



(51) International Patent Classification:

A61F 2/64 (2006.01) A61F 2/76 (2006.01)
A61F 2/74 (2006.01)

(21) International Application Number:

PCT/NL2016/050273

(22) International Filing Date:

19 April 2016 (19.04.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2014674 20 April 2015 (20.04.2015) NL

(71) Applicant: TECHNISCHE UNIVERSITEIT DELFT
[NL/NL]; Stevinweg 1, 2628 CN Delft (NL).

(72) Inventors: SMIT, Gerhardus; c/o Tu Delft, Valorisation
Centre, P.O. Box 5, 2600 AA Delft (NL). VALLERY,
Heike; c/o Tu Delft, Valorisation Centre, P.O. Box 5, 2600
AA Delft (NL).

(74) Agent: VAN BREDA, Jacques; Weteringschans 96, 1017
XS Amsterdam (NL).

(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, 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, ST, 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,

[Continued on next page]

(54) Title: ENERGY STORING PROSTHETIC KNEE ACTUATOR

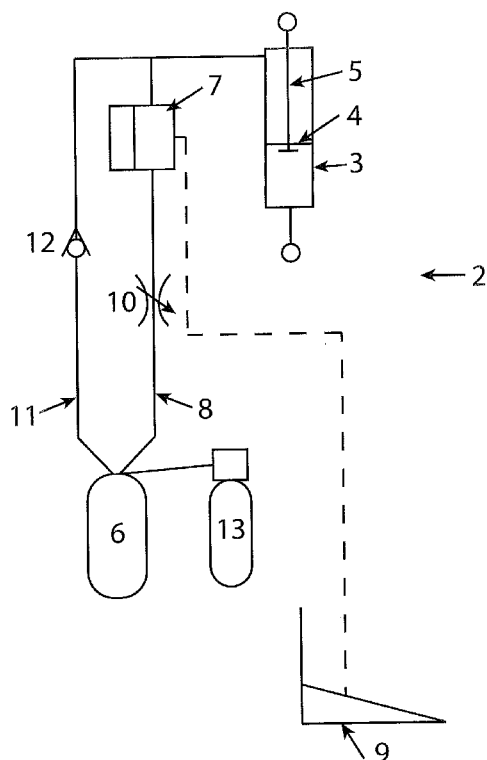


FIG. 3

(57) Abstract: Energy storing prosthetic knee actuator (2) and method of using such an energy storing prosthetic knee actuator comprising a hydraulic or pneumatic cylinder (3) with a piston (4) and a piston rod (5), wherein the piston and the hydraulic or pneumatic cylinder are movable with respect to each other, said actuator further comprising an energy storage accumulator (6) and a control valve (7) provided in piping connecting the hydraulic or pneumatic cylinder with the energy storage accumulator for controlling an exchange of fluid or gas between the energy storage accumulator and the hydraulic or pneumatic cylinder, wherein: - the hydraulic or pneumatic cylinder and the piston are connected to a user's upper leg and lower leg respectively or vice versa, and wherein the actuator is arranged to - close the control valve when the user is sitting down; and - open the control valve when the user is going to stand or standing up.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, —
GW, KM, ML, MR, NE, SN, TD, TG).

*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))*

Published:

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

Energy storing prosthetic knee actuator

The invention relates to an energy storing prosthetic knee actuator comprising a hydraulic or pneumatic cylinder with a piston and a piston rod, wherein the piston and the hydraulic or pneumatic cylinder are movable with respect to each other and are connected or connectable to a user's upper leg and lower leg respectively or vice versa, and further comprising an energy storage accumulator and at least one control valve provided in piping connecting the hydraulic or pneumatic cylinder with the energy storage accumulator for controlling an exchange of fluid or gas between the energy storage accumulator and the hydraulic or pneumatic cylinder.

Such an energy storing prosthetic knee actuator is known from EP 1 415 626.

US2013/0013085 also teaches such an energy storing prosthetic knee actuator, and is provided with at least two controllable variable fluid flow resisting devices and a control system. The control system is actuatable to cause storage of the fluid energy for a predetermined length of time and release of the fluid energy at a predetermined time during the gait cycle. Both the storage and the release of the fluid energy are variable by action of the control system.

The invention has as its prime object and aim to provide a mere standing up assist to amputees who have lost at least one of their lower legs including the knee joint. Such an assist is particularly useful for the elderly or other persons having limited physical condition and who would benefit from a device assisting them in standing up from a seated position.

Another object and aim is to provide such a standing up assist which is low weight, and which is capable to regenerate energy that is stored during sitting down and use it for standing up.

