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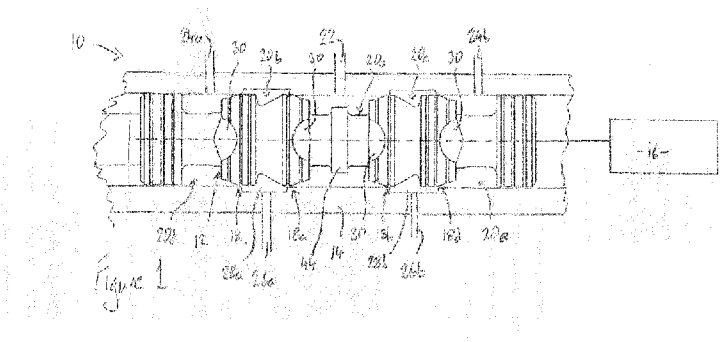
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(54) Title: SPOOL VALVE ARRANGEMENT



(57) Abstract: A spool valve arrangement is described comprising a spool (12) axially moveable along a passage formed in a housing (14) to control communication between ports opening into the passage, and an anti-rotation arrangement (32) operable to resist rotation of the spool (12) relative to the housing (14), wherein the anti-rotation arrangement (32) comprises a roller (40) cooperable with the spool (12) and the housing (14) to resist rotation of the spool (12) relative to the housing (14), the roller (40) being supported such that it extends substantially perpendicularly to the axis of the spool (12). An arrangement is also described in which the spool (12) defines a pair of lands (18a, 18b) cooperable with the housing (14) to define a chamber (20a) therebetween in constant communication with a first port (22) provided in the housing (14) throughout a range of movement of the spool (12) relative to the housing (14), cooperation between at least one of the lands (18a, 18b) and the housing (14) controlling communication between the chamber (20a) and at least a second port (26a, 26b) provided in the housing (14), wherein a distribution step (44) is provided on a part of the spool (12) between the lands (18a, 18b) to enhance the uniformity of the fluid velocity within a part of the chamber (20a) adjacent the said at least one of the lands (18a, 18b).

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SPOOL VALVE ARRANGEMENT

This invention relates to a spool valve arrangement, and in particular to a spool valve arrangement suitable for use as part of, for example, a hydraulic or pneumatic system, the spool valve arrangement including a spool that is axially movable to control communication between a series of ports associated with the valve arrangement.

A number of devices are known that include an axially slidable spool, movable to control the communication between a series of ports, for example serving as a control servo for use in the controlling the operation of an associated valve, or serving as a proportional fluid control valve.

It has been found that in some circumstances, where used as a proportional valve, there is a tendency for the spool of such a device to rotate within the bore or passage along which it is axially slidable, in use. The rotation of the spool tends to commence when the flow rate of fluid through the device exceeds a predetermined level. Whilst, in some arrangements, the rotation of the spool may not be problematic, it has been found that it tends to result in degraded performance of the device, and also increases the noise associated with the operation of the device. Accordingly, in a number of applications, the rotation of the spool may not be acceptable.

Where the spool valve arrangement is electromagnetically controlled, and a position sensor is used to sense the axial position of the spool allow closed loop control over the valve position, the position sensor may require the spool to remain in a fixed angular orientation in order to provide accurate spool position information, and so rotation of the spool may impair the ability to control the operation of the valve.

One known technique to avoid rotation of the spool of such a device is to form a part of the spool with a flat, this part of the spool being received within a washer having an opening shaped to conform with the cross-sectional shape of the part of the spool formed with the flat. The washer is located within a housing of the device, non-rotatably mounted within the housing. In use, the cooperation of the flat formed on the spool with the

corresponding part of the washer that is non-rotatably fixed within the housing resists rotation of the spool.

