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(54) **Rotary actuator for moving a swivel swing door, particularly in vehicles**

(57) A rotary actuator (1) for moving a swivel swing door (2), particularly for vehicles, said rotary actuator (1) defining a rotation axis (3) and comprising a fluid dynamic

linear actuator (4) and a screw drive (8) wherein a rotor shaft (10) of the screw drive forms a part of the cylinder (5) of the linear actuator.

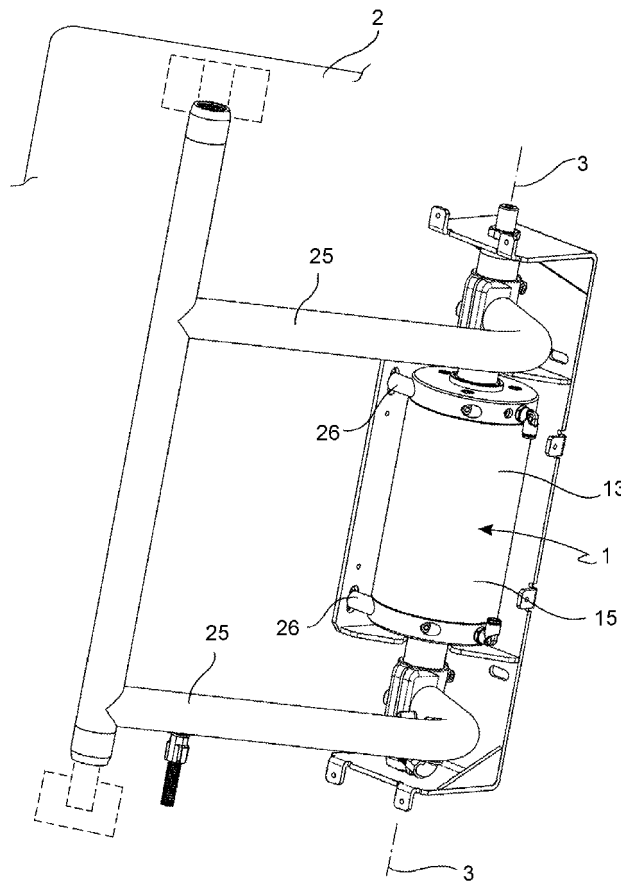


FIG. 1

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Description

[0001] The present invention relates to a rotary actuator for moving a swivel swing door, particularly for vehicles, such as buses and trains.

[0002] The swivel swing door for a vehicle, such as a bus, is connected by means of swivel arms to a rotary column and can be displaced, by a rotational and lifting movement of the rotary column, to a closing and locking position in which locking means of the door and swing frame are engaged. The movement of the rotary column is carried out by means of a rotary actuator which comprises a linear actuator and a screw drive which turns the actuator linear movement into a rotary movement.

[0003] DE3705369 describes a known example of a rotary actuator for moving a swivel swing door in a vehicle, wherein the linear actuator comprises a fluid dynamic piston-cylinder unit and the screw drive is formed externally of the linear actuator and comprises a female screw member which accommodates a cam shaft by the interposition of a set of spheres. The connection of the piston to the female screw member is carried out by means of a stem extending from the piston within the cylinder to the female screw member outside of the cylinder.

[0004] In this known solution, the stroke of the piston, and accordingly the shortest length of the hydrodynamic cylinder-piston unit adds to the length and diameter of the screw drive which are necessary to achieve the rotation angle and torsional moment as required by the particular application. This makes the actuator axially and radially bulky and often incompatible with the narrow spaces provided in the areas of the transport means doors.

[0005] Furthermore, the spheres interposed between the female screw member and the cam shaft only partially work under rolling friction and cause a considerable amount of sliding friction which results in energy dissipation and wear phenomena, which, in turn, make it necessary to further increase both the drive stroke (due to a reduction in the thread pitch) and the cam shaft diameter.

[0006] The object of the present invention is thus to provide a rotary actuator for moving a swivel swing door, particularly for vehicles, such as buses, having such characteristics as to overcome the drawbacks mentioned with reference to the prior art.

[0007] Within the primary object, a particular object of the invention is to provide a rotary actuator which is more compact in terms of length and/or width.

[0008] A still further object of the invention is to provide a rotary actuator having a simplified and sturdy structure which is efficient in terms of power consumption.

[0009] This and other objects are achieved by means of a rotary actuator for moving a swivel swing door, particularly for vehicles, said rotary actuator defining a rotation axis and comprising:

- a fluid dynamic linear actuator with a cylinder defining an annular pressure chamber therein and an an-

nular piston accommodated within the pressure chamber in a sliding manner parallel to the rotation axis,

- a screw drive with a stator which is fastened such as not to rotate about the rotation axis and connected to the piston such as to translate together with the piston in a parallel direction to the rotation axis, as well as a rotor shaft engaged by the stator by means of one or more revolving members and configured such as to rotate about the rotation axis in response to the translation of the stator,

[0010] wherein the rotor shaft forms an inner surface of the cylinder and directly defines the pressure chamber and the piston is in a sealing sliding contact with this inner surface.

[0011] Due to the integration of the rotor shaft in the structure of the fluid dynamic cylinder a reduction is obtained both in the axial and radial dimensions of the actuator as compared with the rotary actuators of the prior art, as well as the total elimination of at least one wall of the fluid dynamic cylinder. This results in considerable structural simplification of the actuator as well as saving of material and working time required for assembling the same.

