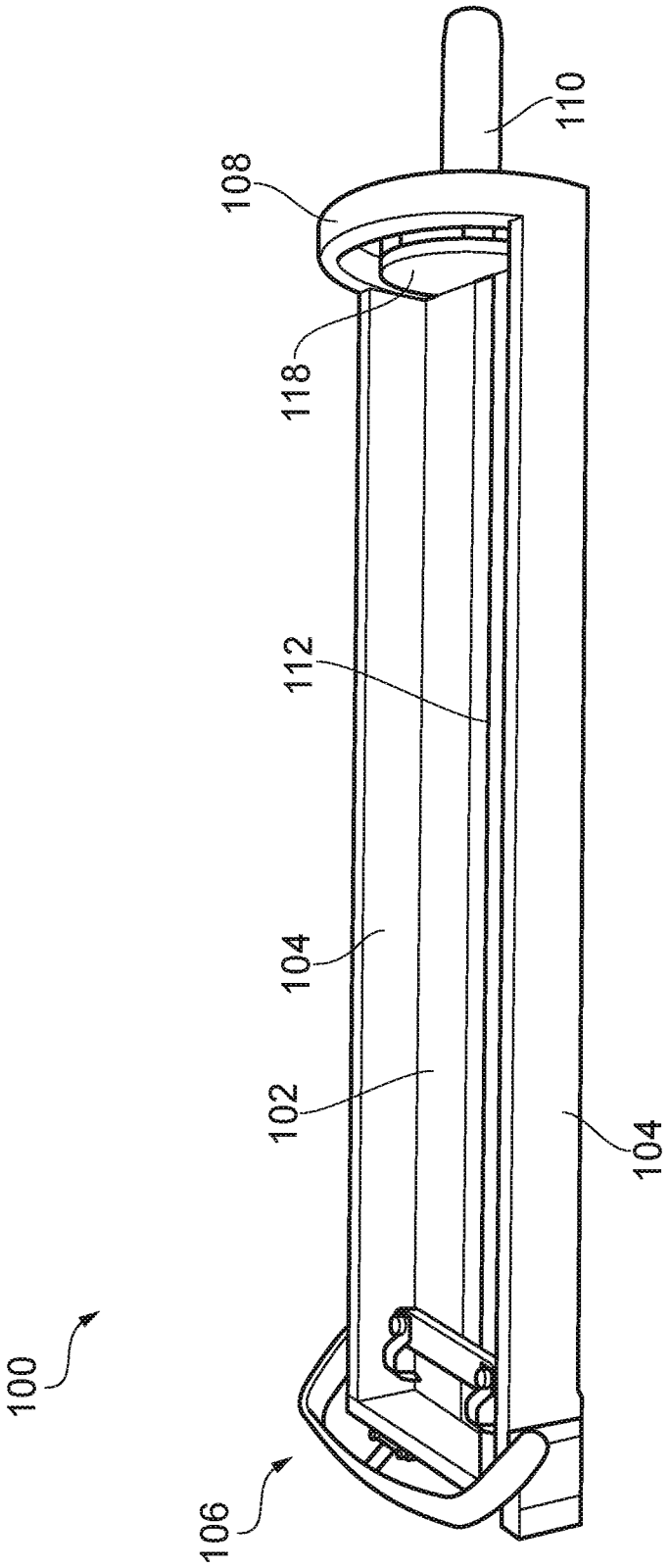

FIG. 1A

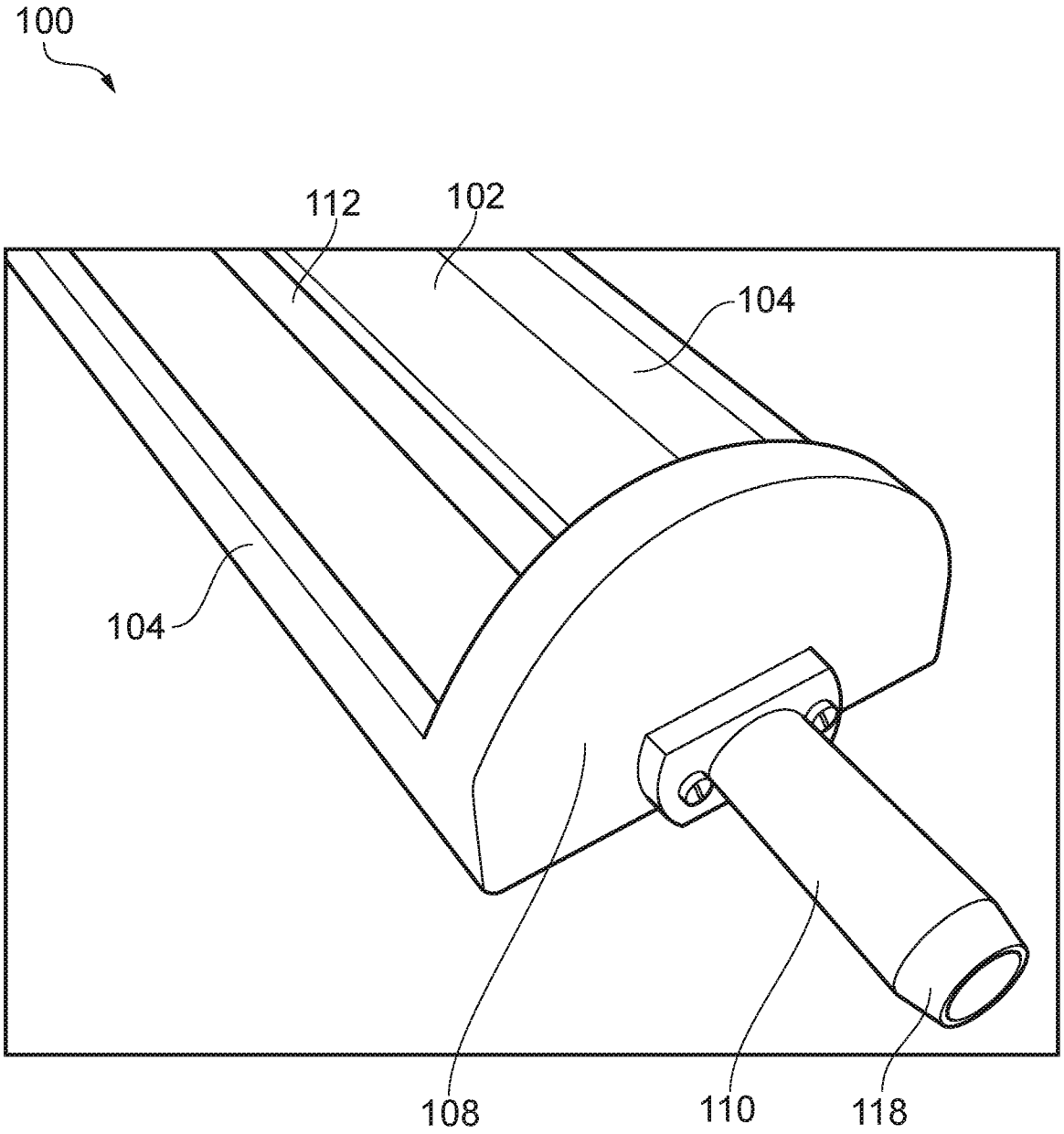

