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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 February 2020 (20.02.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/035256 A1

(51) International Patent Classification:
G01F 22/00 (2006.01) *G01N 29/04* (2006.01)
G01F 23/296 (2006.01) *G01N 29/12* (2006.01)
G01F 25/00 (2006.01)

(21) International Application Number:
PCT/EP2019/069384

(22) International Filing Date:
18 July 2019 (18.07.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1813406.4 16 August 2018 (16.08.2018) GB

(71) Applicant: **LINDE AKTIENGESELLSCHAFT** [DE/DE]; Klosterhofstrasse 1, 80331 Munich (DE).

(72) Inventors: **BAYERL, Wilhelm**; Kirchstraße 18a, 82054 Sauerlach (DE). **BLONDEAU, Jean**; Spreestraße, 1512555 Berlin (DE). **BOHN, Matthias**; Stienitzallee 28, 15370 Petershagen (DE).

(74) Agent: **GELLNER, Bernd**; Linde Aktiengesellschaft, Corporate Intellectual Property, Dr.-Carl-von-Linde-Str. 6-14, 82049 Pullach (DE).

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, 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,

(54) Title: SYSTEM AND METHOD FOR MEASURING THE FILL LEVEL OF GAS IN A CYLINDER, METHOD TO CALIBRATE THE SYSTEM AND A METHOD TO DETECT DEFECTS

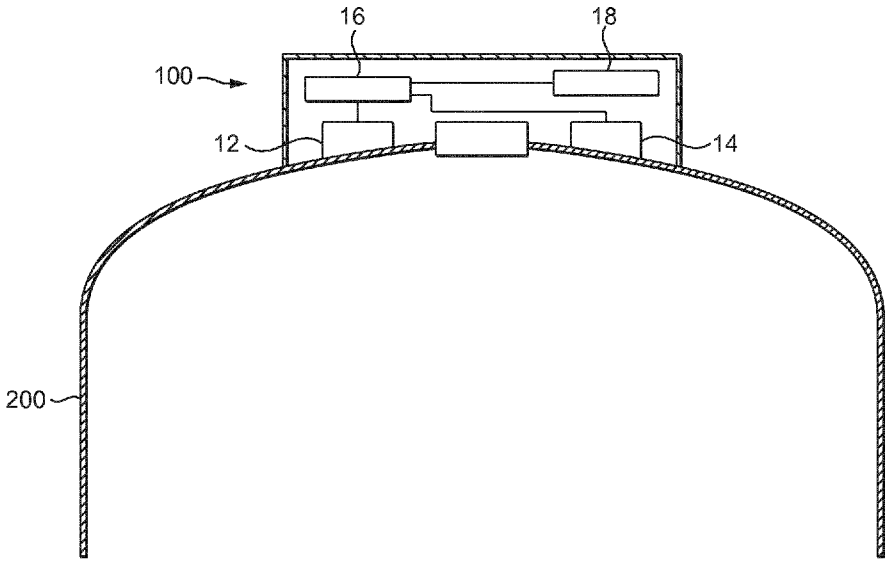

FIG. 1

(57) Abstract: The invention provides a system for measuring the fill level of gas inside a cylinder. The system comprises an impactor configured to apply an acoustic impact to a cylinder; a sensor configured to detect a response from the cylinder to the acoustic impact and generate a signal indicative thereof; and a computer readable storage medium including data representative of a first response from the cylinder to an acoustic impact when the cylinder is at a first fill level. A processor is provided in communication with the sensor and computer readable storage medium, wherein the processor is configured to: receive the signal from the sensor; compare the signal to the data representative of the first response; and determine a fill level of the cylinder based upon this comparison.

WO 2020/035256 A1

[Continued on next page]

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

Published:

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

SYSTEM AND METHOD FOR MEASURING THE FILL LEVEL OF GAS IN A CYLINDER, METHOD TO CALIBRATE THE SYSTEM AND A METHOD TO DETECT DEFECTS

The present invention is directed to a system for measuring the fill level of gas inside a cylinder and corresponding method of use and method calibration.

