(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 048 274 A1

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**27.07.2016 Bulletin 2016/30**

(21) Application number: **15152314.9**

(22) Date of filing: **23.01.2015**

(51) Int Cl.:
***F01L 1/30*** *(2006.01)* ***F01L 1/18*** *(2006.01)*
***F01L 1/14*** *(2006.01)* ***F01L 1/12*** *(2006.01)*

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**

(71) Applicant: **Caterpillar Energy Solutions GmbH**
**68167 Mannheim (DE)**

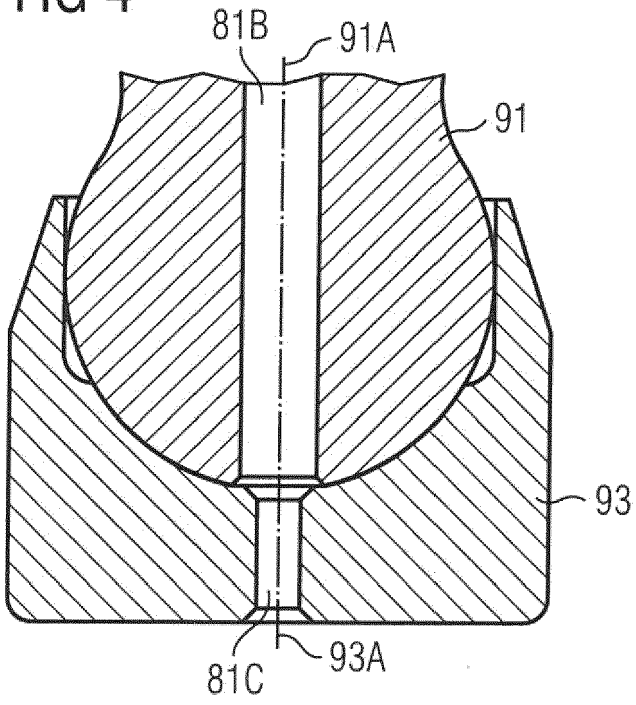
(72) Inventor: **Guisasola, Íñigo**
**76829 Landau (DE)**

(74) Representative: **Kramer Barske Schmidtchen**
**Patentanwälte PartG mbB**
**European Patent Attorneys**
**Landsberger Strasse 300**
**80687 München (DE)**

## (54) Valve configurations for an internal combustion engine

(57) A valve stem extension (23) for connecting a valve stem (27) of an exhaust valve (13) or intake valve (11) with a rocker arm (25), the valve stem extension (23) comprises a rod section (31) having a rocker arm end (31A) and a valve stem end (31B), wherein each of the rocker arm end (31A) and the valve stem end (31B) is configured as a joint part portion such as ball joint or a ball socket part of a ball joint a hinge part or a hinge socket part of a hinge joint, or a pin receiving part of a pin joint. Such a valve stem extension (23) can be provided in an extended valve actuation system (21) for bridging varying rocker shaft positions while, for example, employing in size similar or identical valve stems (27).

FIG 4




EP 3 048 274 A1

## Description

### Technical Field

**[0001]** The present disclosure generally relates to valves for an internal combustion engine and, more particularly, to intake and exhaust valves being closely positioned on a cylinder head and operated via rocker arm configurations.

### Background

**[0002]** In internal combustion engines, rocker arm configurations are used to operate intake and exhaust valves. In particular several valves are provided, for example, within a cylinder head, each being operated by a respective rocker arm configuration. For example, an intake and an exhaust rocker arm configuration may control the opening and closing of two intake valves and two exhaust valves, respectively. A common camshaft driving the rocker arm configurations may, for example, ensure respective timings.

**[0003]** As the space for the respective rocker arm configurations is limited, it is common to provide respective rotation axes of rocker arm configurations for the intake and exhaust valves at different distances with respect to the cylinder head, thereby allowing a compact but still operable set up of multiple intake and exhaust valves. As a consequence, a valve stem interacting with a respective rocker arm has a length that is adapted to the distance of a respective rotation axis of that rocker arm to the cylinder head.

**[0004]** The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of prior systems.

### Summary of the Disclosure

**[0005]** In a first aspect, a valve stem extension for connecting a valve stem of an exhaust valve or intake valve with a rocker arm is disclosed. The valve stem extension comprises a rod section with a rocker arm end and a valve stem end, wherein each of the rocker arm end and the valve stem end is configured as a joint part portion.

**[0006]** In another aspect, an extended valve actuation system for a valve stem of an internal combustion engine comprises a valve stem extension as, for example, described above, a rocker arm mountable to a rocker shaft and comprising a valve actuation section and a push rod section, wherein the valve actuation section comprises a joint part portion forming a first joint with the joint part portion of the rocker arm end of the valve stem extension, and a valve stem having a valve end with a valve head for closing a valve opening of a combustion chamber and a valve stem extension end, the valve stem extension end being configured as a joint part portion forming a second joint with the joint part portion of the valve stem end of the valve stem extension.

**[0007]** In a further aspect, an internal combustion engine comprises a cylinder unit with a cylinder head with an intake opening and an exhaust opening delimiting a combustion chamber, a first valve stem actuation system comprising a first valve stem having a valve end with a valve head for closing one of the intake opening and the exhaust opening and a rocker arm end, which is configured as a joint part portion, and a first rocker arm pivotably mounted to a rocker shaft, which is positioned at a first distance with respect to the cylinder head, and comprising a push rod section and a valve stem actuation section, wherein the valve stem actuation section comprises a joint part portion forming a joint with the joint part portion of the rocker arm end of the first valve stem. The engine comprises further a second valve stem actuation system with a valve stem extension e.g. as described above, a second valve stem having a valve end with a valve head for closing the other one of the intake opening and the exhaust opening and a valve stem extension end, the valve stem extension end being configured as a joint part portion forming a joint with the joint part portion of the valve stem end of the valve stem extension, and a second rocker arm pivotably mounted to a rocker shaft, which is positioned at a second distance with respect to the cylinder head, and comprising a push rod section and a valve actuation section, wherein the valve actuation section comprises a joint part portion forming a joint with the joint part portion of the rocker arm end of the valve stem extension, and wherein the first distance is smaller than the second distance.