Surprisingly the inventors have found that the aims and objects of the invention can at low cost be attained in an energy storing prosthetic knee actuator comprising a hydraulic or pneumatic cylinder with a piston and a piston rod, wherein the piston and the hydraulic or pneumatic cylinder are movable

with respect to each other and wherein the actuator comprises an energy storage accumulator and a control valve provided in piping connecting the hydraulic or pneumatic cylinder with the energy storage accumulator, wherein the control valve is automatically operable and connected to at least one sensor for detection whether the user is standing up. The control valve is then suitably arranged to close off the piping and stop the flow between the hydraulic or pneumatic cylinder and the energy storage accumulator when the at least one sensor detects that the user is seated and to open said piping and thus enable the flow of gas or fluid when the at least one sensor detects that the user is standing up. The control valve is preferably a single control valve. Preferably the cylinder is a pneumatic cylinder.

Using the energy storing prosthetic knee actuator of the invention after connecting the hydraulic or pneumatic cylinder and the piston to a user's upper leg and lower leg respectively or vice versa, enables assisting the standing up of the user by controlling an exchange of fluid or gas between the energy storage accumulator and the hydraulic or pneumatic cylinder, by executing the steps of:

- providing at least one sensor for detection whether the user is seated or standing up;

- closing the control valve when the sensor detects that the user is sitting down to maintain the stored energy in the energy storage accumulator that corresponds to the flow of fluid or gas received into the accumulator as induced by the piston moving in the hydraulic or pneumatic cylinder by reason of the user's motion from standing up to sitting; and

- opening the control valve when the sensor detects that the user intends to stand or is standing up for release of the stored energy from the energy storage accumulator for driving the piston and move it with respect to the hydraulic or pneumatic cylinder to straighten the user's leg again.

It is possible to use different types of sensors, such as a mechanic, electric or a pneumatic sensor. Preferably the sensor is a load sensor, an accelerometer, an inertial measurement unit, or any suitable combination of any such sensors. Advantageously the sensor or sensors can be combined

with a suitable signal processing unit.

One other preferable feature is that the piston is movable along and up to an extremity of the piston rod. In this way the piston does not hinder extension of the knee when the user is sitting.

It may further be preferable that in addition to the control valve the piping comprises a controllable flow restriction member, which can be used to restrict the speed of the extension of the knee.

It may also be preferable that redundant piping is provided between the hydraulic or pneumatic cylinder and the energy storage accumulator, in which redundant piping a one-way valve is included enabling a flow of fluid or gas from the hydraulic or pneumatic cylinder to the energy storage accumulator. This enables that the user can sit down also when the control valve closes off the piping between the hydraulic or pneumatic cylinder and the energy storage accumulator.

One other preferable feature is that a high-pressure reservoir is provided to connect to the energy storage accumulator. This can compensate for energy losses and leakage and - if desired - can also assist the user when he has to deliver power such as when walking the stairs.

The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of an apparatus according to the invention that is not limiting as to the appended claims.

In the drawing:

-figure 1 shows a user standing up and wearing an energy storing prosthetic knee actuator according to the invention;

-figure 2 the user of figure 1 sitting down; and

-figure 3 schematically shows the energy storing prosthetic knee actuator according to the invention.

Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

Making reference first to figure 1 and figure 2 a user 1 is shown respectively standing up and sitting down, and wearing an energy storing prosthetic knee actuator 2 according to the invention, comprising a hydraulic or pneumatic cylinder

3 with a piston 4 and a piston rod 5. The piston 4 and the hydraulic or pneumatic cylinder 3 are movable with respect to each other and are connected to an upper leg 1' and lower leg 1'' of the user 1. The connection can of course also be reversed. Preferably a pneumatic cylinder is applied because of its lower weight than an hydraulic cylinder.

Making now reference to figure 3, it is shown that the actuator 2 further comprises an energy storage accumulator 6 and a control valve 7 provided in piping 8 connecting the hydraulic or pneumatic cylinder 3 with the energy storage accumulator 6. Preferably there is only a single control valve. The energy storing prosthetic knee actuator 2 of the invention thus enables assisting the standing up of the user 1 by controlling an exchange of fluid or gas between the energy storage accumulator 6 and the hydraulic or pneumatic cylinder 3, by executing the steps of:

- providing at least one sensor 9 for detection whether the user 1 is seated or standing up

- closing the control valve 7 when the sensor 9 detects that the user is sitting down to maintain the stored energy in the energy storage accumulator 6 that corresponds to the flow of fluid or gas received in the accumulator 6 as induced by the piston 4 moving in the hydraulic or pneumatic cylinder 3 by reason of the user's motion from standing up (figure 1) to sitting down (figure 2); and

- opening the control valve 7 when the sensor 9 detects that the user 1 intends to stand up or is standing up for release of the stored energy from the energy storage accumulator 6 for driving the piston 4 and move it with respect to the hydraulic or pneumatic cylinder 3 to straighten the user's leg so that the user 1 eventually can assume again the position shown in figure 1.

