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(71) Applicant: FORTEST EUROPE SAGL [CH/CH]; Via
Balestra 12, 6900 Lugano (CH).

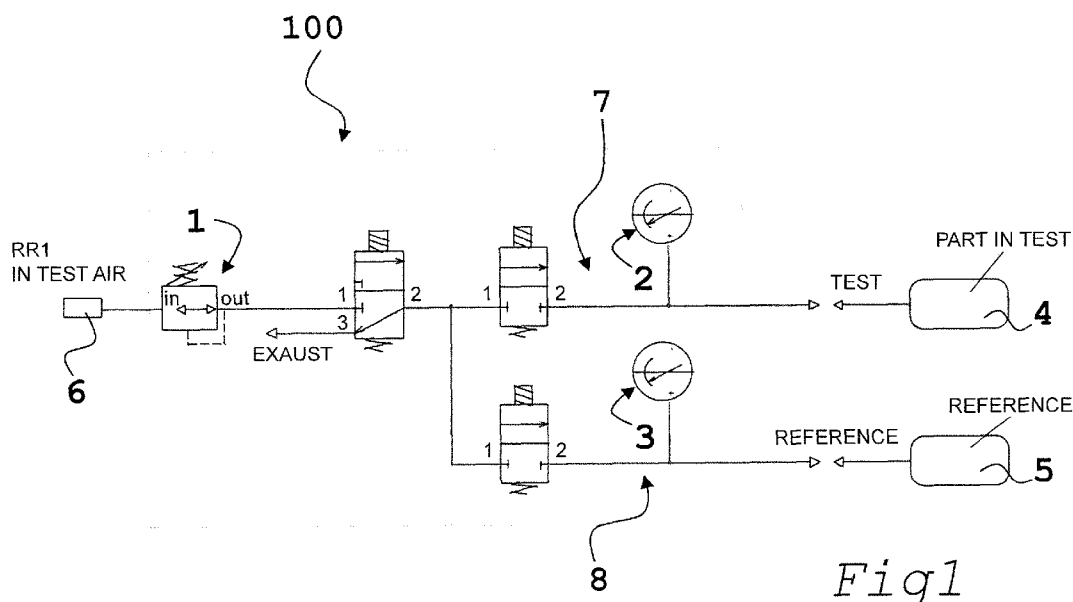
(72) Inventor: TOMASINI, Alessandro; Via Balestra 12, 6900
Lugano (CH).

(74) Agent: GANGUILLET, Cyril et al.; ABREMA Agence
Brevets et Marques, Ganguillet, Av. du Théâtre 16, C.P.
5027, 1002 Lausanne (CH).

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(54) Title: PNEUMATIC LEAK MEASUREMENT SYSTEM BASED ON ABSOLUTE PRESSURE DROP MEASUREMENT,
WITH REFERENCE SAMPLE DIFFERENTIAL COMPENSATION



(57) Abstract: The present invention specifically relates to the pneumatic and electronic application of a pneumatic leak meter based on absolute pressure drop measurement having the peculiarity of compensating for ambient variations such as ambient temperature and temperature of the measured part, as well as mechanical deformations of the component being tested caused by the pressure being applied.



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**PNEUMATIC LEAK MEASUREMENT SYSTEM BASED ON ABSOLUTE
PRESSURE DROP MEASUREMENT, WITH REFERENCE SAMPLE
DIFFERENTIAL COMPENSATION**

FIELD OF APPLICATION OF THE INVENTION

The present invention specifically relates to the pneumatic and electronic application of a pneumatic leak meter based on absolute pressure drop measurement having the peculiarity of compensating for ambient variations such as ambient temperature and temperature of the measured part, as well as mechanical deformations of the component being tested caused by the pressure being applied.

STATE OF THE ART

According to the detailed classification in standard EN1779, the instruments used for leak testing fall into two basic categories, namely:

- tracer gas systems or leak location,
- air/air meters of the ATE type (ATE being the acronym for Automatic Test Equipment).