**[0008]** In some embodiments, the rocker arm end and/or the valve stem end may be configured as a part of a one or more directional joint such as a cylindrical joint e.g. a pin joint or a hinge joint. Moreover, at least one of the rocker arm end and/or the valve stem end may be a part of a more directional joint such as a ball joint.

**[0009]** In some embodiments, the rod section may be configured to be at least partly hollow and comprise an inner volume. The inner volume may be in particular fluidly connected to an outside via a channel in the joint part portion of the rocker arm end and/or a channel in the joint part portion of the valve stem end.

**[0010]** Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

### Brief Description of the Drawings

**[0011]** The accompanying drawings, which are incorporated herein and constitute a part of the specification, illustrate exemplary embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure. In the drawings:

Fig. 1 is a schematic side view of a top section of a cylinder unit of an internal combustion engine;

Fig. 2 shows a schematic illustration of a first exemplary extended valve actuation system of a first em-

bodiment of a valve stem extension;

Fig. 3 shows a schematic illustration of a second exemplary extended valve actuation system of a second embodiment of a valve stem extension;

Fig. 4 shows a schematic illustration of a third exemplary extended valve actuation system of a third embodiment of a valve stem extension;

Fig. 5 shows a schematic illustration of a cross-section of an exemplary hinge joint or ball joint configuration for a valve stem extension-rocker arm joint;

Fig. 6 shows a schematic illustration of an exemplary hinge joint or ball joint configuration for a valve stem extension-valve stem joint; Fig. 7 shows a schematic 3D-illustration of an exemplary ball joint configuration for a valve stem extension-valve stem joint;

Fig. 8 shows a schematic 3D-illustration of an exemplary pin joint configuration for a valve stem extension-valve stem joint; and

Fig. 9 shows a schematic 3D-illustration of a a schematic illustration of an exemplary hinge joint for a valve stem extension-valve stem joint.

Detailed Description

**[0012]** The following is a detailed description of exemplary embodiments of the present disclosure. The exemplary embodiment described herein and illustrated in the drawings are intended to teach the principles of the present disclosure, enabling those of ordinary skill in the art to implement and use the present disclosure in many different environments and for many different applications. Therefore, the exemplary embodiments are not intended to be, and should not be considered as, a limiting description of the scope of patent protection. Rather, the scope of patent protection shall be defined by the appended claims.

**[0013]** The present disclosure may be based in part on the realization that the bending load of a valve stem increases with its length when activated by a rotationally mounted rocker arm. An increased bending may result in an increased wear, in particular as a result of the increased shear movement between the rocker arm sided joint part and the valve stem sided joint part. Moreover, it was realized that longer valve stems may need additional guidance, thereby increasing the complexity of the valve stem guiding mount.

**[0014]** The present disclosure may be further based in part on the realization that using a valve stem extension may allow using shorter valve stems when bridging longer distances between a cylinder head and a rocker arm being mounted at a larger distance. For example, such a valve stem extension based configuration may allow using identical valve stems for intake and exhaust valves or at least valve stems having essentially identical length, thereby simplifying the valve configurations of an internal combustion engine. Moreover, it was realized that introducing a second joint, i.e. resulting in one at each side of the valve stem extension, introduces a more flexible guidance and, thus, may decrease the presence of shear movements and potential bending loads onto the valve stem during operation. Also the required guidance for a shorter valve stem, which is functionally extended by a valve stem extension, may be easier achieved then for a longer valve stem because, for example, an additional adapter positioned on top of the cylinder head may not be needed to ensure proper guidance of the longer valve stem. In addition, the mass of the valve stem/valve stem extension-combination may be reduced in comparison to a single long valve stem as the valve stem extension may be provided in a hollow and, thus, lighter configuration than a solid valve stem, thereby resulting in an overall reduction of the weight of the valve, in particular if larger distances between a rotation axis of a rocker arm and the cylinder head need to be bridged.

**[0015]** In the following, the concept of valve actuation systems being based on a valve stem extension are disclosed in connection with Fig. 1 (showing a partial view of an internal combustion engine), Fig. 2 and Fig. 3 (showing generic illustrations of extended valve actuation systems), and Fig. 4 (showing an example of an extended valve actuation system providing lubrication). Exemplary embodiments of ball joints formed between a valve stem extension and a rocker arm as well as a valve stem extension and a valve stem are disclosed in connection with Figs. 5 to 9.

**[0016]** While most of the wording in the following description is exemplarily directed to ball joint based configurations (Fig. 7), as will be apparent to the skilled person in particular with Figs. 8 and 9, one-directional joints such as pin joints (Fig. 8) or hinge joints (Fig. 9) may be provided for at least one of the two joints at each of the ends of the valve stem extension.

**[0017]** Fig. 1 is a partial view of an internal combustion engine 1, specifically of a top section of a cylinder unit 3. Cylinder unit 3 comprises inter alia a combustion chamber 5 delimited radially by cylinder walls and axially by a piston (not shown) and a cylinder head 7. Cylinder head 7 comprises openings 9 for providing, for example, a charge air-gaseous fuel mixture to combustion chamber 5 (intake opening) and for releasing exhaust gas into an exhaust gas system (not shown), refered to as an exhaust opening.

**[0018]** Exemplarily, in Fig. 1, the concept of a valve stem extension is shown for an intake valve 11 provided for opening and closing an intake opening 11A, while a conventional exhaust valve 13 is indicated for illustration purposes in the background. However, alternative configurations, such as employing extension based exhaust valves for intake and exhaust valves or employing a valve stem extension based exhaust valve and a conventional intake valve will be apparent to the skilled person.

**[0019]** In the following, the valve stem extension based valve will be generally described without explicit reference to the function of the intake valve 11 (or the exhaust valve) for generality. However, when referring to the specific configuration, the extended valve actuation system

will exemplarily be associated with the intake valve 11.

**[0020]** In Fig. 1, an extended valve actuation system 21 is shown in the foreground. Specifically, extended valve actuation system 21 comprises a valve stem extension 23, a rocker arm 25, and a valve stem 27.

**[0021]** Valve stem extension 23 comprises a rod section 31 with a rocker arm end 31A and a valve stem end 31B. Each of rocker arm end 31A and valve stem end 31B are configured as joint part portions.