Although it is possible to include a manual operation, the control valve 7 operates automatically and is therefore connected to the at least one sensor 9, which is for instance provided at the bottom of the lower leg 1'', for detection whether the user 1 is in the process of standing up. According to what is mentioned above the preferably single control valve 7 is then suitably arranged to close off the piping

8 between the hydraulic or pneumatic cylinder 3 and the energy storage accumulator 6 when the sensor 9 detects that the user 1 is seated (as shown in figure 2) and to open said piping 8 and enable again the flow of gas or fluid when the at least one sensor 9 detects that the user 1 is in the process of standing up. It is possible to use different types of sensors, such as a mechanic, electric or a pneumatic sensor. Preferably the sensor 9 is selected from the group comprising a load sensor, an accelerometer, an inertial measurement unit, or any suitable combination of any such sensors.

One other preferable feature is that the piston 4 is movable along and up to an extremity of the piston rod 5. In this way the piston 4 does not hinder extension of the knee when the user 1 is sitting.

In addition to the application of a preferably single control valve 7 the piping 8 comprises advantageously a controllable flow restriction member 10 which can be used to restrict the speed of the extension of the knee.

It may also be preferable that redundant piping 11 is provided between the hydraulic or pneumatic cylinder 3 and the energy storage accumulator 6, in which redundant piping 11 a one-way valve 12 is included enabling a flow of fluid or gas from the hydraulic or pneumatic cylinder 3 to the energy storage accumulator 6. This enables that the user 1 can sit down also when the control valve 7 closes off the piping 8 between the hydraulic or pneumatic cylinder 3 and the energy storage accumulator 6 which would otherwise prevent that the piston 4 moves in the hydraulic or pneumatic cylinder 3 and correspondingly that the knee of the user 1 would be bent.

Finally a high-pressure reservoir 13 can be provided to connect to the energy storage accumulator 6. This can compensate for possible energy losses and leakage. If desired it can also be used to extend the leg in situations that additional power is required that would otherwise have to be delivered by the user, such as when walking the stairs.

Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the energy storing prosthetic knee actuator of the invention, the invention is not restricted to this particular embodiment

which can be varied in many ways without departing from the principles of the invention. The discussed exemplary embodiment shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the
5 embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the invention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of
10 the claims shall be resolved using this exemplary embodiment.

CLAIMS

1. Energy storing prosthetic knee actuator (2) comprising a hydraulic or pneumatic cylinder (3) with a piston (4) and a piston rod (5), wherein the piston (4) and the hydraulic or pneumatic cylinder (3) are movable with respect to each other and are connected or connectable to a user's upper leg (1') and lower leg (1'') respectively or vice versa, and further comprising an energy storage accumulator (6) and at least one control valve (7) provided in piping (8) connecting the hydraulic or pneumatic cylinder (3) with the energy storage accumulator (6) for controlling an exchange of fluid or gas between the energy storage accumulator (6) and the hydraulic or pneumatic cylinder (3), **characterized in that** the control valve (7) is automatically operable and connected to at least one sensor (9) for detection whether the user (1) is standing up.

2. Energy storing prosthetic knee actuator according to claim 1, **characterized in that** the cylinder (3) is a pneumatic cylinder.

3. Energy storing prosthetic knee actuator according to claim 1 or 2, **characterized in that** the control valve (7) is arranged to close off the piping (8) when the sensor (9) detects that the user (1) is seated and to open the piping (8) when the sensor (9) detects that the user (1) is standing up.

4. Energy storing prosthetic knee actuator according to any one of claims 1 - 3, **characterized in that** the sensor (9) is selected from the group comprising a load sensor, an accelerometer, an inertial measurement unit, or any suitable combination of any such sensors.

5. Energy storing prosthetic knee actuator according to any one of the previous claims 1 - 4, **characterized in that** the piston (4) is movable along and up to an extremity of the piston rod (5).

6. Energy storing prosthetic knee actuator according to any one of the previous claims 1 - 5, **characterized in that** in the piping (8) comprising the control valve (7) a controllable flow restriction member (10) is included.

