Title: CONTROL VALVE ARRANGEMENT

Abstract: A control valve arrangement (12) of a fuel injector (10) comprises a bore (18) in which a piston (16) is slidably arranged, the piston piloting injection events and the bore opening in direct and unrestricted fluid communication into a first control chamber (24). The arrangement comprises a further fluid communication path from a high pressure line (20) to a second control chamber (68), the further fluid communication path comprising, for example, a clearance, a channel or a bypass orifice.
Control Valve Arrangement

5 TECHNICAL FIELD

The present invention relates to a fuel injector such as a diesel injector, and more specifically to a control valve arrangement for a fuel injector.

10 BACKGROUND OF THE INVENTION

High pressure fuel injectors are provided with a needle or shaft which is hydraulically piloted via a control valve arrangement. It is known that to minimize undesirable exhaust emissions the lift of the needle must happen at a controlled speed while the closing must be extremely prompt.

In a known embodiment, a fuel injector control valve arrangement comprises a separate filling valve which is operated by a hydraulic servo driven by a two-way control valve. This provides a three-way valve function, with the advantage that the filling valve can have a large flow area and therefore drive the nozzle needle closed quickly. However, this embodiment is not suitable for higher inter-valve volumes, which may be required for example to simplify manufacture, as larger volumes take longer to re-pressurise, thereby resulting in steep gain curves for small injections.

25 SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved control valve arrangement for a fuel injector which at least mitigates the problems as described above.

Accordingly, the present invention comprises a control valve arrangement of a fuel injector comprising a valve housing wherein are arranged a filling channel extending from a high pressure fuel supply line to a filling chamber, the filling chamber being in a first fluid communication with a first control chamber,
wherein the first fluid communication is controlled by a filling valve normally biased open by a first spring, away from a first seat arranged in the valve housing, and a communication channel extending from the first control chamber to a second control chamber which is in a second fluid communication with a low pressure outlet line,

wherein the filling valve comprises a stem, a guiding section of which is located within a guide portion of the valve housing;

wherein the second fluid communication is controlled by a control valve normally biased in a closed position by a second spring, in complementary abutment against a second seat arranged in the housing, the control valve cooperating with an actuator to move from the normally closed position to an open position and, a bore in which a piston is slidably arranged, the piston piloting the injection of the fuel into a compression chamber;

wherein the bore is in a third fluid communication with the first control chamber, and wherein the bore opens into the first control chamber such that the third fluid communication is unrestricted;

wherein a fourth fluid communication is provided between the high pressure supply line and the second control chamber.

The fourth fluid communication may comprise a channel provided between the stem of the filling valve and the guide portion of the valve housing.

Alternatively, the filling valve may additionally comprise an elongate groove, wherein a close clearance is maintained between the guiding section of the stem and the guide portion of the valve housing at regions either side of the groove, wherein the fourth fluid communication comprises clearance between the groove and the guide portion of the valve housing and leak paths between the regions either side of the groove and the guide portion of the valve housing.

Alternatively, the filling valve may be provided with at least one flat, wherein the fourth fluid communication at least partially comprises a clearance between the flat and the guide portion of the valve housing.
The at least one flat may extend along an axial length of the stem of the filling valve. A ridge may be provided on the flat.

Alternatively, the fourth fluid communication may comprise a bypass orifice provided in the filling valve, wherein the bypass orifice opens into the communication channel. The bypass orifice may open into the communication channel at a point between a spill orifice and the second control valve.

The bypass orifice may extend from a flat, or from a groove provided on the stem adjacent the flat. Alternatively, the bypass orifice may extends from the stem at a point of the of the stem which does not comprise the guide portion, and may extend from the filling chamber.

The bypass orifice may extend between the filling chamber and the communication channel, and may be angled relative to a radial axis of the control valve arrangement.

The bypass orifice may be drilled into a groove section of the filling valve which is adjacent the stem and remote from the second control chamber.

In a further aspect, the present invention comprises a fuel injector wherein a movable needle cooperates with a nozzle to enable or prohibit fuel injection, the needle being hydraulically piloted by a control valve arrangement in accordance with any one of the preceding paragraphs.