FIG. 1B

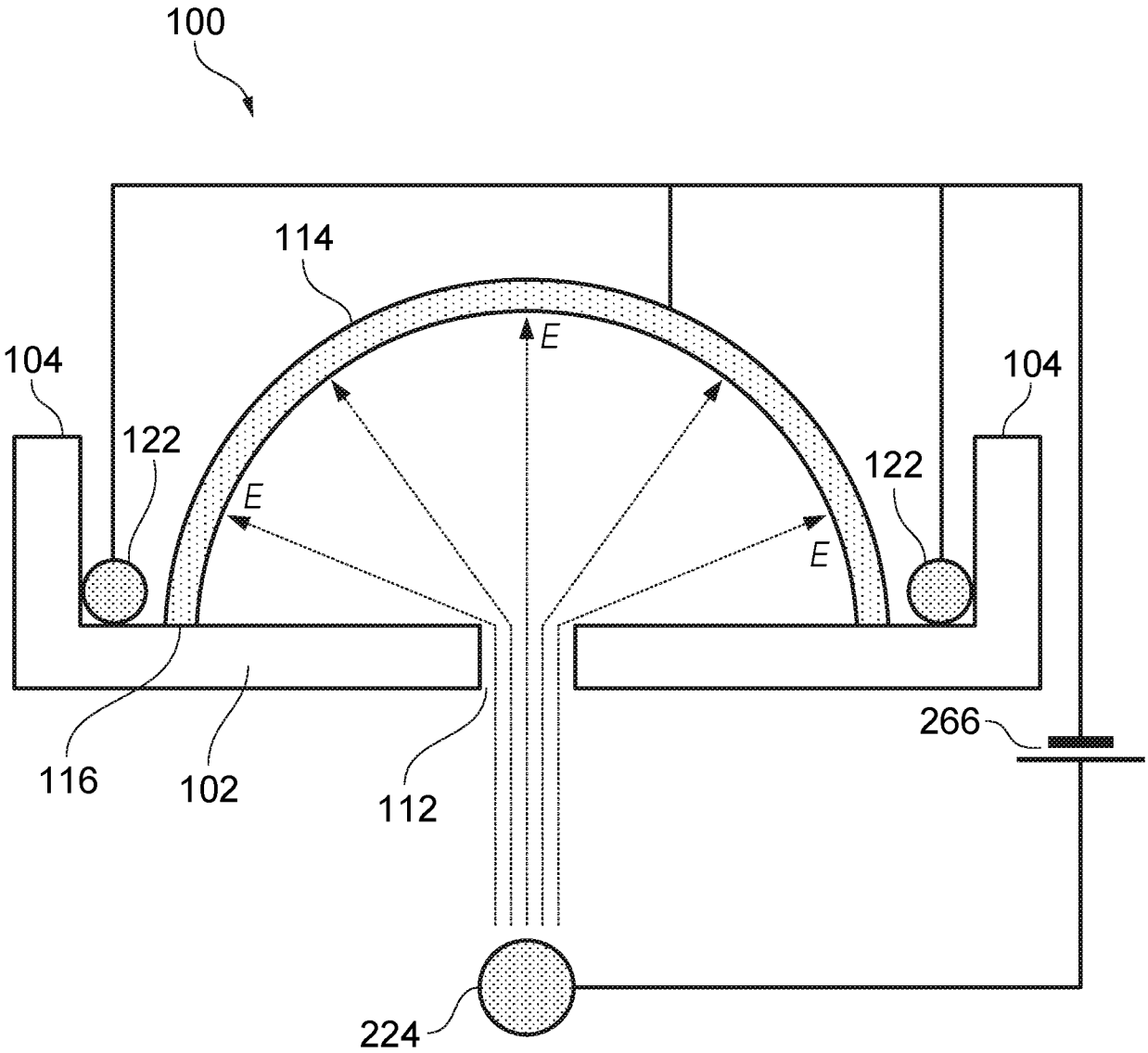

FIG. 1C