7. Energy storing prosthetic knee actuator according

to any one of the previous claims 1 - 6, **characterized in that** it comprises redundant piping (11) between the hydraulic or pneumatic cylinder (3) and the energy storage accumulator (6), in which redundant piping (11) a one-way valve (12) is included enabling a flow of fluid or gas from the hydraulic or pneumatic cylinder (3) to the energy storage accumulator (6).

8. Energy storing prosthetic knee actuator according to any one of the previous claims 1 - 7, **characterized in that** it comprises a high-pressure reservoir (13) connected to the energy storage accumulator (6).

9. Energy storing prosthetic knee actuator according to any one of the previous claims 1 - 8, **characterized in that** the control valve is a single control valve (7).

10. Method of using an energy storing prosthetic knee actuator (2) comprising a hydraulic or pneumatic cylinder (3) with a piston (4) and a piston rod (5), wherein the piston (4) and the hydraulic or pneumatic cylinder (3) are movable with respect to each other, said actuator (2) further comprising an energy storage accumulator (6) and a control valve (7) provided in piping (8) connecting the hydraulic or pneumatic cylinder (3) with the energy storage accumulator (6) for controlling an exchange of fluid or gas between the energy storage accumulator (6) and the hydraulic or pneumatic cylinder (3), comprising the step of:

- connecting the hydraulic or pneumatic cylinder (3) and the piston (3) to a user's upper leg (1') and lower leg (1'') respectively or vice versa, and **characterized by** the steps of:

- providing at least one sensor (9) for detection whether the user (1) is seated or standing up;

- closing the control valve (7) when the sensor (9) detects that the user (1) is sitting down; and

- opening the control valve (7) when the sensor (9) detects that the user (1) is standing up.