**[0022]** The respective joints provide at least a relative movement in one plane. Specifically, the directionality of such one-directional joints provides a plane in which the joined elements move (herein referred to as plane of rotation). That plane of rotation will usually be selected to be in line with the plane of rotation of the rocker arm. In other words, the rotation axis of the one-directional joint, e.g. given by the pin or the cylinder axis, may be in parallel to the rocker shaft of the respective rocker arm. To increasing the flexibility, a more than one directional joint may be used. In particular, in combination with implementations that require a rotation of the valve stem around its axis via a valve rotation unit as known in the art (not shown in the drawings), a ball joint may be used at the valve stem side (the other side may be any other type of acceptable joint, e.g. hinge, ball or pin joint).

**[0023]** Herein, a ball joint part portion is a structural portion configured as a ball joint part. In general, a ball joint as understood herein as a joint providing for at least two-dimensional movability of two joined parts. This is usually achieved by a ball part structure at one side and a ball socket part structure on the other side, wherein the ball socket part structure at least partly surrounds the ball part structure. Thus, besides a flexibility in the bending also an axial rotation is possible.

**[0024]** Referring again to the joint part portions of rod section 31, as an example, rocker arm end 31A and/or valve stem end 31B may be configured as a ball part of a ball joint or as a ball socket part of a ball joint, respectively, or vice versa. Alternatively, each of rocker arm end 31A and valve stem end 31B may be configured as a ball part or a ball socket parts. In addition alternativly, hinge joints or pin joints as exemplary cylindrical joints may be employed as discussed in connection with Fig. 8 and 9 in more detail.

**[0025]** In general, rod section 31 may bridge a distance that depends on the size of the engine, the space available etc. and may be, for example, in the range from 30 mm to 200 mm for medium speed gas engines such as 80 mm for medium speed engines produced by Caterpillar Energy Solutions GmbH. For example, the rod section has an elongated shape with an axial extension in the range from 30 mm to 200 mm. The lateral extension may be, for example, in the range around 20 mm.

**[0026]** As described below in particular with respect to Figs. 4 to 6, rod section 31 may at least be partly hollow and have, for example, a cylinder-like or hollow cylinder-like base shape. In that context, hollow configurations may be used to also provide lubrication for one or both of the joints as also described in connection with Figs. 4 to 6.

**[0027]** Rocker arm 25 is mounted to a rocker shaft 33 positioned at an extended distance $D_E$ from a surface 7A of cylinder head 7. For example, rocker shaft 33 may be mounted on top of a common mounting structure 35 for all rocker arm systems of a respective cylinder head 7 of engine 1.

**[0028]** Rocker arm 25 further comprises a valve actuation section 25A and a push rod section 25B. Valve actuation section 25A comprises a joint part portion for forming a first joint 41A together with the joint part portion of rocker arm end 31A of valve stem extension 23.

**[0029]** Push rod section 25B is functionally connected to a push rod 45 driven, for example, by a camshaft (not shown).

**[0030]** Valve actuation section 25A further comprises a valve adjustment system 43. Valve adjustment system 43 may allow fine adjustment of the position of the joint part portion of valve actuation section 25A as it is known in the art. In some embodiment, alternatively or additionally, a similar adjustment configuration may be provided at push rod section 25B.

**[0031]** Valve stem 27 comprises a valve end 27B at the combustion chamber side, which is configured as a valve head for closing valve opening 11A. At a valve stem extension end 27A, valve stem 27 comprises further a joint part portion for forming a second joint 41B together with the joint part portion of valve stem end 31B of valve stem extension 23.

**[0032]** Furthermore, valve stem 27 is mounted in a guided manner to open and close intake opening 11A. A respective structural guiding element is not explicitly shown and may be fixedly connected to or be a part of cylinder head 7.

**[0033]** Valve stem 27 may be biased by a valve spring 51 positioned between cylinder head 7 and a valve spring mounting plate 53 attached to valve stem 27 at valve stem extension end 27A of valve stem 27.

**[0034]** During operation, the movement of push rod 45 will rotate valve actuation section 25A around rocker shaft 33, thereby guiding rocker arm end 31A of valve stem extension 23 along a circular path 55 as it is connected via first joint 41A with valve actuation section 25A. As a consequence of the connection via second joint 41B and the linear guidance, valve stem 27 will essentially oscillate linearly along a linear path 57. During that movement, valve stem 27 and thus valve stem extension 23 will be pushed in direction of rocker arm 25 via valve spring 51.

**[0035]** Due to the presence of valve stem extension 23, valve stem 27 can be provided in a length, for example, comparable to or identical to a valve stem of an (unextended) conventional valve actuation system 61 (shown in the background of Fig. 1) comprising a rocker arm 25' mounted to a rocker shaft 63 positioned at a (smaller) distance Dc with respect to surface 7A of cylinder head 7 and configured for operating a (convention-

al) valve stem 27'. Accordingly, extended valve actuation system 21 allows the use of at least comparable or identical valve stems for valve actuation systems having rocker shafts at different distances with respect to surface 7A of cylinder head 7.

**[0036]** It is noted that the presence of the second joint will reduce the tilt occurring at each joint with respect to conventional configurations employing a single joint between valve stem and rocker arm. Moreover, the second joint may redirect and reduce any forces acting directly within the joints, in particular the joint part at valve stem 27, which may reduce service and/or replacement of valve stem 27.

**[0037]** In the description of the following figures, previously introduced reference numerals will be used for identical parts and the respective description disclosed herein will be similarly applicable to those components as will be apparent to the skilled person.

**[0038]** For simplifying the description of Figs. 2 to 6, in the following the joints at the valve stem extension 23 are referred to in line with the implementation of ball joints. However, the drawings are similarly illustrating hinge joint configurations or mixed hinge joint and ball joint configurations.

**[0039]** Similarly, the use of other types of one-dimensional joints such as in general cylindrical joints, e.g. pin joints and their respective implantation will be apparent to the skilled person.