In the field of air/air ATE instrumentation, two types of measurement systems based on pressure drop measurement predominantly come into consideration, namely those based on absolute pressure drop measurement of the test part and those based on differential pressure drop measurement of the test part.

Both systems calculate the leak rate by measuring pressure decay over time, which can be expressed by the following function:

$$Leak = dp/dt$$

Meters of the “absolute pressure drop” type calculate the leak by analysing the “direct” pressure decay, i.e. after completion of the filling/pressurization phase, the branch being measured is isolated hermetically using a leak-free valve, enabling the equipment to analyse any possible pressure drop of the object being tested.

Meters of the “differential pressure drop” type perform a similar measurement, but compare the pressure decay of the object being tested with a hermetic sample volume referred to as “reference part”.

Unlike absolute pressure drop systems, differential pressure drop systems use a second differential pressure transducer, and the whole pneumatic circuit is more complex due to the low sensitivity (or resolution accuracy) of past pressure sensors. Indeed, a characteristic of the pressure drop over time (dp/dt) is that the smaller the appreciable difference in pressure (dp), the greater the sensitivity, speed and accuracy of the measurement.

For this reason, as early as in the 1970s, it was possible to produce differential pressure drop meters with a resolution capability of tenths of Pascals, which was not achievable at the time using absolute pressure drop systems.

Furthermore, as a result of the use of differential transducers, the processing and management electronics of this equipment was, at the time, extremely simplified, the measurement having no offset and being indeed “central zero”.

Conversely, and in parallel with the development of industrial force and weight measurements, the quality of pressure measurements and pressure transducers has improved significantly over the years, such that today it is

possible to obtain the same measurement resolution, even with very high offset values, as is the case with leak measurements of the “absolute pressure drop” type.

The application of microprocessors and related calculation and compensation algorithms have led, over time, to performances of measurements of the “absolute pressure drop” type that are more than comparable with measurements of the “differential pressure drop” type, thereby simplifying the pneumatic sections and improving the overall reliability of the measurement systems.

There nonetheless remains an intrinsic benefit in circuitry of the “differential” type, which is related to the partial (or apparent) common-mode compensation of the measurements; in fact, all pressure decay measurement systems implies the Gay-Lussac law of ideal gases:

$$pV=nRT$$

from which it can be inferred that thermal variances of the environment or of the test part cause errors and drift in the measurement.

For this reason, differential pressure drop meters enable compensation, precisely by virtue of the common-mode elision of two components being measured (namely the part being tested and the reference part) under the same thermal conditions.

It is clear, however, that the volume variances caused by expansions of the two components being tested in turn cause measurement errors. Indeed, in a differential pressure drop system, commonly intended for industrial production, with a high operating frequency, the mechanical expansion of the component being tested is understood to be limited to the measurement

operation only, while the mechanical stress on the reference sample part will accumulate for the entire usage time of the equipment to an indefinite number of times, ultimately leading to a continuous drift of the behaviour between the two parts - typically - after just 15/30 minutes of work at steady regime.

5 Similarly, as a result of the continuous pressurization and emptying of the single reference sample part, there is an increasing thermal accumulation that triggers endogenous thermal effects, thereby partially nullifying the effect of thermal compensation.

10 In practice, empirical surveys have shown that a metal component with a volume of 300 cc subjected to a relative pressure of 2 bar requires at least 20 minutes in order to restore the conditions of elasticity and rest temperature, namely return to a repeatability margin of 10% compared to the first test carried out.

15 For this reason, the concept of apparent repeatability has been introduced, over time, in the use of differential pressure drop meters, namely the phenomenon of good repeatability when taking repeated measurements on the same component, measurement stability that is not however maintained during practical use in production.

20 As a partial solution to the foregoing, manufacturers have devised different variants of algorithms designed to integrate and average, over time, the trends in tests considered to be “good”, namely measurements falling within limits of acceptability, and to use this data to obtain an average trend of what is considered to be the “sample part”.

25 The limitations of all of these analysis systems can be found in the basic incongruity of the concept, namely that the components measured from time to

time are not quality standards but rather parts with intrinsic variability.