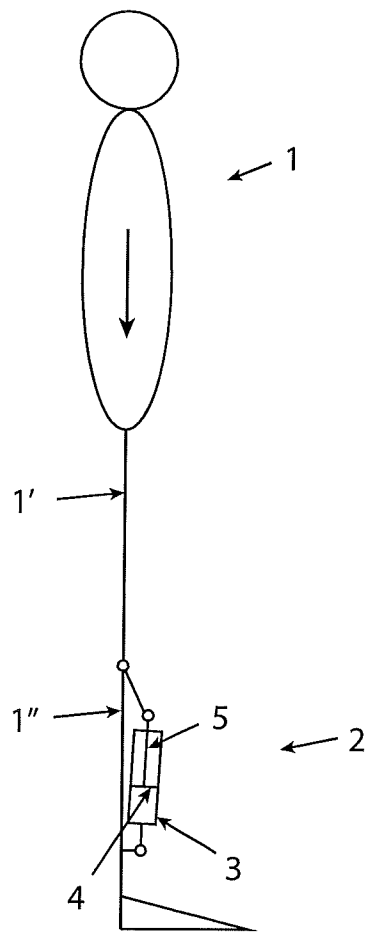


FIG. 1

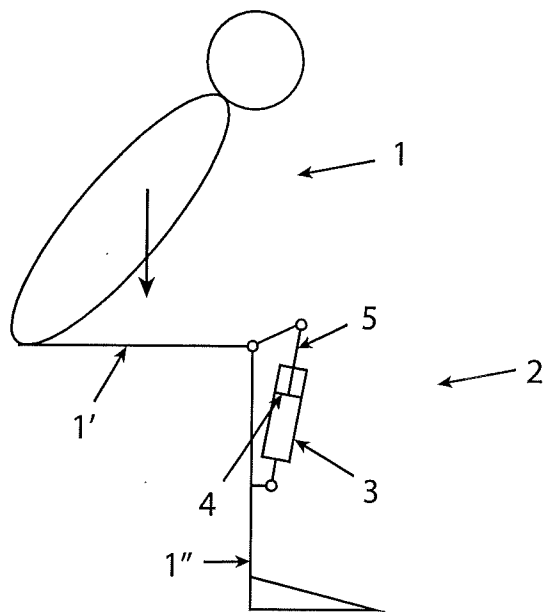


FIG. 2

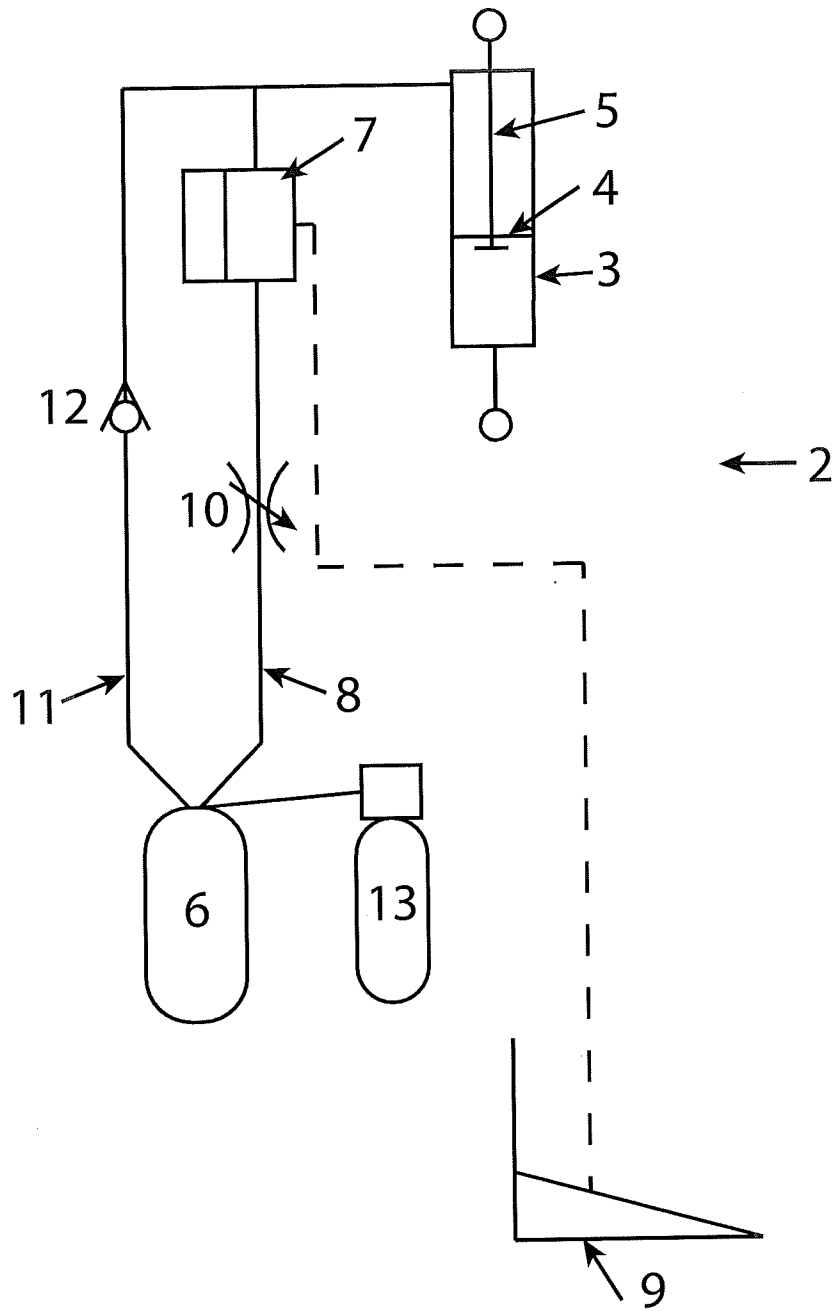


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2016/050273

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F2/64 A61F2/74
ADD. A61F2/76

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)
A61F

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 2013/013085 A1 (SMITH WILLIAM A [US] ET AL) 10 January 2013 (2013-01-10) cited in the application	1-4,6, 8-10
A	paragraph [0026] - paragraph [0073] -----	5,7
A	US 8 317 874 B2 (PUSCH MARTIN [DE] ET AL) 27 November 2012 (2012-11-27) column 7, line 40 - column 9, line 54 -----	1-10
A	EP 1 415 626 A2 (MOLINO JOSEPH L [US]; REBARBER MICHAEL [US]) 6 May 2004 (2004-05-06) cited in the application the whole document -----	1-10



Further documents are listed in the continuation of Box C.



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

5 September 2016

Date of mailing of the international search report

19/09/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Lickel, Andreas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2016/050273

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013013085 A1	10-01-2013	US 2013013085 A1	10-01-2013
		WO 2012151515 A1	08-11-2012

US 8317874 B2	27-11-2012	BR PI0814562 A2	06-01-2015
		CN 103002836 A	27-03-2013
		DE 102007032090 A1	15-01-2009
		EP 2175809 A2	21-04-2010
		RU 2010104244 A	20-08-2011
		TW 200920332 A	16-05-2009
		US 2010191347 A1	29-07-2010
		WO 2009006886 A2	15-01-2009

EP 1415626 A2	06-05-2004	EP 1415626 A2	06-05-2004
		US 2004083008 A1	29-04-2004