Conventionally, the only method suitable for measuring the content of a mobile gas vessel (such as a gas cylinder) filled with under-pressure liquefied gas has been to weigh the full cylinder and subtract the pre-measured weight of the cylinder when it was empty (tare weight). This is not an optimal solution as the gas cylinder should be disconnected from its associated piping in order to ensure a correct weight reading. In particular, the weight could be miscalculated as any cylinder fixation would impact upon the measured weight. Each connection and disconnection of the cylinder is an additional task involved in the measuring process and will allow an amount of gas to be lost to the atmosphere. Some systems do allow a cylinder with connected piping to be weighed. However, this means that the tare weight of the cylinder must also be determined in an identical configuration. This can be altered by any remaining pressure or tension in the connection pipes which still leads to erroneous results.

The content of permanent gasses in gas vessels has typically been measured by using a pressure sensor. For higher accuracy a temperature sensor can also be included to account for the effect of temperature of the gas on the exerted pressure. Each of these sensors requires a direct media contact to the pressurised gas. Accordingly, they will need to be inserted into the cylinder which introduces an additional step and allows for potential losses. The materials used in the sensor must also be carefully selected to ensure that they are compatible with the gas within the cylinder. Furthermore, it is not possible to measure the remaining content in a gas vessel filled with under pressure liquefied gasses simply by measuring the pressure in this manner. The head-pressure in such a cylinder is substantially constant until the very last of the liquid phase has been vaporised. The pressure then experiences a rapid drop. Accordingly, the pressure sensing method suitable for permanent gasses is not applicable in this situation.

There is therefore a need for an easy method to measure the remaining gas content in a gas cylinder.

A system for measuring the fill level of gas inside a cylinder according to the present invention is provided according to claim 1.

This system allows the fill level to be reliably measured without having to insert any probes into physical contact with the vessel's contents. The system can also be used in-situ with a gas cylinder. In particular embodiments, the system can operate remotely without the need for an operator to physically access the system.

The computer readable storage medium may further include data representative of a second response from the cylinder to an acoustic impact when the cylinder is at a second fill level, different to the first fill level; and the processor may be further configured to: compare the signal to the data representative of the second response; and determine the fill level also based upon this comparison.

Having responses at two fill levels allows extrapolation to form a response profile for the cylinder across the entire range of fill levels. The fill level can therefore be accurately measured for any amount of gas in the cylinder.

The first fill level may be between 0% and 10%.

This represents a lower bound, representing when a cylinder is generally empty. This lower bound can be used to inform a user that the cylinder needs replacing.

The first fill level may be between 0% and 10%; and the second fill level may be between 90% and 100%.

These two readings generally span the entire range of fill levels and an accurate extrapolated response profile can be formed therefrom.

A method for measuring the fill level of gas inside a cylinder according to the present invention is provided according to claim 5.

This method allows the fill level to be reliably measured without having to insert any probes into physical contact with the vessel's contents. The system can also be used in-situ with a

gas cylinder. In particular embodiments, the system can operate remotely without the need for an operator to physically access the system.

The method may further comprise the steps of: comparing the response to a second stored response at a second fill level; and determining the fill level of the cylinder based upon the comparison.

Having responses at two fill levels allows extrapolation to form a response profile for the cylinder across the entire range of fill levels. The fill level can therefore be accurately measured for any amount of gas in the cylinder.

The first fill level may be between 0% and 10%.

This represents a lower bound, representing when a cylinder is generally empty. This lower bound can be used to inform a user that the cylinder needs replacing.

The first fill level may be between 0% and 10%; and the second fill level may be between 90% and 100%.

These two readings generally span the entire range of fill levels and an accurate extrapolated response profile can be formed therefrom.