**[0040]** Fig. 2 shows a generic illustration of an extended valve actuation system 21A. Specifically, valve actuation section 25A of the rocker arm comprises a ball part 71A for first joint 41A and valve stem extension 23 has its rocker arm end 31A configured as a ball socket part 72A of first joint 41A. Similarly, valve stem end 31B is configured as a ball socket part 72B and at an upper section of valve stem 27, valve stem extension end 27A is configured as a ball part 71B. Accordingly, valve stem extension 23 can be configured, for example, in a symmetric manner with respect to its opposing ends. This may generally apply to other types of joints, in particular one-dimensional joints as well.

**[0041]** In contrast, Fig. 3 shows an extended valve actuation system 21B with an asymmetric configuration of valve stem extension 23. While the interaction with valve stem 27 is essentially similar to the embodiment of Fig. 2, rocker arm end 31A of valve stem extension 23 comprises a ball part 71C (instead of a ball socket part in Fig. 2) and a respective ball socket part 72C is provided at valve actuation section 25A of the rocker arm.

**[0042]** Assuming that providing a valve stem with a ball part of a joint in a conventional valve actuation system, the embodiment of Fig. 3 may allow the use of a structural identical valve actuation section 25A for the extended valve actuation system 21. This may generally apply to other types of joints, in particular one-dimensional joints as well.

**[0043]** As will be apparent to the skilled person, also inverted configurations, respectively for Fig. 2 and Fig. 3, may be used in extended valve actuation systems.

**[0044]** Fig. 4 illustrates a structure of an extended valve actuation system in more detail. In particular, the aspect of providing lubrication for the respective joints is illustrated.

**[0045]** In general, the lubrication to the valve activation system may be provided via rocker shaft 33 or a specific lubrication connection. For example, in Fig. 4, a lubrication channel system 81 within rocker arm 25 provides lubrication liquid to valve actuation section 25A. Lubrication channel system 81 includes in particular a lubrication channel 81A extending along and within rocker arm 25 and, for example, receiving a lubrication fluid such as oil from rocker shaft 33. Lubrication channel 81A is fluidly connected to a lubrication channel 81B provided within valve adjustment system 43. In Fig. 4, valve adjustment system 43 includes a ball part 71D for forming first joint 41A.

**[0046]** As shown in Fig. 4, lubrication channel 81B extends through ball part 71D such that lubrication fluid will be released to the interface between ball part 71D and rocker arm end 31A of valve stem extension 23. Rocker arm end 31A is configured as a separate ball socket part 72D comprising a recess that at least partially surrounds ball part 71D. As mentioned above, Fig. 4 can similarly be interpreted as showing hinge joints or mixed ball/hinge joint configurations.

**[0047]** Rod section 31 is configured as a hollow-cylinder structure comprising a cylinder wall 83. Cylinder wall 83 surrounds an inner volume 83A. Rocker arm end 31A is, for example, mounted to the hollow-cylinder structure via press fitting of a specifically adapted extension into inner volume 83A. Inner volume 83A is fluidly connected to the interface between ball part 71D and rocker arm end 31A through a channel 81C that extends, for example, axially and centrally within rocker arm end 31A.

**[0048]** Accordingly, when during operation of the engine lubrication fluid is provided to rocker shaft 33, inner volume 83A will be filled with lubrication fluid via channels 81A, 81B, and 81C. Thereby, also first joint 41A is lubricated.

**[0049]** As further shown in Fig. 4, valve stem end 31B is similarly configured as a ball socket part 72E that comprises a channel 81D. Ball socket part 72E at least partially surrounds a ball part 71E of valve stem 27. Ball part 71E is configured as a separate part to form valve stem extension end 27A.

**[0050]** A rod-like end of a valve stem portion and ball socket part 72E may be press-fitted to respective recesses of ball part 71E and the hollow-cylinder structure.

**[0051]** Lubrication fluid accumulated within inner volume 83A will be released through channel 81D to the interface between ball socket part 72E ball part 71E, thereby lubricating second joint 41B.

**[0052]** Fig. 5 shows in more detail an exemplary configuration of first joint 41A for implementation in the embodiment of Fig. 4. Specifically, one can see channel 81B extending within a ball part 91 and channel 81C extending

within a ball socket part 93. First joint 41A is, for example, configured such that a misalignment between 25° and 15° is allowed between a symmetry axis 91A of ball part 91 and a symmetry axis 93A of ball socket part 93. It is noted that, while for a ball joint such a misalignment is not limited in direction, the implantation of a hinge joint would limit that misalignment essentially to one direction.

**[0053]** Fig. 6 shows an alternative configuration for the second joint 41B. Specifically, a hollow valve stem extension 23 is provided at its valve stem end 31B with a ball part 95. Accordingly, valve stem 27 is provided with a ball socket part 97. Ball part 95 and ball socket part 97 form the second joint, in this configuration lubricated by channel 81D provided within ball part 95.

**[0054]** Figs. 7 to 9 show 3D-illustrations of exemplary valve stem extension-valve stem joints (second joint 41B in Fig. 1).

**[0055]** In Fig. 7, a ball joint 141 includes a ball socket part 172 provided at a rod section 123 and interacting with a ball part 171 provided at a valve stem 127 in line with the 2D-illustrations in Figs. 2 and 4.

**[0056]** In Fig. 8, a pin joint 241 includes a single finger pin receiving part 272 provided at a rod section 223 and interacting with a double finger pin receiving part 271 provided at a valve stem 227. Single finger pin receiving part 272 reaches into double finger pin receiving part 271 and is connected thereto via a pin 173 inserted into openings 273A and 237B.

**[0057]** In Fig. 7, a hinge joint 341 includes a hinge socket part 372 provided at a rod section 323 and interacting with a hinge part 371 provided at valve stem 327 in line with the 2D-illustrations in Figs. 2 and 4.

**[0058]** A cylindrical-type joint as shown in Fig. 9 may provide a larger contact face (considering the complete cylinder unit) for the transition of forces than a ball joint shown in Fig. 7. Accordingly, an interface pressure may be lower. However, a cylinder-type joint may be increased on mass and require a well oriented and aligned mounting of the joint.

**[0059]** A pin joint may in particular be of interest for very large engines.

Industrial Applicability

**[0060]** The herein disclosed concepts may be used, for example, in gas engines manufactured by Caterpillar Energy Solutions GmbH.