The practical reason for the unreliability of the aforementioned algorithms can be found in the complexity of the error accumulated during the measurements. In fact, in addition to a temperature and expansion drift, practical application also involves possible elastic phenomena of the systems providing connection to the component being measured, vibrations, and spurious movements during testing.

The accumulation of all of these errors, in practice, significantly limits the use of these filters since the time and level parameters are too different from one another.

PRESENTATION AND ADVANTAGES OF THE INVENTION

In this context, the underlying technical objective of the present invention is to provide a system for measuring pneumatic leaks that overcomes the drawbacks of the prior art mentioned above, which system takes the form of a simple, robust and reliable solution.

This and other objectives are achieved thanks to the features of the invention as set forth in the independent and dependent claims, which outline preferred and/or particularly advantageous aspects of the invention.

In particular, the preferred embodiment of the present invention provides a pneumatic leak measurement system based on differential pressure drop measurement, which system comprises two absolute pressure drop measurement circuits and associated electronics to subtract the pressure values measured by the two measurement circuits one from the other.

Thanks to this solution it is therefore possible to:

- periodically characterize a reference sample of the component

being tested in terms of temperature and expansion, however without using intrusive elements causing thermal or mechanical drift,

- obtain the benefits of measurement of the differential type, without the drawbacks of complexity and, especially, of “apparent repeatability”.

More specifically, the system according to the invention relies on a traditional high-resolution absolute pressure drop meter combined with a second similar branch connected to a reference component/part, wherein the reference component/part is understood to be a quality, leak-free reference sample.

These objectives and advantages are all achieved thanks to the pneumatic leak measurement system based on absolute pressure drop measurement, with reference sample differential compensation according to the present invention, as characterized in the claims appended hereto.

BRIEF DESCRIPTION OF THE FIGURES

This and other features of the present invention will appear more clearly from reading the following detailed description of embodiments of the invention which are presented solely by way of non-restrictive examples and illustrated by the attached drawings in which:

- Figure 1 illustrates a schematic pneumatic diagram of a pneumatic leak measurement system according to an embodiment of the invention; and

- Figure 2 illustrates basic electronics of the system shown in Figure 1, configured to acquire two pressure values ($P_{TEST}/Press_Test$ and $P_{REF}/Press_Ref$) and to continuously sample a difference ($Press_Diff$)

between said values.

DESCRIPTION OF THE INVENTION

With particular reference to Figure 1, reference numeral 100 generally designates the system for measuring pneumatic leaks of an object or part 4 in accordance with an embodiment of the present invention, namely a pneumatic leak meter based on absolute pressure drop measurement that compensates for ambient variations such as ambient temperature and temperature of the part 4 being measured, as well as mechanical deformations of the component being tested caused by pressure being applied, as detailed below.

More specifically, reference numeral 1 designates a pneumatic “filling” or pressurization section of the object 4 being measured.

Industrial air, designated by reference numeral 6 in Figure 1, is commonly used to carry out the filling or pressurization phase.

As shown in the diagram of Figure 1, filling or pressurization of the object 4 to be measured is performed via a common pneumatic valve and a first circuit 7. This first circuit 7 includes a dedicated pneumatic valve for selectively coupling the first circuit 7 to the aforementioned pressurization section 1 during the pressurization phase and for selectively decoupling the first circuit 7 from the pressurization section 1 during the measurement phase, as well as a pressure meter 2 connected on the pneumatic line with the part or object 4 to be tested. In that respect, an end portion of the first circuit 7, namely of the pneumatic line thereof, is connectable to the part or object 4 to be tested, as shown.

Filling or pressurization of the test object 4 is monitored over time by the pressure meter 2. In the illustrated embodiment, the pressure meter 2 is a

relative pressure meter operating relative to ambient pressure, i.e. the pressure value measured by the pressure meter 2 is measured relative to ambient pressure.

The aforementioned first circuit 7 thus acts as a first absolute pressure drop measurement circuit 7 for the purpose of measuring pressure decay over time of the test object 4.