The invention is also related to a fuel injector wherein a movable needle cooperates with a nozzle to enable or prohibit fuel injection, the needle being hydraulically piloted by a control valve arrangement as described in the preceding paragraphs.
BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now described by way of example with reference to the accompanying figures in which:

Figure 1a is a cross-sectional partial view of a fuel injector comprising a control valve arrangement in accordance with the present invention;

Figure 1b is a detailed cross-section partial view of the fuel injector of Figure 1a;

Figure 1c is an isometric view of the filing valve of the control valve arrangement of Figure 1a;

and

Figures 2a to 9c are views corresponding to those of Figure 1a to 1c, of alternative control valve arrangements in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a fuel injector such as a Piezo injector, wherein an additional fluid flow path is provided from a high pressure supply to an inter-valve volume, i.e. a volume between a control valve and filling valve. Alternative embodiments of the present invention are described below.

For clarity, the vertical orientation of the figures will be referred to; words indicating relative positioning of components are not intended to limit the scope of protection.
Only Figure 1a has been fully referenced; like numerals can be assumed in respect of corresponding figures except where indicated.

A first embodiment of the present invention, as illustrated in Figures 1a to lc, comprises a fuel injector 10 comprising a control valve arrangement 12. The fuel injector further comprises a needle guide housing 14 in which a needle 16 is slidable within a bore 18 and engageable with a needle seat (not shown), to control a flow of fuel from a high pressure supply line 20, through the needle guide housing 14.

Above the needle guide housing 14 is provided a valve housing 22, comprising a through hole extending along a vertical valve axis A2, which is slightly offset relative to a main vertical axis A1. The through hole comprises several coaxial sections as described below from bottom to top.

A first through hole section comprises a first control chamber 24, and a first frustoconical valve seat 26, above which is provided a filling chamber 28, defined by a wall 30. Above the filling chamber 28 is provided a cylindrical guide portion 32, which restricts at the top to form a second frustoconical valve seat 34. A central aperture of the second valve seat 34 opens into a large low pressure chamber 36, from which is connected a low pressure line 38.

As illustrated, the offset of the axis A2 from axis A1, i.e. the offset of the bore 18 from the through hole, is such that an unrestricted fluid communication is enabled between the bore 18 and the first control chamber 24.

A first poppet valve, comprising a filling valve 40, is arranged so as to cooperate with the first valve seat 26. The filling valve 40 comprises a disc-plug portion 42, a stem 44 which extends axially upwardly from the disc-plug portion 42, and a groove 43 between the disc-plug portion 42 and the stem 44. Part of the stem 44 is contained within the guide portion 32 of the valve housing 22; this part of the stem 44 acts as a guide, thereby guiding the filling valve 40 within a guide clearance between the guide portion 32 and the filling valve 40.
A coil spring 46 is provided in the filling chamber 28, the coil spring 46 being compressed between a top portion of wall 30 and an upper face of the disc-plug portion 42. The coil spring 46 maintains the filling valve 40 in an open position away from the first valve seat 26.

The filling valve 40 is further provided with an internal axial communication channel 48 extending throughout the filling valve 40 from a lower face of the disc-plug portion 42 to a top surface 50 of the stem 44. The communication channel 48 comprises an upper section 48a and a lower section 48b, the upper and lower sections 48a, 48b being separated by restriction provided by a spill orifice 52. The communication channel 48 opens downwardly into the first control chamber 24 and also into the bore 18.

A lift stop 54 is provided on the lower face of the disc-plug portion 42; the lift stop 54 abuts a top face of the needle guide housing 14 when the filling valve 40 opens, thereby to limit the range of displacement of the filling valve 40.

A second poppet valve, comprising a control valve 56, is arranged above the filling valve 40, so as to cooperate with the second valve seat 34. Similarly to the filling valve 40, the control valve 56 comprises a disc-plug portion 58 and a stem 60, which extends upwardly into the low pressure chamber 36.

A spring 62 is provided in the low pressure chamber 36 around the stem 60; the spring 62 maintains the control valve 56 in a closed position, wherein the disc-plug portion 58 is in abutment with the second valve seat 34.

An actuator (not shown, indicated generally at 66) such as a piloted actuator, cooperates with the control valve 56, to provide a downward force to, and thereby open, the control valve 56, by pushing it away from the second valve seat 34.
A second control chamber 68 is defined within the guide portion 32, between the filling valve stem 44 and the control valve 56. The second control chamber 68 thereby defines an inter-valve volume.

A filling channel 70 extends from the supply line 20. A further restriction orifice 72 is provided between the filling channel 70 and the filling chamber 28, such that the restriction orifice 72 opens in the wall 30 of the filling chamber 28.