[0012] In order to better understand the invention and appreciate the advantages thereof, several exemplary and non-limiting embodiments thereof will be described below with reference to the drawings, in which:

[0013] Fig. 1 is a perspective view of a rotary actuator mounted to the door of a transport means;

[0014] Fig. 2 is a view of a rotary actuator according to an embodiment, wherein an outer wall has been removed;

[0015] Fig. 3 is a view of a rotary actuator according to an embodiment, wherein an outer wall and a stator have been removed;

[0016] Fig. 4 shows an enlarged detail of the actuator in Fig. 3;

[0017] Fig. 5 is a cross-sectional view of a revolving body of the rotary actuator according to an embodiment;

[0018] Fig. 6 is a cross-sectional view of a screw drive of the rotary actuator according to an embodiment;

[0019] Fig. 7 is a longitudinal sectional view of a rotary actuator according to an embodiment in a first operating configuration (retracted piston);

[0020] Fig. 8 is a longitudinal sectional view of the rotary actuator of Fig. 7 in a second operating configuration (forward piston);

[0021] Fig. 9 is a longitudinal sectional view of a rotary actuator according to a further embodiment.

[0022] With reference to the figures, a rotary actuator 1 for moving a swivel swing door 2, particularly for vehicles, is generally referenced 1.

[0023] The rotary actuator 1 defines a rotation axis 3 and comprises a fluid dynamic linear actuator 4 with a cylinder 5 defining an annular pressure chamber 6 therein and an annular piston 7 accommodated within the pres-

sure chamber 6 in a sliding manner parallel to the rotation axis 3. The rotary actuator 1 further comprises a screw drive 8 with a stator 9 being fastened such as not to rotate about the rotation axis 3 and connected to the piston 7 such as to translate together with the piston 7 in a direction parallel to the rotation axis 3, as well as a rotor shaft 10 engaged with the stator 9 by means of one or more revolving members 11 and configured such as to rotate about the rotation axis 3 in response to the translation of the stator 9. The rotor shaft 10 provides an inner surface 12 of the cylinder 5 and directly defines the pressure chamber 6, the piston 7 being in sealing sliding contact to the inner surface 12.

[0024] As the rotor shaft 10 is incorporated within the structure of cylinder 5 a reduction in the axial and radial dimensions, as well as the complete elimination of at least one cylinder fluid dynamic wall are obtained for the actuator 1 as compared with prior art rotary actuators. This results in a considerable structural simplification and in a saving of both material and processing and assembling times.

[0025] In accordance with an embodiment, the rotor shaft 10 is co-axially integrated in the actuator fluid dynamic 4 and the inner surface 12 provides an inner circumferential surface of the annular pressure space 6.

[0026] The concentric arrangement of the rotor shaft 10 within the linear actuator 4 relative to the annular pressure chamber 6 minimizes the outer diameter of the pressure chamber, with the axial pressure surface and diameter of the rotor shaft 10 being equal, and allows defining the annular pressure chamber 6 by means of a simple outer tubular wall 13 which is radially positioned outside the rotor shaft 10.

[0027] In accordance with a further aspect of the invention, the fluid dynamic actuator 4 can be configured as a double-effect actuator wherein the pressure chamber 6 is divided by the piston 7 into a first pressure chamber 6A and a second pressure chamber 6B which are arranged on opposite sides of the piston 7. In this case, the rotor shaft 10 can directly define a part of both first 6A and second 6B pressure chambers. Advantageously, also the translatable stator 9, the revolving members 11 and a cam surface 14 (or race) engaged by them are accommodated within the annular pressure chamber 6.

[0028] Thereby, the area in which the translational motion is turned into a rotary motion is completely enclosed within the pressure chamber 6 of the fluid dynamic linear actuator 4, thereby allowing to provide one outer housing 15 only for the entire rotary actuator 1, the side and end walls thereof being capable of directly defining also the pressure chamber.

[0029] This further reduces the overall axial dimensions of the rotary actuator, simplifies and makes the structure thereof lighter and facilitates processing and assembly thereof.

[0030] In accordance with a further embodiment, the revolving members 11 comprise a pin 16 being provided at the translating stator 9 and a bush 17 pivotally sup-

ported on the pin by means of the interposition of a set of (cylindrical) rolls and having a cam-follower surface 18 which engages by rolling contact the cam surface 14 provided in the rotor shaft 10.

[0031] The arrangements of the pin 16 and cam-surface 14 on the rotor shaft 10 and on the translating stator 9 can be inverted according to the particular design requirements and design choices.

[0032] The revolving members 11 are thus provided by (cylindrical) rolling bearings, the inner support thereof (pin 16) being connected to the stator 9 and the outer ring (bush 17) thereof forming the cam-follower surface 18 in contact to the cam surface 14 of the rotor shaft 10 or vice versa.

[0033] Advantageously, the orientation of the pin 16 or, in other words, the local rolling axis of the bush 17 is substantially radial relative to the rotation axis 3 which, in turn, corresponds to the longitudinal axis of the rotor shaft 10.

[0034] Two revolving members 11 may be provided in diametrically opposite positions relative to the rotation axis 3 or three revolving members with 120° angular pitch.

[0035] The cam-follower surface 18 is advantageously convex or rounded in the direction of the rolling axis to eliminate the sliding friction due to the rolling differential between the radially outer area of the bush and the radially inner area thereof.

[0036] In accordance with one exemplary embodiment, the actuator 1 comprises an outer housing 15 provided by a tubular wall 13 and two opposite head walls 19 connected to each other and to the tubular wall 13 by means of a plurality of preferably three tie rods 20. The head walls 19 radially support the rotor shaft 10, by means of roller bearings 21, and axially, by means of one or two axial roller bearings 22 enclosed within fifth wheels against which a shoulder 23 of the rotor shaft 10 is abutted. The tie rods 20 axially extend at an angular pitch (either constant, e.g. of 120° or irregular depending on the inner space conditions of the device) through the annular pressure chamber 6 provided between the outer tubular wall 13 and the rotor shaft 10 and provide translation and anti-rotation guides for the piston 7. At least one, preferably both head walls 19 have a central hole through which at least one end 24 is extended, preferably both opposite ends 24 of the rotor shaft 10 outside the housing 15. The ends 24 of the rotor shaft 10 can be either grooved or profiled such as to allow an integral connection with a swivel arm 25 of a door 2.