The system 100 also includes a second absolute pressure drop measurement circuit 8, similar to the first circuit 7, likewise including a dedicated pneumatic valve and a pressure meter 3 connected on the relevant pneumatic line of the circuit 8. Similarly to pressure meter 2, the pressure meter 3 is a relative pressure meter operating relative to ambient pressure.

An end portion of the measurement circuit 8, namely of the pneumatic line thereof, can be connected or not to a reference element or sample 5 as a function of the required measurement, that is:

- in case of symmetrical differential measurement, the reference element/sample 5 is connected to the end portion of the measurement circuit 8;
- in case of asymmetrical differential measurement, the reference element/sample 5 is not connected to the end portion of the measurement circuit 8, which end portion is plugged or kept closed in such case.

In the asymmetrical differential measurement mode (with no reference element/sample connected to the measurement circuit 8), the electronics associated with the system 100 of Figure 1 (see Figure 2 which shows the basic functionality thereof) are configured to acquire both pressure values measured

by the pressure meters 2, 3 (which pressure values are designated in Figure 2 as test value P_TEST/Press_Test and reference value P_REF/Press_Ref) and therefore to continuously sample the difference between the two pressure values.

5 Alternatively, in the case of symmetrical measurement (with a hermetic sample/reference part 5 connected to the measurement circuit 8), the electronics associated with the system 100 of Figure 1 (see again Figure 2) are configured to:

- 10 - acquire, or sample, and save in a permanent data array, a measurement trend of the reference part 5, and
- determine, during the measurements, a difference in real time between the acquired wave and the saved array, point by point in phase with time.

15 The aforementioned method ensures that the resulting differential measurement is free from and unaffected by mechanical stress phenomena and variations in ambient temperature.

More specifically, in addition to the associated electronics, the system 100 may further provide for the management of calculations using software such that it is possible to:

- 20 - measure the trend of the sample reference part 5 at intervals of time, thereby avoiding unnecessary mechanical stresses and heat accumulation;
- allow variations in ambient temperature to be “chased” or tracked.

To do so (and also to avoid creating unnecessary downtime in production cycles), via hardware indications of external automations, and internal logic of

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the instrument, the software may further manage a “reservation” and “execution” cycle of the “reference” sample part, and via percentage parameters of the totality of the measurements taken, as well as minimum and maximum times, take measurement samples at intervals of time that are long enough not to wear out the mechanical characteristics of the reference part, but frequent enough to “chase” or track ambient variations.

Sampling takes place in any case each time the system is turned on, and special “average” algorithms on the acquired points enable the different reference curves acquired to be refined over time and filtered, while avoiding any sudden and unwanted spurious effects.

Naturally, a person skilled in the art can undertake further modifications and variations to the invention described above in order to meet specific contingent applicational requirements, said variations and modifications nonetheless falling within the scope of protection defined in the subsequent claims.

ADVANTAGES

Compared to a traditional differential pressure drop meter based on a differential transducer, the present invention brings the following technical improvements:

- Resolves the problem of “apparent repeatability” in the case of “symmetrical differential measurement”.
- Resolves the problem of measurement uncertainty in the case of “central-zero differential” measurement, namely with two parts being tested simultaneously.
- Resolves the drift in the pneumatic branch of reference in the case

of “asymmetrical differential measurement”, by means of partial and controlled discharging of the reference branch for test purposes.

- Resolves the technical problem of intrinsic lack of safety of traditional differential pneumatic systems.
- Achieves greater construction simplicity.
- Ensures greater reliability over time.
- Offers the possibility of “stepwise” diagnosis of the two measurement branches.

CLAIMS

1. A system (100) for measuring pneumatic leaks of an object (4), said system being of the differential pressure drop type, characterized in that the system (100) comprises two absolute pressure drop measurement circuits (7, 8), wherein the respective pressure values measured by the two absolute pressure drop measurement circuits (7, 8) are subtracted from one another by related electronics of the system (100).

5
2. The system (100) according to claim 1, wherein each absolute pressure drop measurement circuit (7, 8) comprises a relative pressure meter (2, 3) operating relative to ambient pressure.