A method of calibrating a system for measuring the fill level of gas inside a cylinder according to the present invention is provided according to claim 9.

The first fill level may be between 0% and 10%; and the second fill level may be between 90% and 100%.

These two readings generally span the entire range of fill levels and an accurate extrapolated response profile can be formed therefrom.

A method of detecting defects in a cylinder according to the present invention is provided according to claim 11.

This method allows defects in the cylinder to be remotely detected without requiring inspection of the cylinder. The defects are also detected without requiring any physical contact between a sensor and the contents of the cylinder.

The present invention will now be described with respect to the following Figures in which:

Figure 1 shows a schematic cross-section of a system according to the present invention.

Figure 1 shows a system 100 for measuring the fill level of gas inside a cylinder 200. While the present invention is described with respect to a cylinder 200, this is merely exemplary and the gas container could be any shape. In particular, the gas is preferably an under-pressure liquefied gas or a permanent gas. The system 100 comprises an impactor 12 which is in physical contact with an outer surface of the cylinder 200. The impactor 12 may be arranged to physically strike the cylinder 200. Alternatively, the impactor 12 may use some other method to generate vibrations in the cylinder 200. The impactor 12 may be an actuator, in particular a piezoelectric actuator, a solenoid actuator, a spring powered actuator or a simple mechanical (hammer) actuator. The impactor 12 is configured to apply an acoustic impact to the cylinder 200. This acoustic impact will travel through the cylinder 200 and the characteristics thereof will be determined by the fill level of the cylinder 200.

A sensor 14 is further provided in communication with an outer surface of the cylinder 200. The sensor 14 may be any suitable sensor which is capable of determining the response of the cylinder 200 to the acoustic impact. In particular, the sensor 14 may be a vibrometer or microphone. As the acoustic impact travels through the cylinder 200 a response thereto will be generated by the cylinder 200. This sensor 14 is configured to detect this response and generate a signal indicative thereof.

The signal generated by the sensor 14 is transmitted to a processor 16. The processor 16 is further in communication with a computer readable storage medium 18. The computer readable storage medium 18 may be provided locally in proximity to the cylinder 200. Alternatively, or in addition, the computer readable storage medium may be a remote system which can be accessed by the system 100, such as via the internet (the “Cloud”). The computer readable storage medium 18 includes data representative of at least a first response from the cylinder 200 to an acoustic impact when a cylinder 200 is at a first fill

level F_1. The processor 16 compares the received signal from the sensor 14 to the first response and based upon this comparison determines the fill level of the cylinder 200.

The number of responses stored in the computer readable storage medium 18 that the processor 16 is configured to determine the fill level depends upon the accuracy required. For simple operations, it may be sufficient to have a single stored response and the processor 16 simply configured to determine whether the contact fill level F_C is higher or lower than the fill level F, for this stored response. In particular, this fill level F, could be between 40% and 60%. In preferred embodiments this fill level F, may be approximately 50%. Accordingly, the processor 16 would be able to determine whether the cylinder 200 is above or below half-full. In further embodiments, this first fill level F, could be set at a lower bound, such as between 0 to 20%, in order to warn the user that the cylinder 200 is substantially empty and near replacement.

In a preferred solution, the computer readable storage medium 18 includes first and second responses from the cylinder to an acoustic impact when the cylinder is at first and second fill levels F_1, F_2 being different to one another. The first and second fill levels F_1, F_2 may be selected to generally correspond to a full state of the cylinder 200 and an empty state of the cylinder 200 respectively. While it may not be possible to completely empty or completely fill the cylinder it is appreciated that within 10% thereof may be suitable for the present invention. With these empty and full responses stored, the processor 12 may extrapolate a reference for the entire range of fill-levels that the detected signal can be compared to. This allows the current fill level F_C of the cylinder 200 to be generally known at any level.