[0037] At the head walls 19 or at the outer wall 13 brackets 26 can be provided for securing the rotary actuator 1 to a utility, particularly a vehicle, for example a bus or railway wagon.

[0038] The piston 7 can comprise an annular body that can be either single-piece or made of several pieced joined to each other, which forms:

- an outer circumferential surface 27, preferably with one or more seats accommodating outer annular

gaskets 28, for sliding and sealing engagement with an outer surface of the cylinder formed by the tubular wall 13,

- an inner circumferential surface 29, preferably with one or more seats accommodating inner annular gaskets 30, for sliding and sealing engagement with the inner surface 12 of the cylinder formed by the rotor shaft 10,
- as well as a plurality of preferably three axial holes 31, which are possibly provided with annular gaskets 32, which accommodate the axial tie rods 20 to fasten the piston 7 such as not to be capable of rotating about the rotation axis 3.

[0039] The translatable stator 9 can comprise a tubular portion that provides the stator and can be formed either as one piece with the piston 7 or connected thereto integrally in rotation (for example by means of a key 33).

[0040] At an end area of the pressure chamber 6 being defined by the cam surface 14 of the screw drive (and, accordingly, not involved in the movement of the piston) an (annular) filling body 34 can be advantageously provided which is suitable to reduce, in this area, the volume that can be filled with pressure fluid, with the axial length of the end area (Fig. 7,8) being equal. This allows a fast emptying and a fast pressurization of the fluid volume, e.g. compressed air in that area (for example, during the return-stroke of the piston), without any requirement of sealingly isolating the area from the remaining part of the pressure chamber.

[0041] Thereby, a further structural simplification is obtained as compared with prior art solutions.

[0042] The return stroke of the piston 7 can be obtained by means of pneumatic or hydrodynamic control (pressurization of the second pressure chamber 6B in the case of a double-effect actuator (shown in the drawings) or, alternatively, by means of a return spring acting on the piston (not illustrated).

[0043] In accordance with a further aspect of the invention, the linear actuator 4 comprises a pneumatic dampening system that slows down the movement of the piston 7 when it enters an end-of-stroke area.

[0044] In an embodiment, the cylinder 5 provides a first duct 35 for feeding and draining the pressure fluid, which communicates with a first opening in the pressure chamber 6 and a second feed and drain duct 36 communicating with a second opening in the pressure chamber, wherein the second duct 36 has a throttled section (by means of an adjustment screw 37) relative to the section of the first duct 35. Furthermore, the piston 7 provides an isolating annular wall 38 which is adapted to sealingly engage an isolating annular seat 39 (which is possibly provided with a gasket) when the piston 7 enters the end-of-stroke area. The isolation annular seat 39 extends between the first opening and the second opening such that, when the piston 7 enters within the end-of-stroke area, the engagement of the isolating wall 38 with the isolating seat 39 separates an air volume within the pressure chamber 6

from the first opening and forces it to pass only through the second opening and the second duct 36 with the throttling. Thereby, the speed of the piston 7 is damped when approaching the end-of-stroke thereof.

[0045] In accordance with an embodiment, the second duct 36 is connected to the first duct 35 at a downstream location (drain direction) of the throttling, such as to allow a feeding and a pressurization of the pressure fluid (compressed air) through the first duct 35 and first opening, thereby avoiding any undesired slowing down during the initial phases of the movement of piston 7, and accordingly of the door being operated.

[0046] As shown in Fig. 7 and 8, this concept and the structure of the pneumatic damper described herein can be similarly implemented in both pressure chambers 6A, 6B of a double-effect actuator.

[0047] In accordance with a further embodiment (Fig. 9), at one or both axial ends of the cam surface 14 there is provided a stop surface 40 against which the revolving members 11 or the stator 9 are abutted when the end of a first length 41 of the stroke of the stator 9 (or the piston 7) intended to rotate the rotor shaft 10 is reached. When the stator 9 moves past the end of a first length and enters a second length 42 of stroke intended to translate or lift the rotor shaft 10, the axial engagement between the revolving members 11 or the stator 9 and the stop surface 40 causes the rotor shaft 10 to translate axially along with the stator 9 until the total end-of-stroke is reached (represented in Fig. 9 by the abutment surface 43 for example of an upper fifth wheel 22).

[0048] When the stator 9 is in the first length 41 of stroke (length dedicated to rotation) the axial translation of the rotor shaft 10 results to be prevented from the gravity force applied for example by the door connected to the rotor shaft, by a return spring (not illustrated) biasing the rotor shaft axially from a stopped position or by a counter-surface being shaped such as to allow for the axial displacement of the rotor shaft 10 only to a predetermined angular position which corresponds to the completion of the rotational movement thereof.

[0049] Thereby, the rotary actuator 1 provides both to rotation and translation of the rotor shaft 10 in two well-distinct steps, and then to the orientation, locking lifting and release lowering of the door to which it is mounted.

[0050] Advantageously, sensors of axial and angular positions can be mounted to the housing 15 of the rotary actuator 1 and interact to the end/s 24 of the rotor shaft 10 which project outwards from the housing 15. These sensors can comprise e.g. potentiometric, mechanic, optical ad/or inductive sensors.