10
3. The system (100) according to claim 1, wherein an end portion of one (8) of the absolute pressure drop measurement circuits (7, 8) is connected to a reference element or sample (5),

15

and wherein the electronics of the system (100) are configured to:
 - a. acquire, or sample, and save, in a permanent data array, a measurement trend of the reference part (5), and
 - b. determine, during the measurements, a difference in real time between the acquired wave and the saved array, point by point in phase with time.

20
4. The system (100) according to claim 1, wherein an end portion of one (8) of the absolute pressure drop measurement circuits (7, 8) is not connected to any reference element or sample (5) and is plugged or kept

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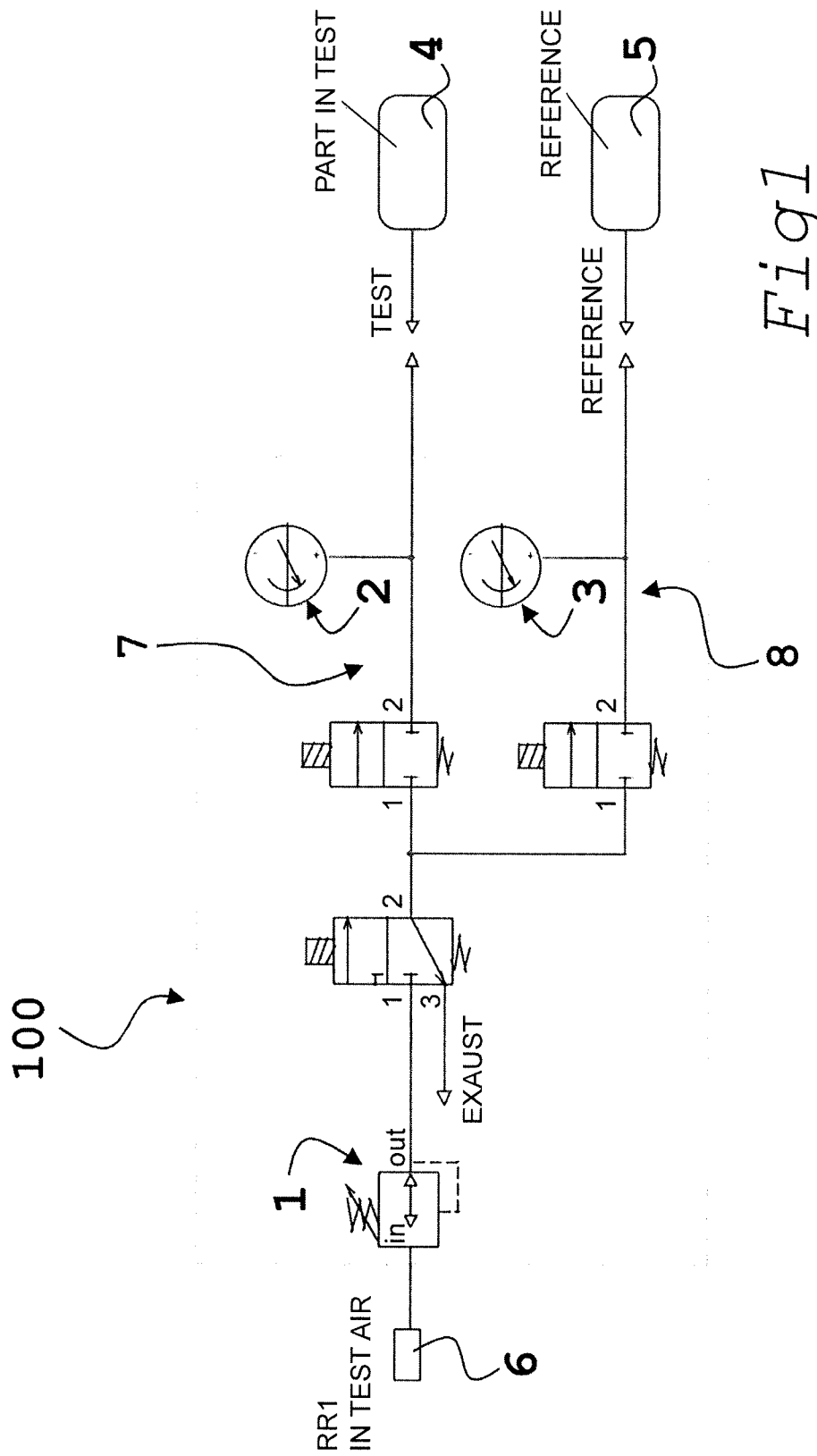
closed,