In order to obtain these empty and full fill levels a calibration method may need to be carried out on the cylinder 200. In particular, the cylinder 200 when empty can have the acoustic impact applied by the impactor 12 and the response detected by the sensor 14. This response is then stored in the computer readable storage medium 18 (whether locally or remotely, as discussed above). The cylinder 200 is then filled with the relevant gas and the impactor 12 applies a second acoustic impact to the now full cylinder 200. Again, the response thereto is detected by the sensor 14 and stored in the computer readable storage medium 18. The system 100 is then configured to determine the current fill-level F_C of the cylinder 200. This configuration needs to be done only once for each combination of cylinder 200 and fill-gas.

While this calibration can be done locally at each time, it is also anticipated that the calibration may be done globally for known cylinder and gas combinations and stored on the computer readable storage medium 18. The system 100 may then further comprise an input for the user to select which pre-stored calibration they desire without the need to locally re-calibrate.

The system 100 may further include a transmitter which is configured to send a signal when the cylinder 200 reaches a pre-determined low level. This signal may be for example a warning signal which could be sent to a user's device such as a smart phone. Alternatively, the signal could automatically trigger an order for a replacement cylinder to be delivered. The signal can be sent via any known transmission method with an appropriate transmitter selected. This includes, but is not limited to, via Bluetooth (RTM) and/or the internet.

A further use of the system 100 may be to detect damage in the cylinder 200 (cracks, corrosion, etc.). The response of the cylinder 200 to the acoustic impact can be compared to a response at a known pressure stored on the computer readable storage medium 18 (whether locally or remotely, as discussed above). The differences between the response of the cylinder 200 and the stored response can then be analysed in order to determine any defects in the cylinder 200. For example, cracks or corrosion may cause a reflection of the response to be generated, which can be detected. The comparison may, in particular embodiments, take the form of a comparison of the acoustic spectrum of the responses.

While the system 100 depicted in the Figures is shown generally in the valve region of the cylinder 200 this is not necessarily the case. In particular, the system 100 could be provided at any point on the cylinder 200. This may be in the form of a further attachable component which attaches to the cylinder. However, it is convenient if the system can be incorporated into the valve as there may already be further use for components therein.

CLAIMS:

1. A system for measuring the fill level of gas inside a cylinder, the system comprising:

an impactor configured to apply an acoustic impact to a cylinder;

a sensor configured to detect a response from the cylinder to the acoustic impact and generate a signal indicative thereof; and

a computer readable storage medium including data representative of a first response from the cylinder to an acoustic impact when the cylinder is at a first fill level;

a processor in communication with the sensor and computer readable storage medium, wherein the processor is configured to:

receive the signal from the sensor;

compare the signal to the data representative of the first response; and

determine a fill level of the cylinder based upon this comparison.

2. The system of claim 1, wherein:

the computer readable storage medium further includes data representative of a second response from the cylinder to an acoustic impact when the cylinder is at a second fill level, different to the first fill level; and

the processor is further configured to:

compare the signal to the data representative of the second response; and

determine the fill level also based upon this comparison.

3. The system of claim 1 or 2, wherein the first fill level is between 0% and 10%.

4. The system of claim 2, wherein:

the first fill level is between 0% and 10%; and

the second fill level is between 90% and 100%.

5. A method for measuring the fill level of gas inside a cylinder, the method comprising the steps of:

providing a cylinder;

applying an acoustic impact to the cylinder;

detecting a response from the cylinder to the acoustic impact;

comparing the response to a first stored response at a first fill level; and

determining a fill level of the cylinder based upon the comparison.

6. The method of claim 5, further comprising the steps of:
comparing the response to a second stored response at a second fill level; and
determining the fill level of the cylinder based upon the comparison

7. The method of claim 5 or 6, wherein the first fill level is between 0% and 10%.

8. The method of claim 6, wherein:
the first fill level is between 0% and 10%; and
the second fill level is between 90% and 100%.