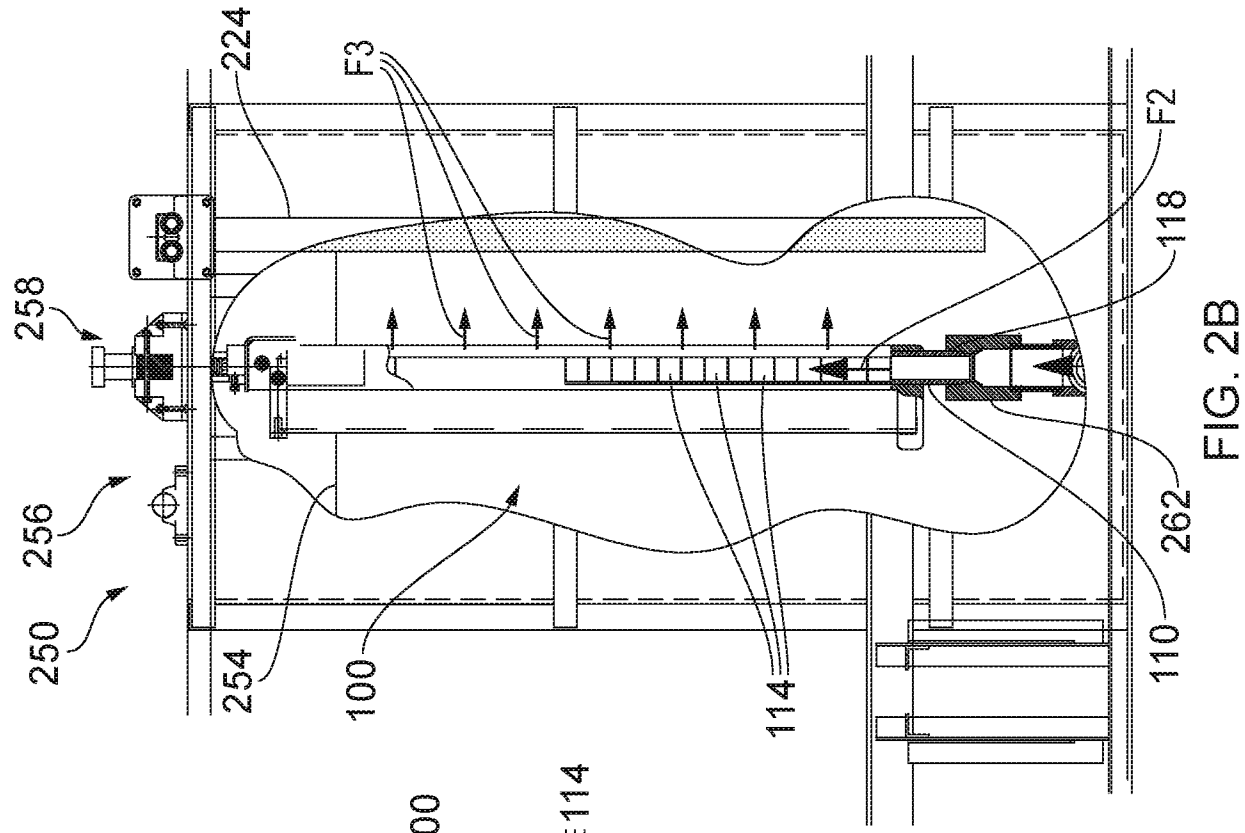
224
F3
F2
118
258
256
250
254
100
114
262
110

FIG. 2B