Whilst such an arrangement operates satisfactorily in resisting rotation, and so the disadvantages associated with rotation of the spool are avoided, the cooperation between the flat on the spool and the corresponding part of the washer results in the frictional resistance to axial movement of the spool being increased. Where the spool is driven for axial movement by an electromagnetic actuation arrangement, the solenoid current required to achieve movement of the spool to a desired position may be increased as a result of the need to overcome the increased frictional resistance to movement. A faster operating controller controlling the operation of the electromagnetic actuator may also be required. Clearly, therefore, the known technique for avoiding rotation of a spool in such an arrangement has disadvantages associated therewith, and it is an object of the invention to provide a spool valve arrangement in which at least some of the disadvantages associated with a known spool valve arrangement are overcome or are of reduced effect.

According to an aspect of the present invention there is provided a spool valve arrangement comprising a spool axially moveable along a passage formed in a housing to control communication between ports opening into the passage, and an anti-rotation arrangement operable to resist rotation of the spool relative to the housing, wherein the anti-rotation arrangement comprises a roller cooperable with the spool and the housing to resist rotation of the spool relative to the housing, the roller being supported such that it extends substantially perpendicularly to the axis of the spool.

The roller is preferably supported in such a manner that it can translate relative to both the spool and the housing, such translation being accompanied by rotation of the roller about its axis.

The roller conveniently comprises a roller pin.

The roller is conveniently carried by a support member, the roller extending into a slot formed in the spool and at least one the end of the roller being received in a recess formed in the housing, the roller being capable of translational movement within both the slot and the recess in the direction of the axis of the spool. Preferably, both ends of the roller are

received within respective recesses formed in the housing, the roller conveniently extending across the full diameter of the spool.

The support member conveniently takes the form of a washer encircling part of the spool.

According to another aspect of the invention there is provided a spool valve arrangement comprising a spool slidable within a housing, the spool defining a pair of lands cooperable with the housing to define a chamber therebetween in constant communication with a first port provided in the housing throughout a range of movement of the spool relative to the housing, cooperation between at least one of the lands and the housing controlling communication between the chamber and at least a second port provided in the housing, wherein a distribution step is provided on a part of the spool between the lands to enhance the uniformity of the fluid velocity within a part of the chamber adjacent the said at least one of the lands.

Whilst only a pair of lands is mentioned above, it will be appreciated that in practise the spool may include a greater number of lands than this.

The distribution step thus results in the formation of a part of the chamber of reduced flow area.

At least one of the lands is preferably provided with flow control notches shaped to allow the spool valve arrangement to serve as a proportional valve, the restriction to fluid flow between the first and second ports being variable and related to the position occupied by the spool.

It is thought that non-uniform velocity and pressure distributions within the chamber create an applied torque acting upon the spool, in use, which in turn can result in the application of an axial force to the spool. The provision of a distribution step to reduce such non-uniformities reduces the level of the applied torque, reducing the tendency for rotation of the spool to occur and so reduces frictional resistance to axial movement.

The spool valve arrangement according to the second aspect of the invention may further incorporate an anti-rotation arrangement in accordance with the spool valve arrangement of the first aspect of the invention.

The invention will further be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of a spool valve arrangement in accordance with an embodiment of the invention;

Figure 2 is a view illustrating part of the arrangement of Figure 1;

Figures 3 to 5 illustrate components of the part of the arrangement shown in Figure 2; and

Figures 6a, 6b and 6c are views illustrating the effect of presence of a distribution step in the valve arrangement of Figure 1.

Referring firstly to Figure 1, a spool valve arrangement in the form of a proportion spool valve 10 is illustrated. The spool valve 10 comprises a spool 12 axially movable within a passage formed in a housing 14. An electromagnetic actuator arrangement 16 is provided to drive the spool 12 for movement, controlling the position occupied by the spool 12, in use.

The spool 12 includes a series of lands 18a, 18b, 18c, 18d that cooperate with a surface of the housing 14 defining the passage to form a series of chambers 20a, 20b, 20c, 20d, 20e.

A high pressure port 22 communicates with the first chamber 20a throughout the range of axial movement of the spool 12. Return ports 24a, 24b communicate, respectively, with the chambers 22d, 22e throughout the range of movement of the spool 12, in use. A first control port 26a communicates with an annular chamber 28a formed in the housing 14 which registers with the chamber 20b, and a second control port 26b communicates with an annular chamber 28b formed in the housing which registers with the chamber 20c throughout the range of movement of the spool 12.