[0051] The rotary actuator of the present invention has a number of advantages, particularly it has reduced axial and radial dimensions, a sturdy, though simplified and lightened structure as well as a high energy efficacy in turning the translational movement produced by the linear actuator into a rotational movement of the rotor shaft.

[0052] Obviously, to the rotary actuator according to the present invention, those skilled in the art, aiming at

meeting specific and contingent requirements, will be able to carry out further modifications and variations, all being encompassed within the scope of protection of the invention, such as defined by the following claims.

Claims

1. A rotary actuator (1) for moving a door (2) particularly a swivel swing door, particularly for vehicles, said rotary actuator (1) defining a rotation axis (3) and comprising:
 - a fluid dynamic linear actuator (4) with a cylinder (5) internally defining an annular pressure chamber (6), an annular piston (7) accommodated within the pressure chamber (6) in a sliding manner parallel to the rotation axis (3),
 - a screw drive (8) having a stator (9) fastened such as not to rotate about the rotation axis (3) and connected to the piston (7) such as to translate along with the piston (7) in the direction parallel to the rotation axis (3), and a rotor shaft (10) being engaged with the stator (9) by means of one or more revolving members (11) and configured such as to rotate about the rotation axis (3) in response to the translation of the stator (9), **characterized in that** the rotor shaft (10) provides an inner surface (12) of the cylinder (5) and directly defines the pressure chamber (6) and **in that** the piston (7) is in sealing sliding contact with said inner surface (12).
2. The rotary actuator (1) according to claim 1, wherein the rotor shaft (10) is co-axially connected in the fluid dynamic actuator (4) and the inner surface (12) provides an inner circumferential surface of the annular pressure space (6).
3. The rotary actuator (1) according to claim 1 or 2, wherein the linear actuator (4) is configured such as a double-effect actuator and the pressure chamber (6) is divided from the piston (7) into a first pressure chamber (6A) and a second pressure chamber (6B) and wherein the rotor shaft (10) directly defines a part of the first (6A) and second (6B) pressure chambers.
4. The rotary actuator (1) according to any preceding claim, wherein the translatable stator (9), the revolving members (11) and a cam surface (14) engaged by the revolving members (11) are also arranged within the annular pressure chamber (6).
5. The rotary actuator (1) according to any preceding claims, wherein the revolving members (11) comprise roller bearings with an inner support (16) connected to the stator (9) and an outer ring (17) forming a cam-follower surface (18) in contact with a cam surface (14) of the rotor shaft (10) or vice versa.
6. The rotary actuator (1) according to claim 5, wherein the cam-follower surface (18) is rounded in the direction of a rolling axis thereof.
7. The rotary actuator (1) according to any preceding claims, comprising an outer housing (15) formed by a tubular wall (13) and two opposite head walls (19), wherein the head walls (19) support the rotor shaft (10) both in a radial manner by means of roller bearings (21) and in an axial manner by means of at least one axial roller bearing (22).
8. The rotary actuator (1) according to claim 7, wherein the head walls (19) are connected to each other by means of a plurality of tie rods (20) axially extending through the annular pressure chamber (6) formed between the outer tubular wall (13) and the rotor shaft (10) and forming translational and anti-rotation guides for the piston (7).
9. The rotary actuator (1) according to claim 7, wherein each of the head walls (19) has a central hole through which the two opposite ends (24) of the rotor shaft (10) extend outwards of the housing (15).
10. The rotary actuator (1) according to claim 8, wherein the piston (7) comprises an annular body forming:
 - an outer circumferential surface (27) in sliding and sealing contact with the tubular wall (13),
 - an inner circumferential surface (29) in sliding and sealing contact to the inner surface (12) of the cylinder being formed by the rotor shaft (10),
 - a plurality of axial holes (31) accommodating the axial tie rods (20),
 - a tubular portion forming the translatable stator (9).
11. The rotary actuator (1) according to any preceding claim, wherein in an end area of the pressure chamber (6) being defined by a cam surface (14) of the screw drive there is arranged a filling body (34) which reduces the volume that can be filled with the pressure fluid, with the axial length of the end area being equal.
12. The rotary actuator (1) according to any preceding claim, wherein the linear actuator (4) comprises a pneumatic dampening system which slows down the movement of the piston (7) when it enters an end-of-stroke area.
13. The rotary actuator (1) according to claim 12, wherein the cylinder (5) forms:

- a first duct (35) for feeding and draining the pressure fluid in communication with a first opening in the pressure chamber (6), and
- a second feeding and drain duct (36) in communication with a second opening within the pressure chamber (6), wherein the second duct (36) has a throttled section relative to the section of the first duct (35),
and wherein the piston (7) forms an isolation wall (38) such that, when the piston (7) enters the end-of-stroke area, it sealingly engages an isolation seat (39) extending between the first opening and the second opening such as to separate an air volume within the pressure chamber (6) from the first opening and forcing the latter to be vented only through the second opening and second duct (36).

14. The rotary actuator (1) according to claim 13, wherein the second duct (36) is connected to the first duct (35) at a point downstream the throttling as viewed in the draining direction.
15. The rotary actuator (1) according to any preceding claim, wherein the rotor shaft (10) forms a stop surface (40) against which the revolving members (11) or the stator (9) are abutted when the end of a first length (41) of the stroke of the stator (9) is reached and wherein, when the stator (9) moves past the end of the first length and enters a second length (42) of the stroke thereof, the rotor shaft (10) axially translates together with the stator (9) until reaching a total end-of-stroke, wherein the rotary actuator (1) comprises means that prevent an axial translation of the rotor shaft (10) when the stator (9) is within the first length (41) of stroke.