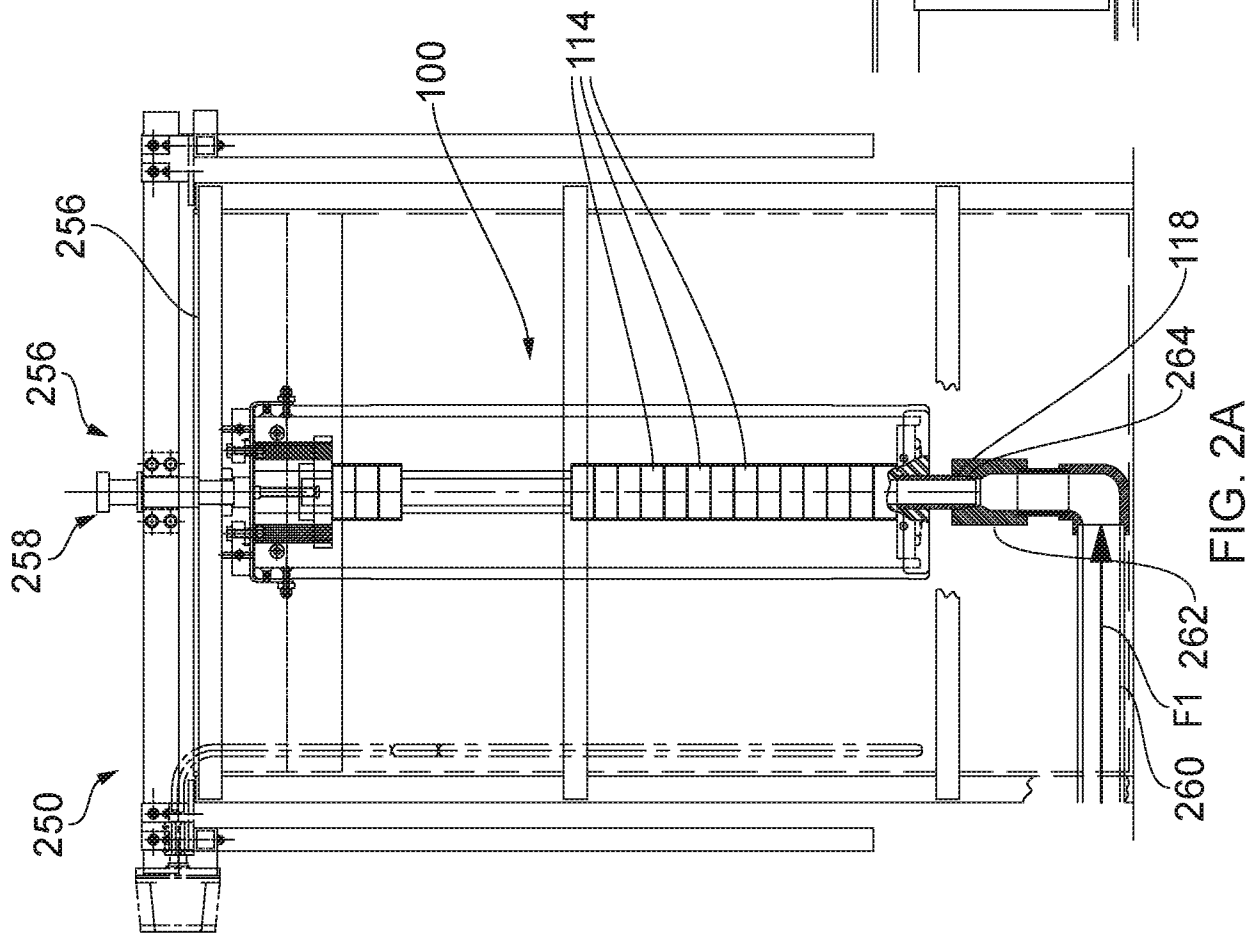
100
114
256
256
118
264
258
262
F1
260
250