**[0061]** In general, the internal combustion engine may be of any size, with any number of cylinders, and in any configuration (V-type, in-line, radial, etc.). Moreover, the internal combustion engine may be used to power any machine or other device, including locomotive applications, on-highway trucks or vehicles, off-highway trucks or machines, earth moving equipment, generators, aerospace applications, marine applications, pumps, stationary equipment, or other engine powered applications. In general, depending on the generated engine power and, thus, ignition pressure, the various components may vary with respect to structural parameters such as wall thinkness, diameter, and bending and bucking resistance and respective types of valves may be selected.

**[0062]** Although the preferred embodiments of this invention have been described herein, improvements and modifications may be incorporated without departing from the scope of the following claims.

## Claims

1. A valve stem extension (23) for connecting a valve stem (27) of an exhaust valve (13) or intake valve (11) with a rocker arm (25), the valve stem extension (23) comprising:

   a rod section (31) having a rocker arm end (31A) and a valve stem end (31B), wherein each of the rocker arm end (31A) and the valve stem end (31B) is configured as a joint part portion.

2. The valve stem extension (23) of claim 1, wherein the rocker arm end (31A) and/or the valve stem end (31B) is configured as a part of a one or more directional joint such as a cylindrical joint e.g. a pin joint (241) or a hinge joint (341); and in particular at least one of the rocker arm end (31A) and/or the valve stem end (31B) is a part of a more directional joint such as a ball joint (141),
   in particular wherein the rocker arm end (31A) is configured as a ball part (71C) of a ball joint (41A) and the valve stem end (31B) is configured as a ball socket part (172) of a ball joint (141), or vice versa; or
   the rocker arm end (31A) is configured as a hinge part (71C) of a hinge joint (41A) and the valve stem end (31B) is configured as a hinge socket part (72B) of a hinge joint (41B), or vice versa; or
   the rocker arm end (31A) and the valve stem end (31B) are configured as pin receiving parts (271, 272) of a pin joint (241); and/or
   the rocker arm end (31A) is configured as a hinge part (71C) of a hinge joint (41A) or as a pin receiving parts (71C) of a pin joint (41A) and the valve stem end (31B) is configured as a ball part (71C) of a ball joint (41A) of a ball socket part (172) of a ball joint (141).

3. The valve stem extension (23) of claim 1, wherein each of the rocker arm end (31A) and the valve stem end (31B) is configured as a ball part (171) or a ball socket part (172) or a hinge part (372) or a hinge socket part (371).

4. The valve stem extension (23) of any one of the preceding claims, wherein
   the rod section (31) has an elongated shape, for example with an axial extension in the range from 30 mm to 200 mm and/or a lateral extension in the range

of about 20 mm, and/or
the rod section (31) comprises a cylinder-like or hollow-cylinder-like base shape.

**5.** The valve stem extension of any one of the preceding claims, wherein
the rod section (31) is configured to be at least partly hollow and comprise an inner volume (83A), and
the inner volume (83A) is in particular fluidly connected to an outside via a channel (81C) in the joint part portion of the rocker arm end (31A) and/or a channel (81D) in the joint part portion of the valve stem end (31B).

**6.** An extended valve actuation system (21) for a valve stem (27) of an internal combustion engine (1), the valve actuation system (21) comprising:

a valve stem extension (23) of any one of the preceding claims;
a rocker arm (25) mountable to a rocker shaft (33) and comprising a valve actuation section (25A) and a push rod section (25B), wherein the valve actuation section (25A) comprises a joint part portion forming a first joint (41A) with the joint part portion of the rocker arm end (31A) of the valve stem extension (23); and
a valve stem (27) having a valve end (27B) with a valve head for closing a valve opening (11A) of a combustion chamber (5) and a valve stem extension end (27A), the valve stem extension end being configured as a joint part portion forming a second joint (41B) with the joint part portion of the valve stem end (31B) of the valve stem extension (23).

**7.** The extended valve actuation system (21) of claim 6, wherein the joint part portions of the valve stem extension (23) of the valve stem (27), and the valve actuation section (25A) of the rocker arm (25) are configured as pin joint parts (271, 272), a hinge part (371) or a hinge socket part (372), or a ball part (171) or a ball socket part (172), to pair-wise form the first and the second joint (41A, 41B).

**8.** The extended valve actuation system (21) of claim 6 or claim 7, wherein the rocker arm (25) comprises a lubrication channel system (81) and the joint part portion of the valve actuation section (25A) comprises a lubrication channel (81B) as a fluidly connected section of the lubrication channel system (81) for lubricating the first joint (41A).

**9.** The extended valve actuation system (21) of claim 8, wherein the valve stem extension (23) comprises an inner volume (83A) fluidly connected via a channel (81C) in the joint part portion of the rocker arm end (31A) of the valve stem extension (23) for receiving a lubrication fluid from the lubrication channel (81B), and
the valve stem extension (23) is in particular further configured to provide the lubrication fluid via a channel (81D) in the joint part portion of the valve stem end (31B) of the valve stem extension (23) to the second joint (41B).

**10.** An internal combustion engine (1) comprising:

a cylinder unit (3) with a cylinder head (7) with an intake opening (11A) and an exhaust opening delimiting a combustion chamber (5);
a first valve stem (27') actuation system (61) comprising
a first valve stem having a valve end with a valve head for closing one of the intake opening (11A) and the exhaust opening and a rocker arm end, which is configured as a joint part portion, and
a first rocker arm (25') pivotably mounted to a rocker shaft (63), which is positioned at a first distance (Dc) with respect to the cylinder head (7), and comprising a push rod section and a valve stem actuation section, wherein the valve stem actuation section comprises a joint part portion forming a joint with the joint part portion of the rocker arm end of the first valve stem (27'); and
a second valve stem actuation system (21) comprising:

a valve stem extension (23) of any one of claim 1 to claim 5,
a second valve stem (27) having a valve end (27B) with a valve head for closing the other one of the intake opening (11A) and the exhaust opening and a valve stem extension end (27A), the valve stem extension end (27A) being configured as a joint part portion forming a joint (41B) with the joint part portion of the valve stem end (31B) of the valve stem extension (23), and
a second rocker arm (25) pivotably mounted to a rocker shaft (33), which is positioned at a second distance ($D_E$) with respect to the cylinder head (7), and comprising a push rod section (25B) and a valve actuation section (25A), wherein the valve actuation section (25A) comprises a joint part portion forming a joint (41A)with the joint part portion of the rocker arm end (31A) of the valve stem extension (23), and

wherein the first distance ($D_C$) is smaller than the second distance ($D_E$).