In a first phase of operation of the fuel injector 10, injection of fuel is prevented as the needle 16 is in a downward position and in abutment against the needle seat. The actuator 66 is not energised, and therefore the control valve 56 is in a closed position and the filling valve 40 in an open position. A continuous fluid communication is established between the high pressure line 20 and the second control chamber 68, via the filling channel 70, restriction orifice 72, the filling chamber 28, the first control chamber 24, the communication channel 48. This volume is filled with high pressure fuel; maintaining the needle 16 in the downward position.

An additional fluid communication flow path is provided between the high pressure line 20 and the second control chamber 68; this additional flow path is described below.

In a second phase of operation of the fuel injector 10, an injection event, to eject fuel into a compression chamber (not shown), is initiated by energising of the actuator 66, thereby to push the control valve 56 downwardly to an open position. High pressure fuel inside the second control chamber 68 flows into the low pressure chamber 36, causing depressurisation of the second control chamber 68 and thereby urging the filling valve 40 into a closed position, thereby interrupting the fluid communication described above.

High pressure fuel in first control chamber 24 flows through the communication channel 48, the velocity of the fuel flow being limited by the spill
orifice 52, thereby decreasing the pressure of the flow through the communication channel 48.

The pressure in the first control chamber 24 decreases and the needle 16 moves upwardly at a controlled speed.

The actuator 66 is subsequently de-energised, thereby ending the second phase of operation. In a third phase of operation, the spring 62 urges the control valve 56 upwardly, thereby closing it against the second valve seat 34. Fuel in the first control chamber 24, the communication channel 48, and the second control chamber 68, quickly adjusts to a common pressure. The coil spring 46 and high pressure fuel in the filling chamber 28 cause the filling valve 40 to open, thereby re-establishing full volume in the fluid communication described above. Re-pressurisation of the fuel in this volume acts to push the needle 16 towards the closing needle seat, thereby ending the injection event.

The further restriction orifice 72 acts to damp any hydraulic wave activity in the high pressure line 20 and the filling channel 70.

The re-establishing of full volume and re-pressurisation in the fluid communication volume as described above is aided by the additional flow path between the high pressure line 70 and the second control chamber 68, i.e. between the high pressure line 20 and the inter-valve volume. In the embodiment of Figures 1a to lc, the additional flow path comprises a clearance channel 100 defined by a guide clearance between the stem 44 of the filling valve 40 and the guide portion 32 of the valve housing 22, which is increased in comparison to prior art embodiment, i.e. the guide clearance is increased sufficiently to allow fluid flow between the stem 44 and the guide portion 32.

In Figures 1a to lc, the increased guide clearance between the stem 44 and the guide portion 32 is exaggerated for illustration purposes; the diameter of the guide clearance could be in the range 3µm to 7µm.
The clearance channel 100 extends between the filling chamber 28 and the second control chamber 68. Therefore in the present embodiment, an additional flow of fuel is enabled from the high pressure line 20 to the second control chamber 68, via the filling channel 70, the restriction orifice 72, the filling chamber 28, and the clearance channel 100.

The second control chamber 68, i.e. the inter-valve volume, is therefore able to fill and re-pressurise more quickly than in prior art embodiments, thereby avoiding steep gain curves for small injections, particularly where a large inter-valve volume is provided, for example for ease of manufacture.

In a second embodiment of the present invention, as illustrated in Figures 2a to 2c, a circumferential elongate groove 205 is provided on the stem 44.

A close clearance is maintained between the stem 44 and the guide portion 32, in regions 230, above and below (i.e. either side of) the groove 205. The distance over which the groove 205 extends is sufficiently long, to limit the length over which the close-clearance regions 230 extend, to ensure that the leakage is enabled between the stem 44 and guide portion 32 at the close-clearance regions 230.

The additional flow path in the second embodiment therefore is similar to that of the first embodiment, however instead of channel 100, the flow path comprises a clearance between the stem 44 and the guide portion 32 along the length of the groove 205, and the two leak paths which are enabled at close-clearance regions 230.

Due to the close clearance at regions 230, the guiding of the filling valve 40 is improved compared to that of the first embodiment. This improved guiding results in a reduction in shot-to-shot variations which could be caused by the filling valve 40 moving radially within the clearance between the filling valve 40 and the valve housing 22.
In a third embodiment of the present invention, as illustrated in Figures 3a to 3c, at least one flat 306 is provided along the length of the stem 44 of the filling valve 40. The additional flow path therefore includes a channel 300, which is defined by the clearance between the flat 306 and the guide portion 32.