FIG. 2A

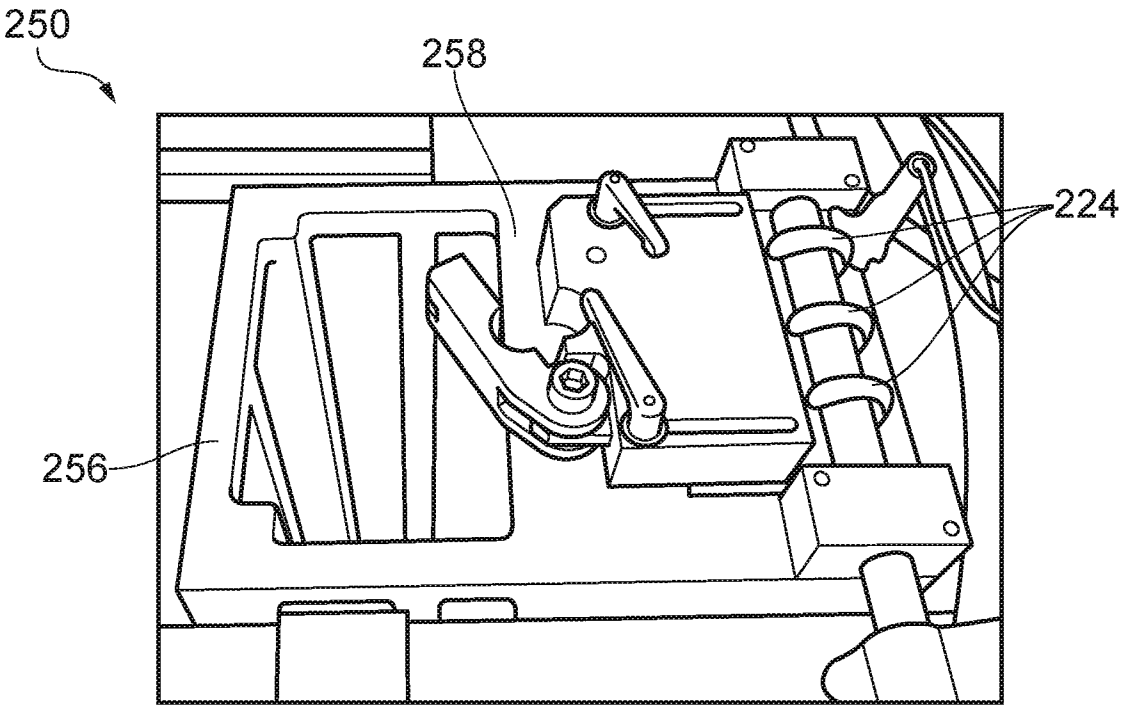

FIG. 2C

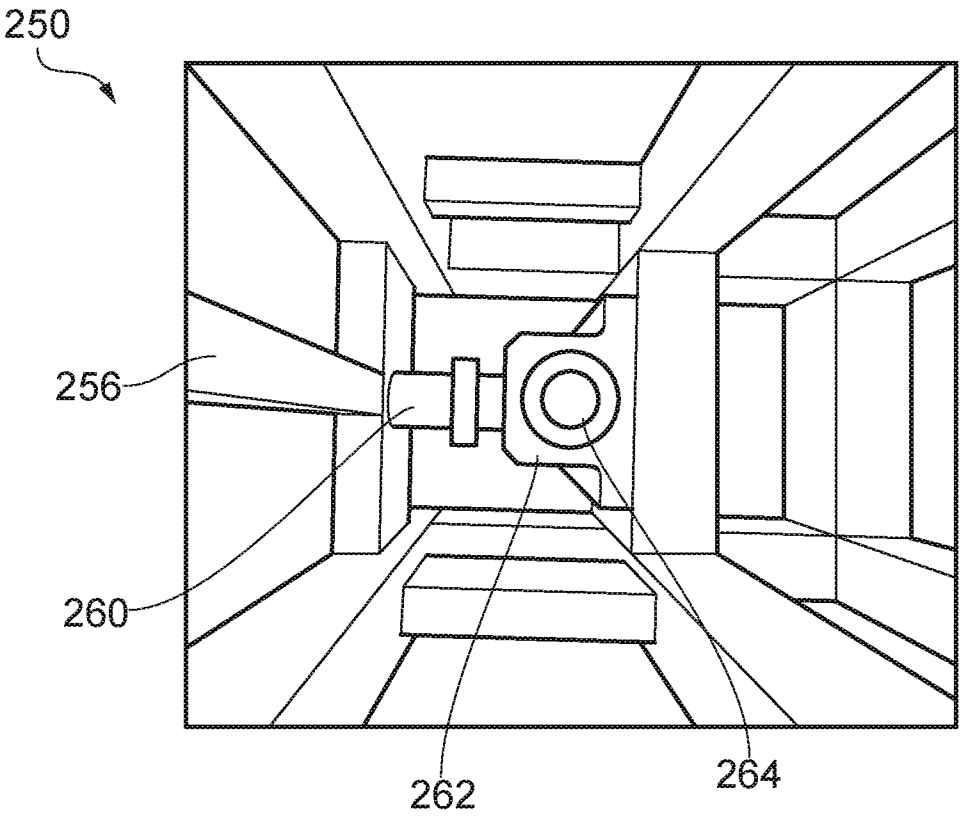

FIG. 2D

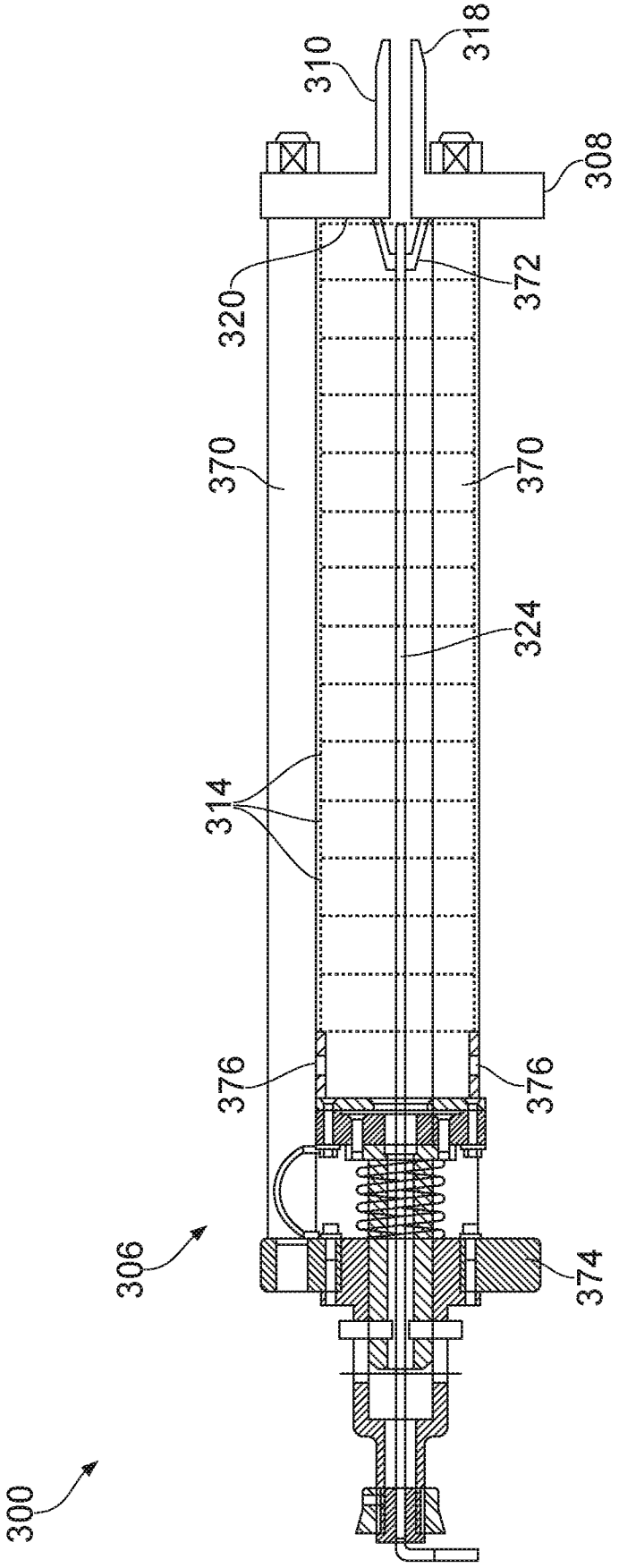

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/051166

A. CLASSIFICATION OF SUBJECT MATTER
INV. C25D17/00 C25D5/02 C25D5/08 C25D7/04 C25D7/10
C25D17/06 F16C33/00
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)
C25D F16C

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	BR 9 204 745 A (METAL LEVE SA [BR]) 5 July 1994 (1994-07-05) page 2, line 22 - page 5, line 13; figures 1-5	1-6,8, 10-13
X	US 2 500 205 A (SCHAEFER RALPH A) 14 March 1950 (1950-03-14) column 4, lines 44-72; figures 1,2,4,5,9-11 the whole document	1,6, 11-13