**11.** The internal combustion engine (1) of claim 10, wherein the first valve stem (27') and the second

valve stem (27) are essentially of the same size, and the internal combustion engine (1) further comprising:

an essentially identical valve stem guidance for the first valve stem (27') and the second valve stem (27); and
an essentially identical valve spring (51) for the first valve stem (27') and the second valve stem (27), each mounted by essentially an identical valve spring retainer (53).

**12.** The internal combustion engine (1) of claim 10 or claim 11, wherein the first valve stem (27') forms an intake valve (11) and the second valve stem (27) forms an exhaust valve (13) or vice verca.

**13.** The internal combustion engine (1) of any one of claim 10 to claim 12, further comprising a cam shaft and push rods (45) for interacting with the respective push rod sections of the first second valve stem actuation system (61) and the second valve stem actuation system (21).

**14.** The internal combustion engine of any one of claim 10 to claim 13, wherein the second valve stem actuation system is configured in accordance with any one of claim 6 to claim 9.

FIG 1

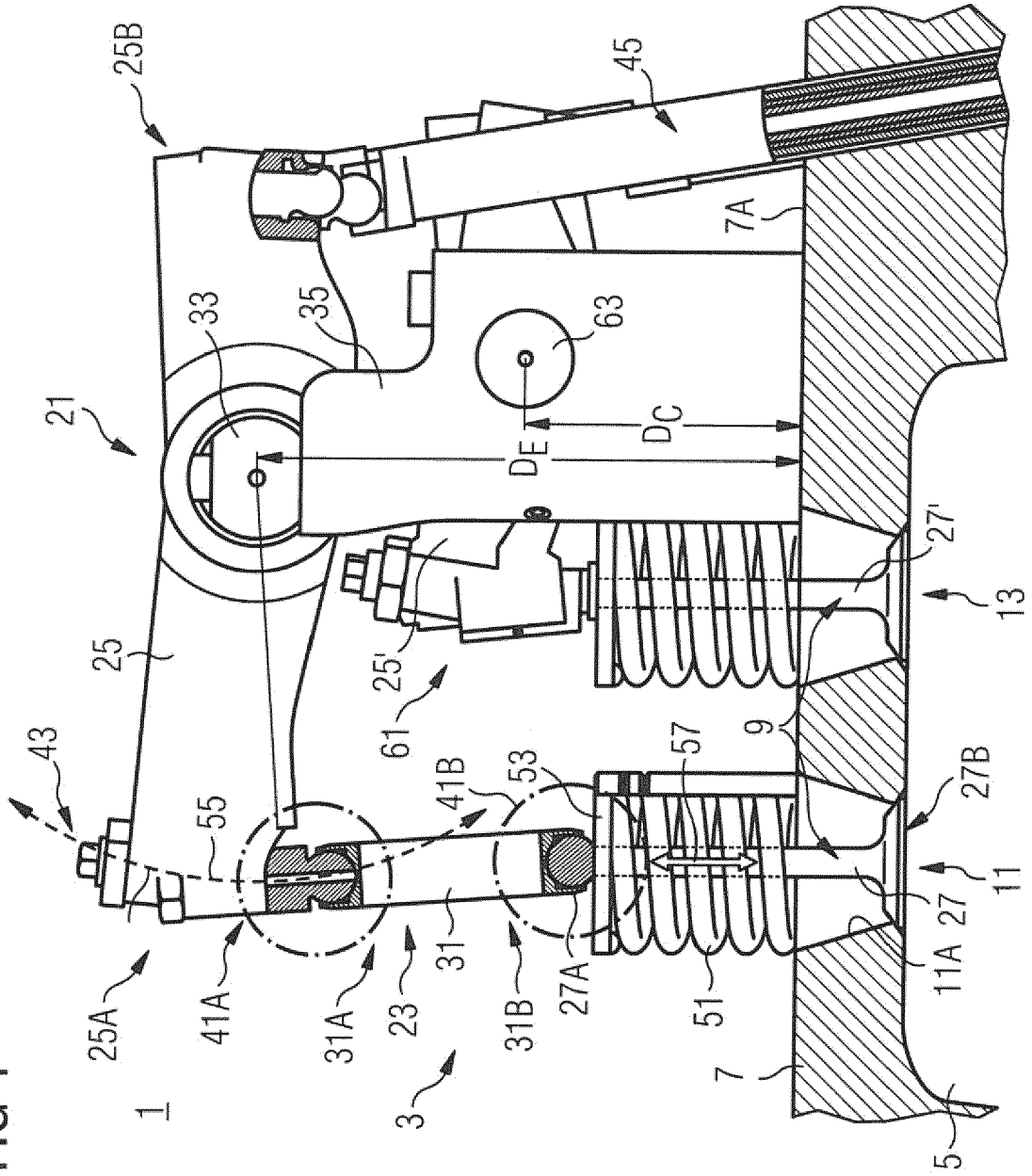

25B
45
7A
33
35
63
21
$D_E$
$D_C$
27'
25
25'
13
61
9
57
43
53
27B
55
41B
11
27
11A
25A
41A
31A
23
31
31B
27A
51
7
1
3
5

FIG 2

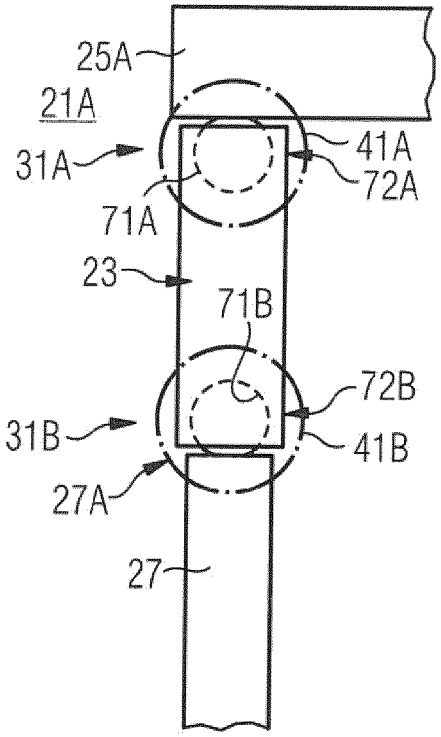



FIG 3

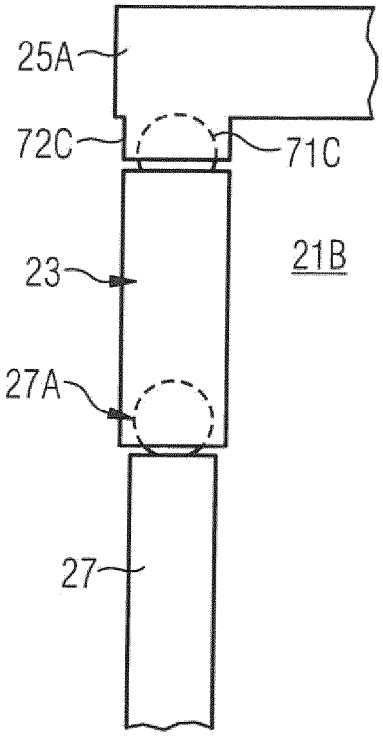



FIG 4

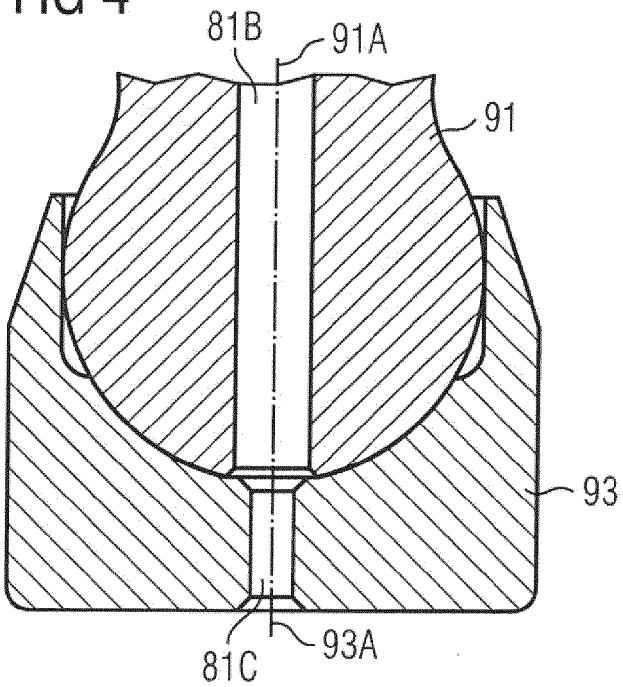


FIG 6

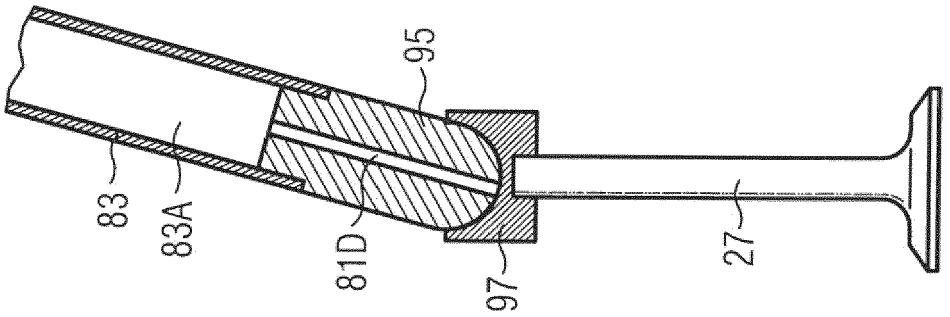

95
83
83A
81D
97
27

FIG 5

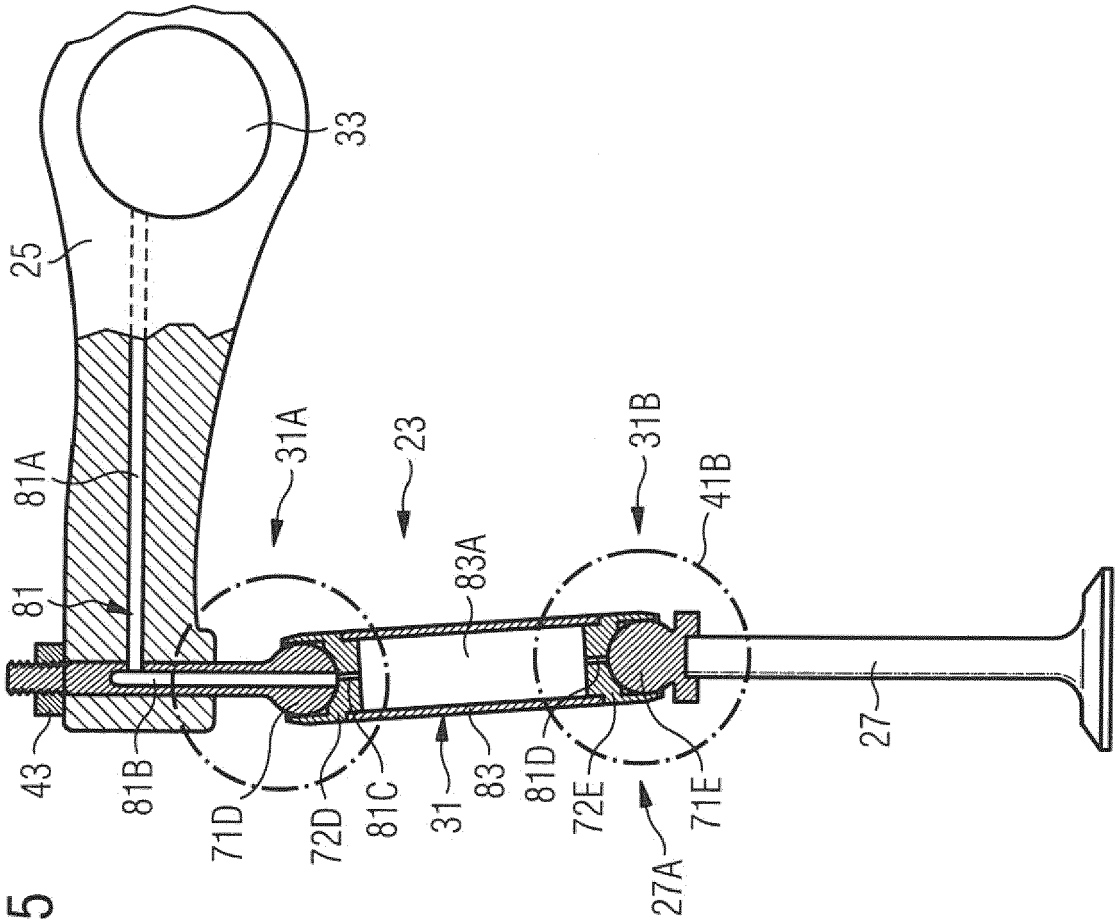

33
25
81A
31A
23
31B
41B
81
83A
43
81B
71D
72D
81C
31
83
81D
72E
71E
27A
27

FIG 7

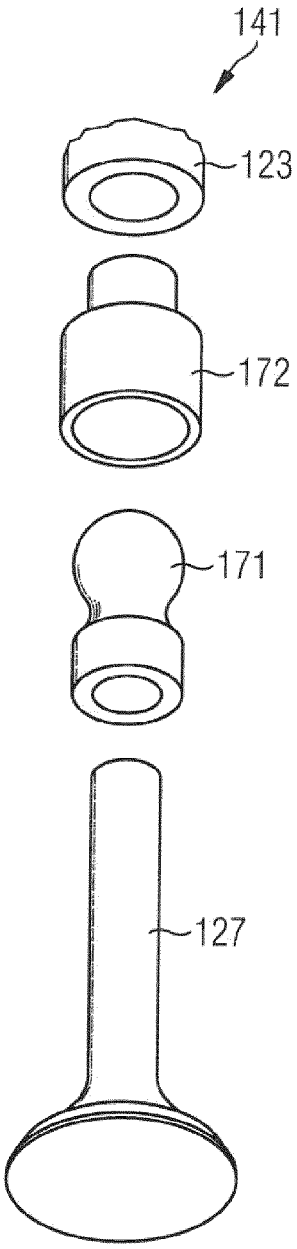



FIG 8

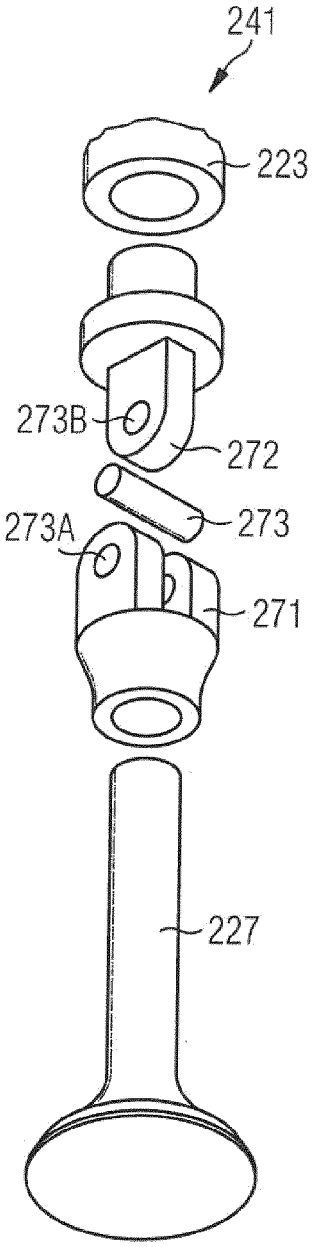
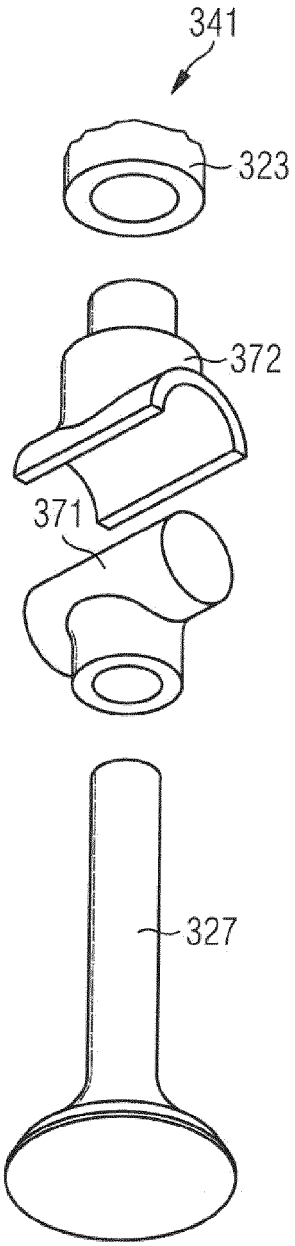



FIG 9



Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 15 15 2314

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | WO 2014/174268 A1 (CAMCON AUTO LTD [GB]) 30 October 2014 (2014-10-30) * the whole document * | 1-9 | INV. F01L1/30 F01L1/18 F01L1/14 |
| X | US 1 541 081 A (EDMOND VAREILLE PIERRE HENRI) 9 June 1925 (1925-06-09) * the whole document * | 1-4,6,7 | F01L1/12 |
| X | DE 11 08 981 B (KLOECKNER HUMBOLDT DEUTZ AG) 15 June 1961 (1961-06-15) * the whole document * | 1-4,6,7 | |
| X | US 4 364 341 A (HOLTMANN TEODORO) 21 December 1982 (1982-12-21) * the whole document * | 1 | |

TECHNICAL FIELDS SEARCHED (IPC)

F01L

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 25 June 2015 | Klinger, Thierry |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 15 2314

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-06-2015

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| WO 2014174268 A1 | 30-10-2014 | NONE | |
| US 1541081 A | 09-06-1925 | NONE | |
| DE 1108981 B | 15-06-1961 | NONE | |
| US 4364341 A | 21-12-1982 | DE 3022188 A1 | 24-12-1981 |
| | | US 4364341 A | 21-12-1982 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82