9. A method of calibrating a system for measuring the fill level of gas inside a cylinder, the method comprising the steps of:
providing a generally empty cylinder at a first fill level;
applying an acoustic impact to the cylinder;
detecting an empty response from the cylinder to the acoustic impact;
storing the empty response in a computer readable storage medium;
filling the cylinder with a gas to a generally full second fill level;
applying a further acoustic impact to the cylinder;
detecting a full response from the cylinder to the acoustic impact; and
storing the full response in the computer readable storage medium.

10. The method of claim 9, wherein:
the first fill level is between 0% and 10%; and
the second fill level is between 90% and 100%.

11. A method of detecting defects in a cylinder, the method comprising the steps of:
providing a cylinder;
applying an acoustic impact to the cylinder;
detecting a response from the cylinder to the acoustic impact;
comparing the response to a first stored response at a first fill level; and
determining whether there are any defects in the cylinder based upon the comparison.

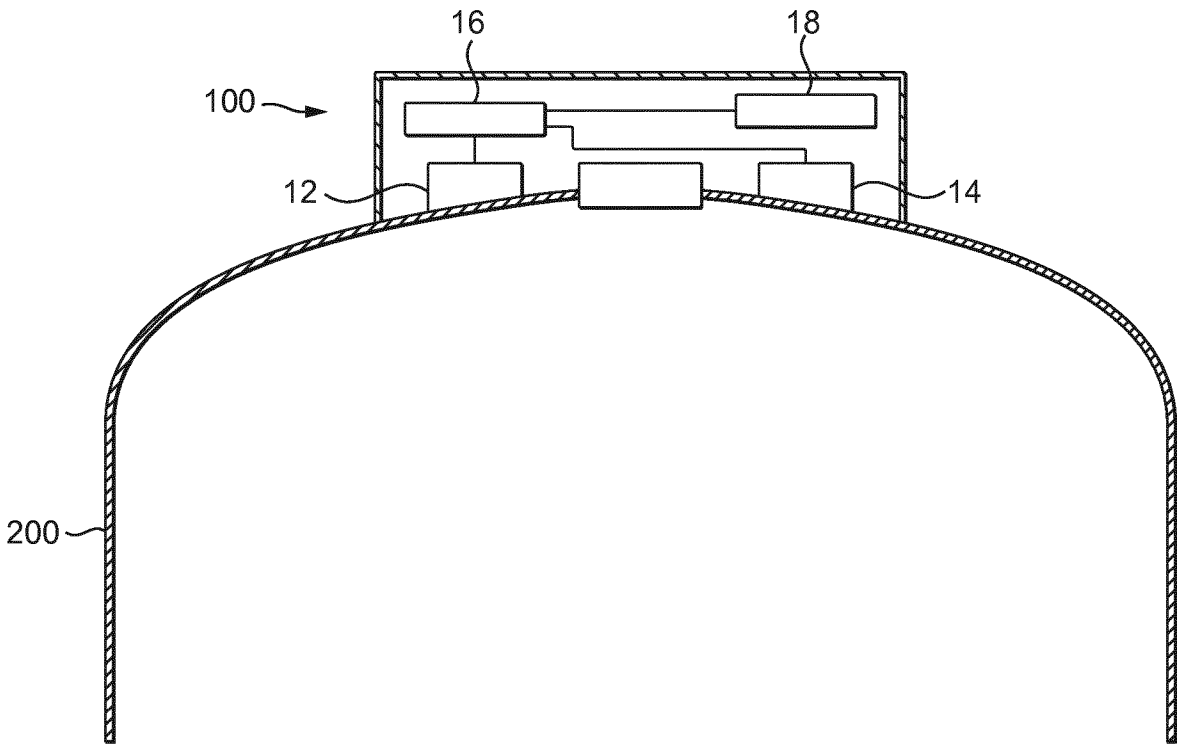

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/069384

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F22/00 G01F23/296 G01F25/00 G01N29/04 G01N29/12
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)
G01F G01N