and wherein the electronics of the system (100) are configured to acquire both pressure values and to continuously sample a difference between both pressure values.

5

5. A differential pressure drop measurement method for measuring pneumatic leaks of an object (4), in particular using a system according to any one of the preceding claims, wherein the method includes performing subtraction of pressure values measured by two absolute pressure drop leak measurement circuits (7, 8) one from the other.

10



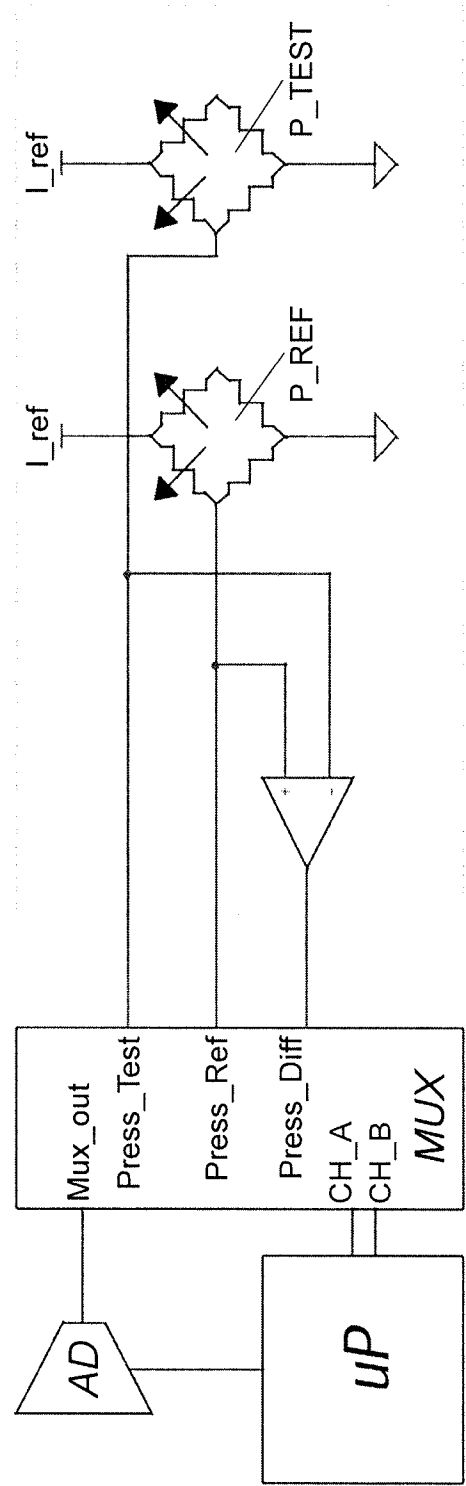


Fig2

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. G01M3/32
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)

G01M G01L

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)

EP0-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	DE 102 42 491 A1 (CONSENS GMBH [DE]) 22 May 2003 (2003-05-22) abstract column 0009 figure 1	1-5
A	----- US 9 638 559 B1 (ZUMMO PETER [US] ET AL) 2 May 2017 (2017-05-02) column 3, lines 24-33 -----	1,2

☐

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

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"&" document member of the same patent family

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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

Grewe, Clemens F.

INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 10242491	A1	22-05-2003	NONE

US 9638559	B1	02-05-2017	CN 107063555 A 18-08-2017
			EP 3205995 A1 16-08-2017
			JP 2017142239 A 17-08-2017
			KR 20170094509 A 18-08-2017
			US 9638559 B1 02-05-2017