Each of the lands 18a, 18b, 18c, 18d is formed with equiangularly spaced notches 30, in this embodiment four notches 30 being provided on each land, which are cooperable with the edges of the annular chambers 28a, 28b to control communication between the various ports and chambers.

In the neutral position shown in Figure 1 none of the notches 30 overlies either of the annular chambers 28a, 28b, and so the various ports are isolated from one another. From this position, if the spool 12 were moved to the left under the control of the actuator 16, then the notches 30 formed in the land 18a would register with the annular chamber 28a, and so fluid communication would be established between the port 22 and the first control port 26a. The size of the restriction to fluid flow between the port 22 and the first control port 26a will be dependent upon the distance moved by the spool 12 which, in turn, controls the degree of opening between the notches 30 formed in the first land 18a and the first annular chamber 28a.

In addition to establishing communication between the port 22 and the first control port 26a, the movement of the spool 12 will further result in the notches 30 formed in the land 18d registering with the annular chamber 28b, and so controlled communication will be established between the second control port 26b and the return port 24b.

Movement of the spool 12 in the opposite direction from the neutral position establishes communication between the port 22 and the second control port 26b, and between the first control port 26a and the return port 24a.

The features described hereinbefore with reference to Figure 1 are largely conventional, and so their design and operation will not be described herein in further detail, save as required for the understanding of the invention.

As outlined hereinbefore, there is a tendency in arrangements of this type for the velocity of the high pressure fluid within the first chamber 20a to be non-uniformly distributed, in use, and as a consequence in the application of non-uniformly distributed pressures to the notches 30 of the lands 18a, 18b associated with the first chamber 20a. This results in a torque being applied to the spool 12, urging the spool 12 for rotation about its axis. Such rotation of the spool 12 can result in increased noise of operation and valve performance degradation, and so is undesirable.

In accordance with the invention, as shown in Figures 2 to 5, this embodiment includes a mechanical anti-rotation arrangement 32. The arrangement 32 comprises an extension 12a of the spool 12 in which an elongate slot 34 is formed, the slot 34 extending

diametrically relative to the spool 12. The extension 12a may be formed integrally with the spool 12 or, as illustrated, may be a separate component rigidly secured thereto by any suitable technique. A support member 36 in the form of a washer of significant axial extent encircles part of the extension 12a, the support member 36 being formed with diametrically opposed openings 38 that align with the slot 34. The support member 36 defines a face that, in use, is engaged by a resilient spring or the like arranged to apply a restoring force to the spool 12 urging it towards a neutral rest position.

A roller pin 40 extends through the slot 34 and through the openings 38 provided in the support member 36, the ends of the roller pin 40 projecting from the openings 38. The manner in which the roller pin 40 is supported is such as to allow the roller pin 40 to rotate about its axis. In the arrangement illustrated, the support member 36 may additionally support the roller pin 40, ensuring that the roller pin 40 is held in an orientation substantially perpendicular to the axis of the spool 12. However, arrangements in which the support member 32 does not provide this function, or indeed in which no separate support member 32 is provided, are possible without departing from the scope of the invention.

The part of the housing 14 adjacent the extension 12a is formed with a pair of diametrically opposed recesses 42 in which the ends of the roller pin 40 are located. The recesses 42, like the slot 34, are of elongate form, the ends of the pin 40 being able to translate lengthwise of the recesses 42 to allow the support member 36 to undertake limited movement in the direction of the axis of the spool 12.

In use, the cooperation of the roller pin 40 with the slot 34 and recesses 42 serves to resist angular or rotary movement of the spool 12. Accordingly, the noise and performance degradation that may otherwise occur are avoided. From the neutral position shown in Figure 1, movement of the spool 12 to the left will result in the support 36 and roller pin 40 also being moved to the left, the roller pin 40 rotating about its axis and translating along the length of the recesses 42 to accommodate this movement of the spool 12. The rotation of the roller pin 40 reduces frictional resistance to the axial movement of the spool 12. Movement of the spool 12 in the opposite direction from the neutral position is accommodated by roller pin 40 rotating about its axis and moving relative to the slot 34. Compared to the conventional anti-rotation arrangement, frictional resistance to axial movement of the spool 12 is reduced and so the force that must be applied by the actuator

16 to drive the spool 12 for movement is correspondingly reduced. The telescopic nature of the anti-rotation arrangement allows this reduction in frictional resistance to be achieved without significantly increasing the axial length of the valve.