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 2006/021448 A1 (YOUNG WINSTON B [US] ET AL) 2 February 2006 (2006-02-02) paragraphs [0022] - [0032]; figure 1 paragraph [0035] - paragraph [0037] paragraphs [0057] - [0058] paragraph [0060] - paragraph [0061]; figure 5 ----- -/--	1-10

[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
2 October 2019	16/10/2019

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	Tomasoni, Flora

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HSIEN-HUANG P. WU ET AL: "Analysis and Implementation of Noncontact Level Sensing for a Pressurized Cylinder", JOURNAL OF SENSORS, vol. 2016, 1 January 2016 (2016-01-01), pages 1-10, XP055614187, US ISSN: 1687-725X, DOI: 10.1155/2016/5027916 3; figure 3 4 5	1-10
X	EP 2 765 399 A1 (PRIMAGAZ NEDERLAND B V [NL]) 13 August 2014 (2014-08-13) paragraph [0023] - paragraph [0025]; figure 1 figure 3	1-10
X	WO 2010/070758 A1 (JAPAN APPLIED FLOW CO LTD [JP]; KAIJO SONIC CORP [JP] ET AL.) 24 June 2010 (2010-06-24) paragraphs [0015] - [0028]; figures 2,3	1-10
X	US 6 338 272 B1 (HEUFT BERNHARD [DE] ET AL) 15 January 2002 (2002-01-15) column 3, lines 52-60 column 5, line 41 - column 6, line 15; figure 1 column 6, lines 17-36; figure 2 column 6, lines 37-57; figure 3	1-11
X	US 2013/263657 A1 (SIDES PAUL J [US]) 10 October 2013 (2013-10-10) paragraphs [0016] - [0017]; figure 1 paragraph [0018] - paragraph [0021]; figures 2-5	1-10
X	WO 2009/118542 A1 (JONHSON MATTHEY PLC [GB]; PARTINGTON THOMAS JOHN [GB] ET AL.) 1 October 2009 (2009-10-01) page 6, lines 32-35 page 11, lines 8-49; figure 10 page 14, lines 1-6	1-10
X	US 2013/118261 A1 (STOTHERS IAN MCGREGOR [GB] ET AL) 16 May 2013 (2013-05-16) paragraph [0004] paragraphs [0009] - [0013]; figure 1	11

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/069384

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006021448 A1	02-02-2006	US 2006021448 A1	02-02-2006
		US 2008115581 A1	22-05-2008
		US 2010218599 A1	02-09-2010
		US 2012053862 A1	01-03-2012
		US 2014366619 A1	18-12-2014
		US 2018238728 A1	23-08-2018
EP 2765399 A1	13-08-2014	CN 103983325 A	13-08-2014
		EP 2765399 A1	13-08-2014
		NL 2010286 C2	13-08-2014
WO 2010070758 A1	24-06-2010	JP 3171135 U	20-10-2011
		WO 2010070758 A1	24-06-2010
US 6338272 B1	15-01-2002	AT 221990 T	15-08-2002
		BR 9713340 A	09-05-2000
		CA 2268549 A1	22-05-1998
		DE 19646685 A1	14-05-1998
		DK 0938653 T3	02-09-2002
		EP 0938653 A1	01-09-1999
		ES 2182135 T3	01-03-2003
		JP 3856478 B2	13-12-2006
		JP 2001503868 A	21-03-2001
		PT 938653 E	31-12-2002
		US 6338272 B1	15-01-2002
		WO 9821557 A1	22-05-1998
US 2013263657 A1	10-10-2013	NONE	
WO 2009118542 A1	01-10-2009	NONE	
US 2013118261 A1	16-05-2013	CN 103221815 A	24-07-2013
		EP 2596344 A1	29-05-2013
		GB 2482124 A	25-01-2012
		US 2013118261 A1	16-05-2013
		WO 2012010863 A1	26-01-2012