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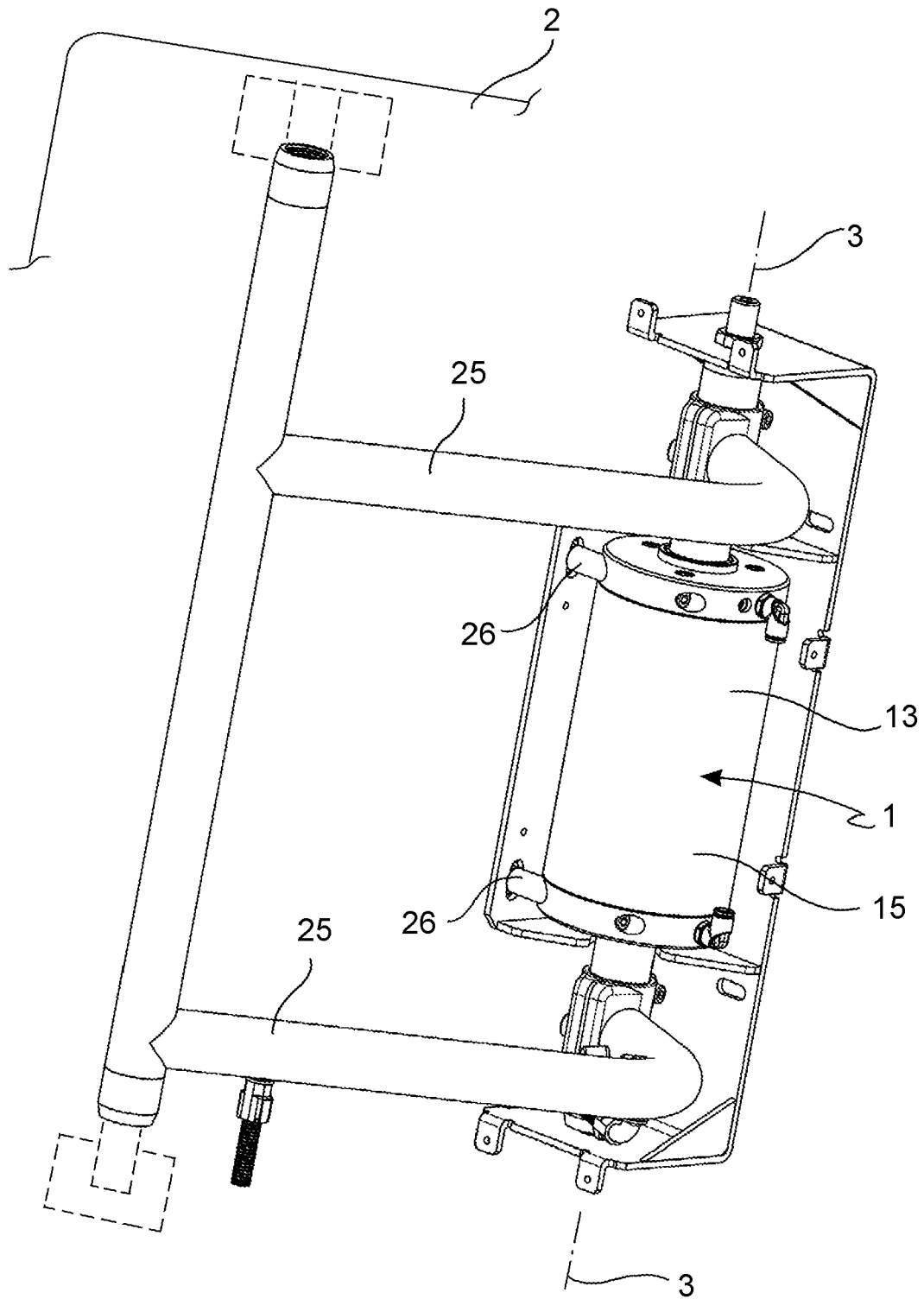