Whilst, in some arrangements, the mechanical anti-rotation arrangement 32 may resist rotation of the spool 12 whilst maintaining a sufficiently low level of frictional resistance that the actuator 16 may be of relatively low power, in some applications the frictional resistance arising from the presence of the anti-rotation arrangement 32 may still be significant. In accordance with another aspect of the invention, therefore, as shown in Figures 1 and 6, the spool 12 is formed, in a chamber defined between a pair of the lands 18a, 18b, with a distribution step 44. As shown in Figure 1, when the spool 12 occupies the neutral position, the distribution step 44 is aligned, in this embodiment, with the port 22.

The diameter of the step 44 is such that a reduced annular flow area region is formed in the chamber 22a.

In use, when the spool 12 is moved, for example to the left in the orientation illustrated to establish communication between the port 22 and the first control port 26a, fluid flowing from the port 22 to the notches 30 provided in the land 18a has to pass over the distribution step 44 through the reduced flow area region, and as a result, the fluid velocity within the chamber 20a is more uniformly distributed. Figure 6 illustrates the velocity of fluid flowing through different parts of the valve under these circumstances, Figure 6a illustrating the fluid velocity profile in a plane including the port 22, Figure 6b illustrating the velocity profile in a plane including the distribution step 44, and Figure 6c illustrating the fluid pressure profile in a plane including the notches 30 formed in the land 18a. Figure 6a illustrates that the velocity is high in the part of the chamber 20a immediately adjacent the port 22, but considerably lower opposite the port 22. It also clearly shows that the velocity profile is not symmetrical, and this would give rise to the application of a torque to the spool 12 in a traditional valve. As shown in Figure 6b, the presence of the distribution step 44 serves to smooth the variations in velocity about the chamber 20a, and Figure 6c shows that by smoothing out the velocity variations using a distribution step 44, the notches 30 experience substantially the same fluid pressure as one another, and so the application of a torque to the spool 12 is significantly reduced.

The size and shape (diameter and width) of the distribution step 44, and the position thereof, required to enhance the uniformity of the fluid velocity profile, and hence the pressure applied to the notches 30, will depend upon the shape and size of the chamber 20a, the applied pressure, the shapes and sizes of the notches 30 and a number of other factors, and is thus selected according to the application in which the invention is to be used. It has been found that the use of the invention can reduce the applied torque significantly, for example by in the region of 50%.

Clearly, the embodiment of the invention described hereinbefore incorporates both a distribution step 44 serving to reduce the magnitude of the torque applied to the spool 12, and the provision of a mechanical anti-rotation arrangement 32 to resist any rotation of the spool 12. Whilst this embodiment incorporates both a distribution step 44 and an anti-rotation arrangement 32, these aspects of the invention may be used independently of one another, if desired.

Whilst a specific embodiment of the invention is described hereinbefore, it will be appreciated that a wide range of modifications and alterations may be made without departing from the scope of the invention as defined by the appended claims.

CLAIMS:

1. A spool valve arrangement comprising a spool axially moveable along a passage formed in a housing to control communication between ports opening into the passage, and an anti-rotation arrangement operable to resist rotation of the spool relative to the housing, wherein the anti-rotation arrangement comprises a roller cooperable with the spool and the housing to resist rotation of the spool relative to the housing, the roller being supported such that it extends substantially perpendicularly to the axis of the spool.

2. An arrangement according to Claim 1, wherein the roller is supported in such a manner that it can translate relative to both the spool and the housing, such translation being accompanied by rotation of the roller about its axis.