X	US 4 399 019 A (KRUPER WAYNE A [US] ET AL) 16 August 1983 (1983-08-16) column 2, line 58 - column 3, line 8; figures 1,2 column 3, lines 57-62 the whole document	1-4,7-13

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 August 2014	25/08/2014

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	Suárez Ramón, C

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/051166

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 3 065 153 A (HOUGH FRED O ET AL) 20 November 1962 (1962-11-20) the whole document	1,7-13
A	US 3 331 764 A (BEEBE JR AUSTIN H ET AL) 18 July 1967 (1967-07-18) the whole document	1-13
A	US 2 944 945 A (ALLISON PAUL R) 12 July 1960 (1960-07-12) the whole document	1-13

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2014/051166

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
BR 9204745 A	05-07-1994	NONE	
US 2500205 A	14-03-1950	DE 939416 C	23-02-1956
		FR 978829 A	18-04-1951
		GB 627294 A	05-08-1949
		US 2500205 A	14-03-1950
US 4399019 A	16-08-1983	AU 554426 B2	21-08-1986
		AU 8481482 A	27-01-1983
		BR 8204220 A	12-07-1983
		CA 1175778 A1	09-10-1984
		DE 3226621 A1	10-02-1983
		FR 2510146 A1	28-01-1983
		GB 2102836 A	09-02-1983
		IN 154810 A1	15-12-1984
		JP H0259239 B2	11-12-1990
		JP S5825500 A	15-02-1983
		MX 153519 A	10-11-1986
		US 4399019 A	16-08-1983
US 3065153 A	20-11-1962	NONE	
US 3331764 A	18-07-1967	GB 1056723 A	25-01-1967
		US 3331764 A	18-07-1967
US 2944945 A	12-07-1960	NONE	