FIG. 1

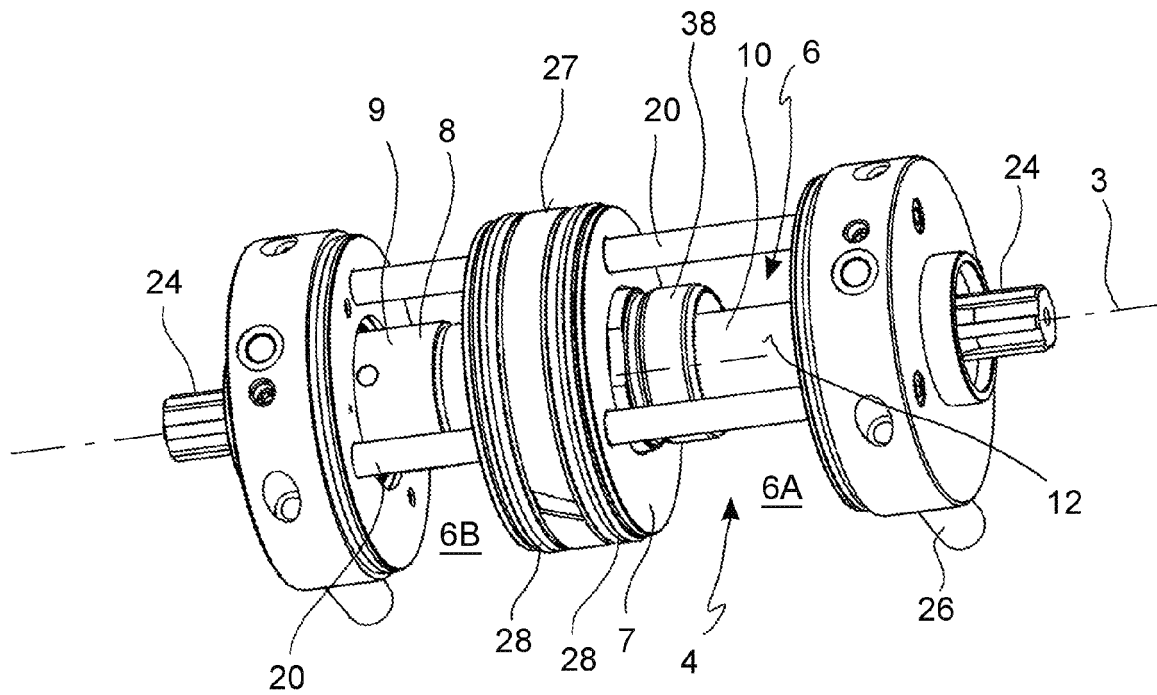


FIG. 2

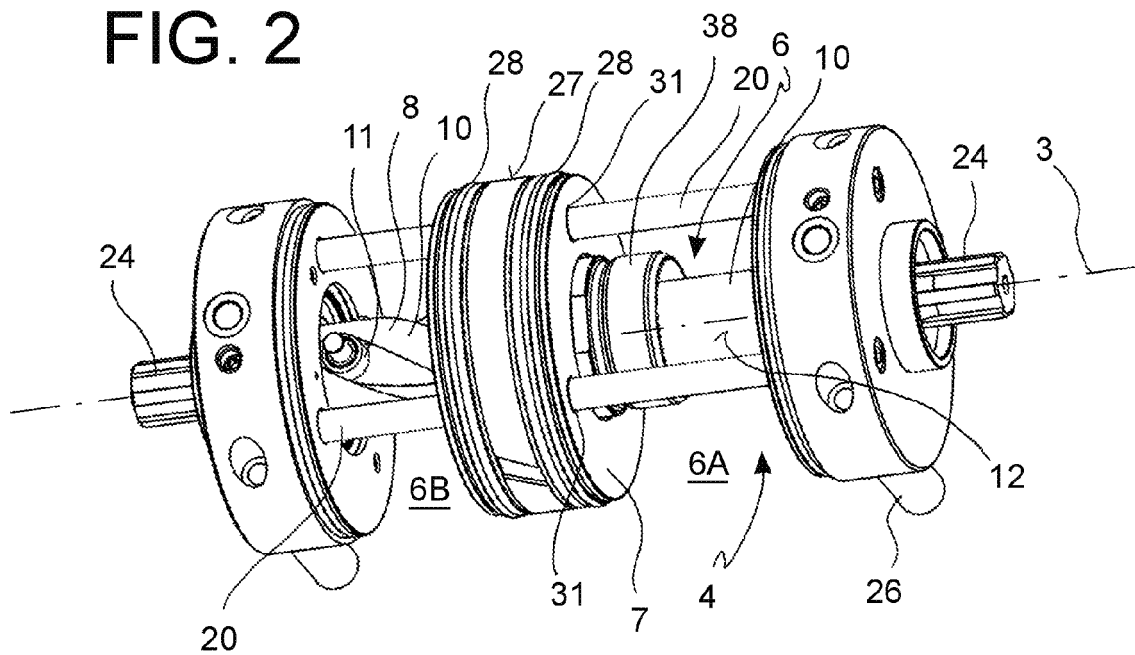


FIG. 3

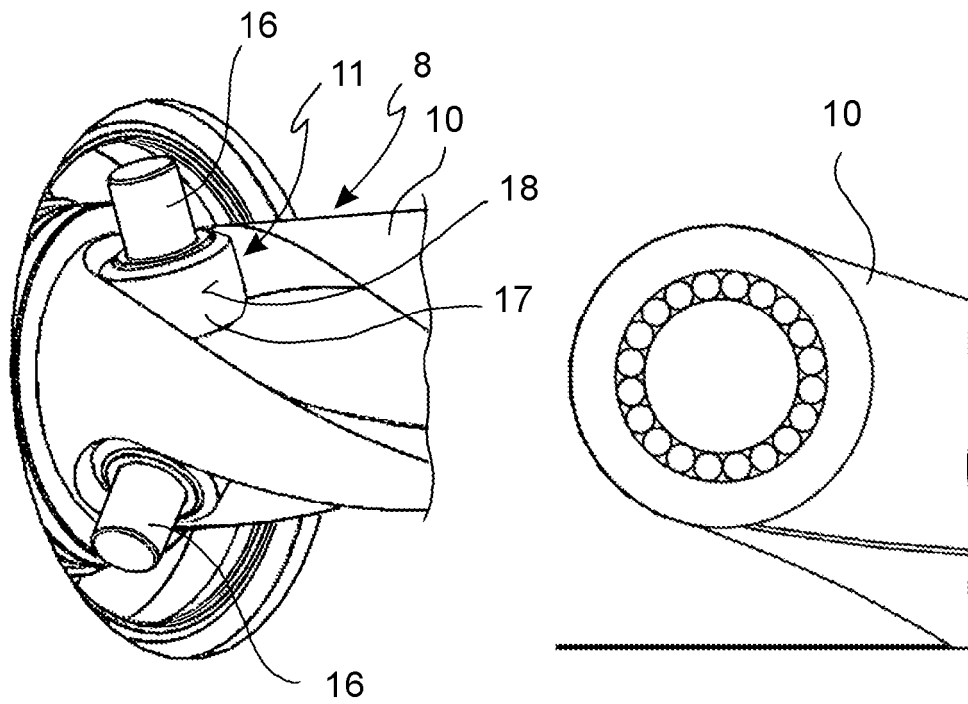


FIG. 4

FIG. 5

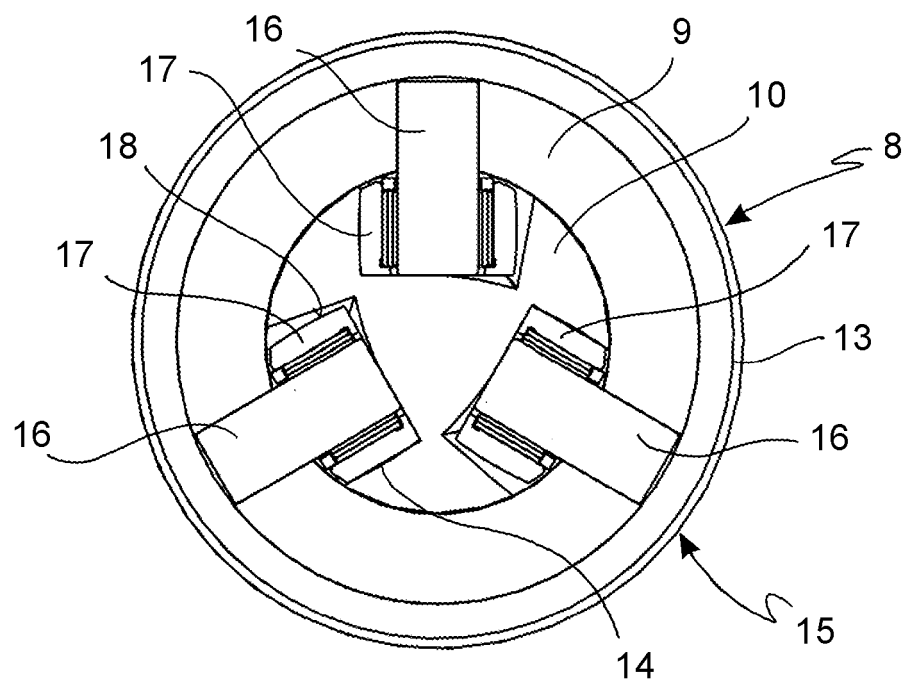


FIG. 6

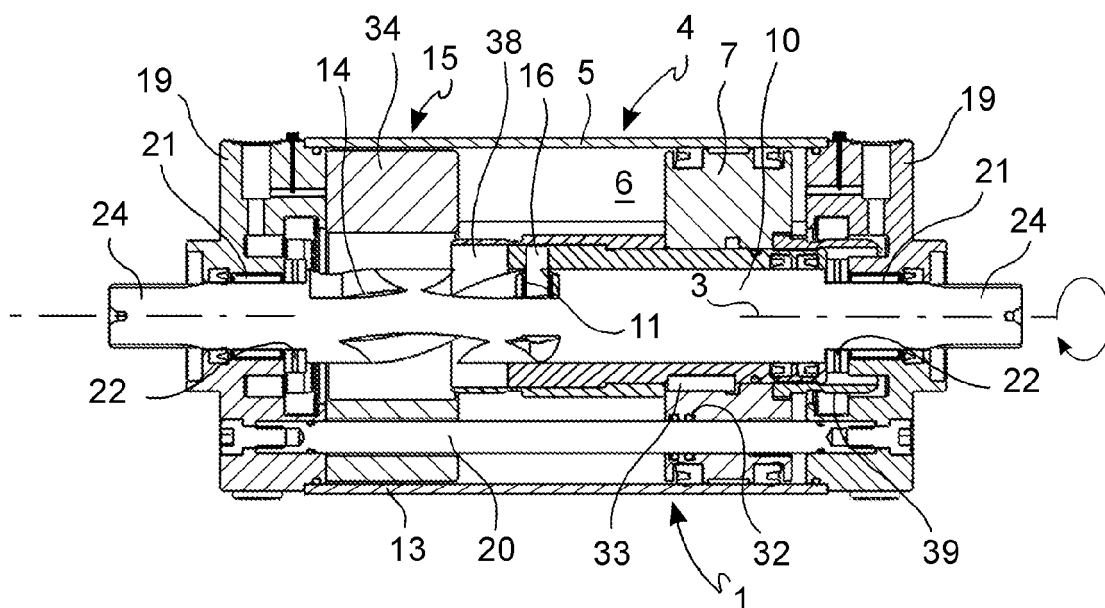


FIG. 7

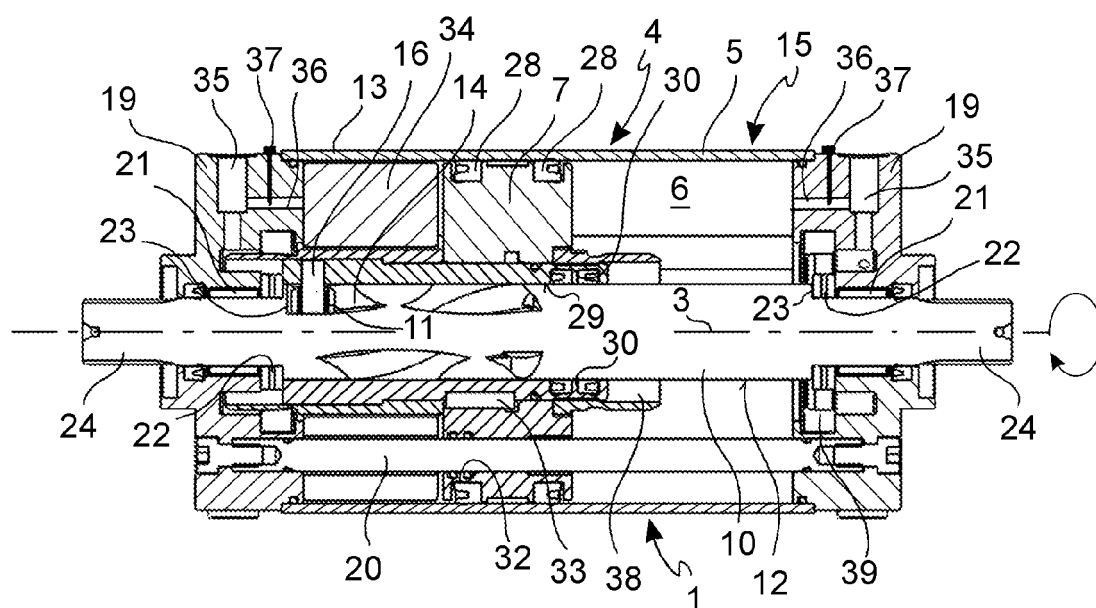


FIG. 8

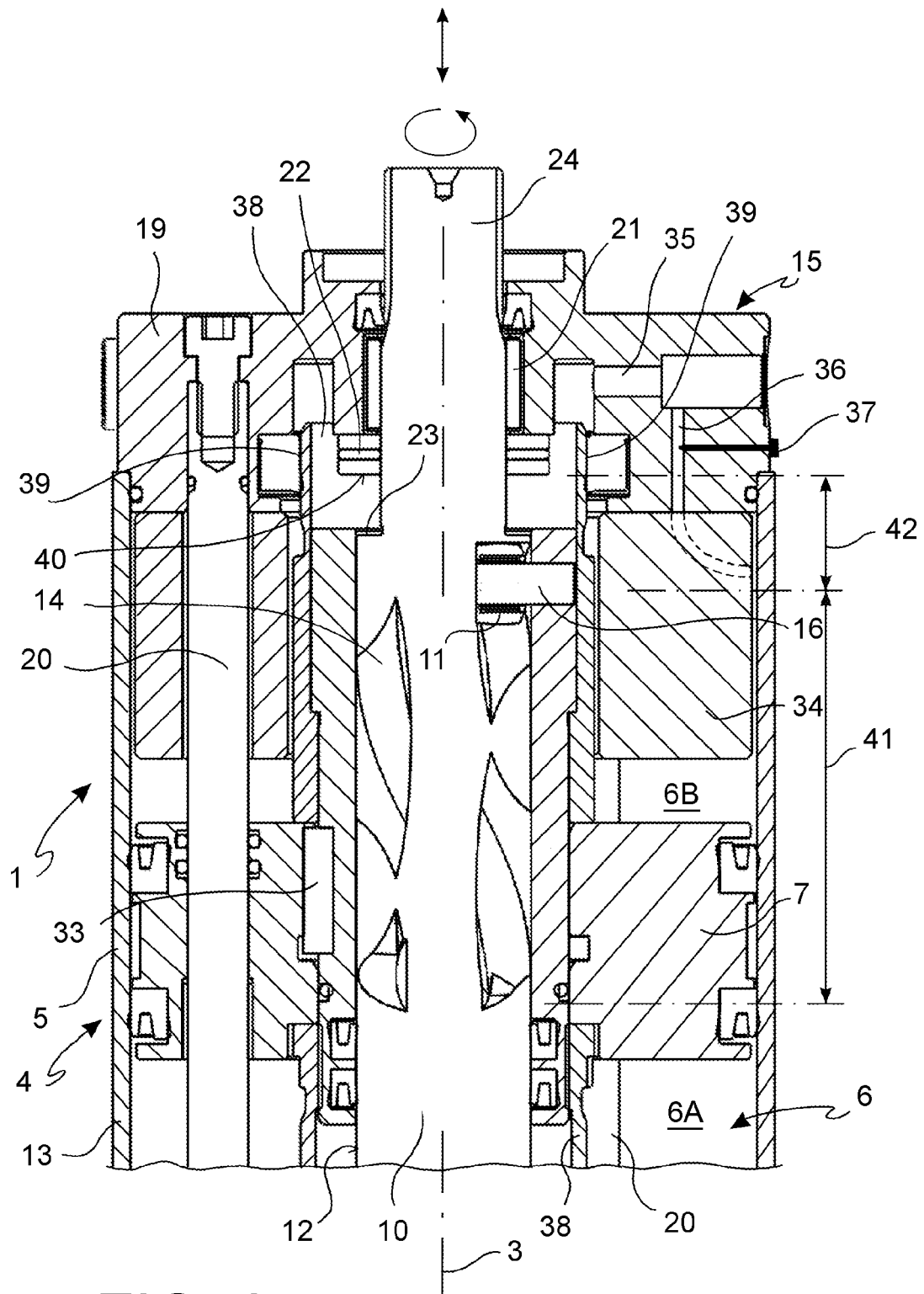


FIG. 9



EUROPEAN SEARCH REPORT

Application Number
EP 11 42 5180

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 255 806 A (MEYER KENNETH H ET AL) 14 June 1966 (1966-06-14)	1-4,7,9	INV. E05F15/04 F15B15/06
Y	* column 3, line 50 - column 5, line 25; figures 2,3 *	5,6, 11-15	
X	DE 10 2009 027794 B3 (SCHULTE REINHOLD [DE]) 28 October 2010 (2010-10-28) * paragraph [0029] - paragraph [0033]; figure 3 *	1-4,7-10	
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			TECHNICAL FIELDS SEARCHED (IPC)
			E05F F15B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 6 December 2011	Examiner Guillaume, Geert
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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The members are as contained in the European Patent Office EDP file on
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REFERENCES CITED IN THE DESCRIPTION

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