3. An arrangement according to Claim 1 or Claim 2, wherein the roller comprises a roller pin.

4. An arrangement according to any of the preceding claims, wherein the roller is carried by a support member, the roller extending into a slot formed in the spool and at least one the end of the roller being received in a recess formed in the housing, the roller being capable of translational movement within both the slot and the recess in the direction of the axis of the spool.

5. An arrangement according to Claim 4, wherein both ends of the roller are received within respective recesses formed in the housing.

6. An arrangement according to Claim 4 or Claim 5, wherein the roller extends across the full diameter of the spool.

7. An arrangement according to any of the preceding claims, wherein the support member takes the form of a washer encircling part of the spool.

8. An arrangement according to Claim 7, wherein the support member defines an end face engaged, in use, by a restoring spring.

9. A spool valve arrangement comprising a spool slidable within a housing, the spool defining a pair of lands cooperable with the housing to define a chamber therebetween in constant communication with a first port provided in the housing throughout a range of movement of the spool relative to the housing, cooperation between at least one of the lands and the housing controlling communication between the chamber and at least a second port provided in the housing, wherein a distribution step is provided on a part of the spool between the lands to enhance the uniformity of the fluid velocity within a part of the chamber adjacent the said at least one of the lands.

10. An arrangement according to Claim 9, wherein the spool further includes a plurality of additional lands.

11. An arrangement according to Claim 9 or Claim 10, wherein at least one of the lands is provided with flow control notches shaped to allow the spool valve arrangement to serve as a proportional valve, the restriction to fluid flow between the first and second ports being variable and related to the position occupied by the spool.

12. An arrangement according to any of Claims 1 to 8, wherein the spool defines a pair of lands cooperable with the housing to define a chamber therebetween in constant communication with a first port provided in the housing throughout a range of movement of the spool relative to the housing, cooperation between at least one of the lands and the housing controlling communication between the chamber and at least a second port provided in the housing, wherein a distribution step is provided on a part of the spool between the lands to enhance the uniformity of the fluid velocity within a part of the chamber adjacent the said at least one of the lands.

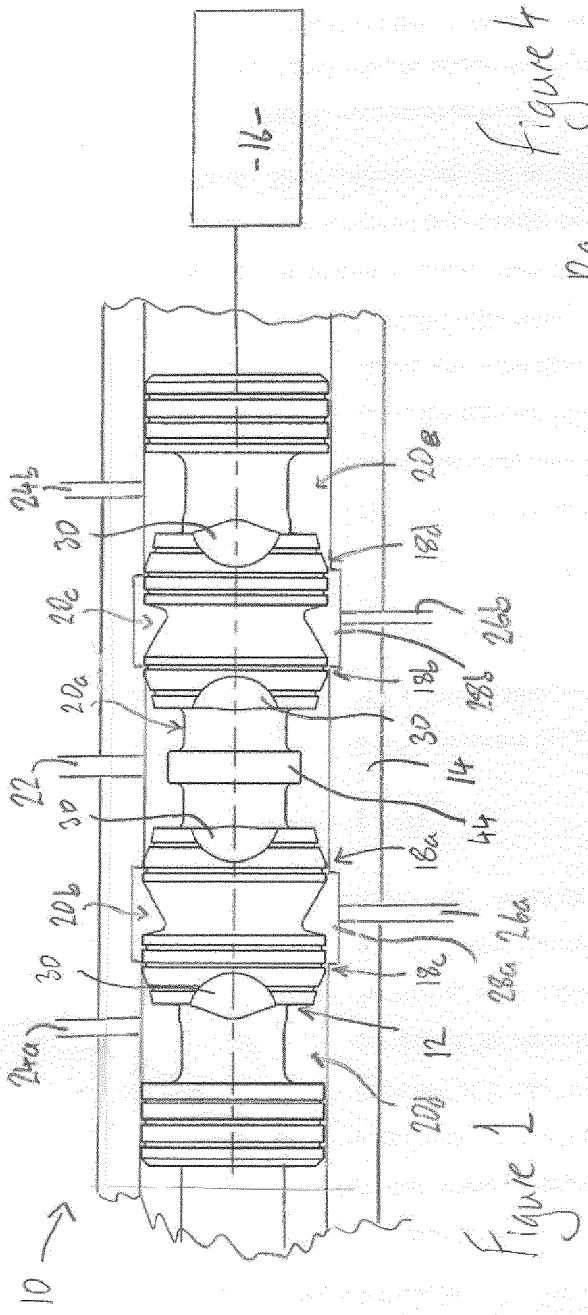


Figure 1

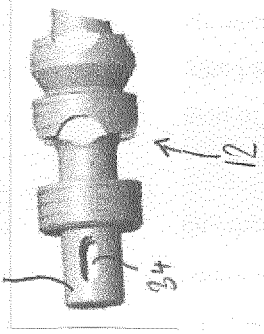


Figure 4

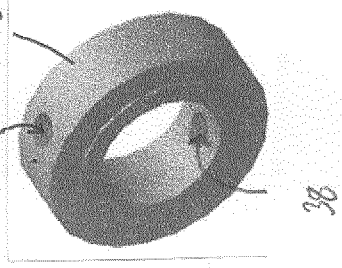


Figure 5

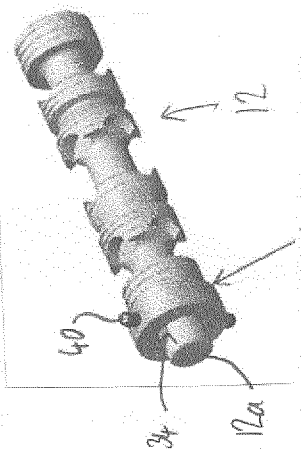


Figure 3

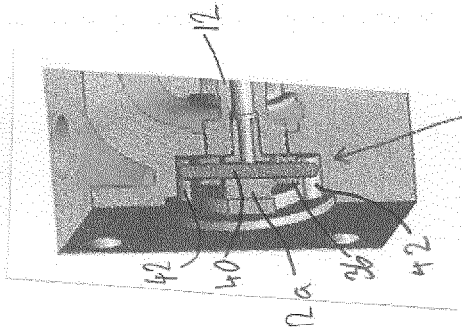
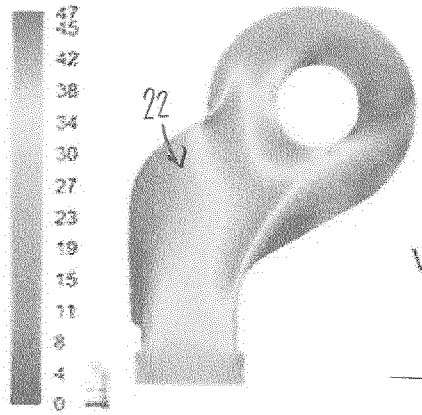


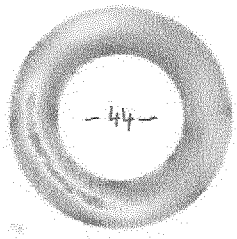
Figure 2

Figure 6a



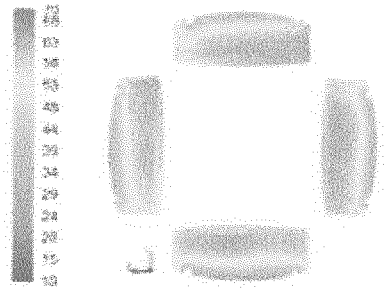
Velocity (m/s) inlet plane

Figure 6b



Velocity (m/s) mid section

Figure 6c



Pressure (bar) on spool notch surfaces

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065164

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16K11/07 F16K27/04
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)
F16K

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

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X	US 4 890 647 A (PFUHL BERTHOLD [DE] ET AL) 2 January 1990 (1990-01-02) abstract; figures 1-7	1-12
X	DE 10 2008 059434 B3 (PARKER HANNIFIN GMBH & CO KG [DE]) 7 January 2010 (2010-01-07) abstract; figures 1-3	1-12
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X	CN 103 453 170 A (UNIV ZHEJIANG) 18 December 2013 (2013-12-18) figures 1-3	1-12

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

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
1 September 2016	12/09/2016

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	Bilo, Eric

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065164

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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