In the third embodiment, the guiding of the filling valve 40 within the clearance between the filling valve 40 and the guide portion 32, is again improved in comparison to the first embodiment, as a close clearance is maintained between the stem 44 and the guide portion 32 around the non-flat area of the stem 44.

Furthermore, the third embodiment is less sensitive to fuel viscosity (and therefore temperature) than the first and second embodiments, due to the reduced viscosity sensitivity of a flat compared to that of a guide leakage.

A fourth embodiment of the present invention, as illustrated in Figures 4a to 4c comprises, in common with the third embodiment, at least one flat 406, and additionally comprises a localised ridge 407 provided on the flat 406, such that the flat 406 is separated into two portions, 406a and 406b. The resulting channel 400 acts more like an orifice than the earlier embodiment due to the ridge 406. The fourth embodiment therefore has a further reduced sensitivity to fuel viscosity and therefore temperature.

In further alternative embodiments of the present invention as described below, a bypass orifice is provided, which opens into the communication channel 48.

In a fifth embodiment of the present invention, a bypass orifice 510 is drilled through the filling valve 40, in the guiding region of the stem 44. At least one flat 506 is provided, only to ensure that the bypass orifice 510 can be drilled upstream of, i.e. above, the spill orifice 52.
The additional flow path between the high pressure line 20 and the second control chamber 68 in the fifth embodiment is therefore enabled via the filling channel 70, the restriction orifice 72, the filling chamber 28, a clearance channel 500 (between the flat 506 and the guide portion 32), the bypass orifice 510, and the upper section 48a of the communication channel 48.

In the fifth embodiment, sensitivity to fuel viscosity is further reduced.

A sixth alternative embodiment of the present invention, as illustrated in Figures 6a to 6c, is similar to the fifth embodiment, however the bypass orifice 610 is drilled into a circumferential groove 620 provided in the stem 44 adjacent a flat 606. Compared to the fifth embodiment, the additional flow path of the sixth embodiment therefore additionally comprises the groove 620.

Accordingly in this embodiment, circumferential alignment of the bypass orifice 610 is not critical (as it would be if it was drilled into the flat 606).

In a seventh alternative embodiment of the present invention, as illustrated in Figures 7a to 7c, the spill orifice 52 is located lower down the communication channel 48 than in the earlier embodiments, at a point below the guide section of the stem 44, i.e. below the section of the stem 44 which is contained within the guide portion 32 of the valve housing 22.

The bypass orifice 710 of the seventh embodiment communicates the filling chamber 28 directly with the upper section 48a of the communication channel. In this embodiment, the bypass orifice 710 is drilled into a flat 706.

In this embodiment, the drilling of the bypass orifice 710 into the filling valve 40 does not affect the guiding leakage of the stem 44/guide section 32.

The additional flow path between the high pressure supply line 20 and the second control chamber 68 in enabled via the filling channel 70, the restriction
orifice 72, the filling chamber 28, the bypass orifice 710, and the upper section 48a of the communication channel 48.

In the eight embodiment of the present invention, as illustrated in Figures 8a to 8c, the spill orifice 52 is located within the guide section of the stem 44, as in the first to sixth embodiments. However, possible effects on the guide leakage are again avoided by drilling an angled bypass orifice 810 (i.e. the bypass orifice 810 is angled with respect to a radial axis R1 of the control valve arrangement), directly from the filling chamber 28 to the upper section 48a of the communication channel 48.

The additional flow path of the eighth embodiment is therefore the same as that of the seventh embodiment.

In the embodiment of Figures 8a to 8c, the angled bypass orifice 810 comprises a first section 812 and a second section 814 which is of a smaller cross-sectional area than the first section 812.

A ninth embodiment of the present invention, as illustrated in Figures 9a to 9c, is a combination of certain features of the seventh and eighth embodiments. The spill orifice 52 is in a lower position similarly to the seventh embodiment, and a bypass orifice 910 is again drilled directly from the filling chamber 28 to the upper section 48a of the communication channel 48, similarly to the eighth embodiment. To enable this combination, without affecting the guide clearance of the stem 44 within the guide portion 32, the bypass orifice 910 drilled into the groove section 43 of the filling valve 40, i.e. between the disc-plug portion 42 and the stem 44. Similarly to the eighth embodiment, the bypass orifice 910 is drilled at an angle to a radial axis R1 of the control valve arrangement 12.

In common with the first embodiment, the alternative embodiments of the present invention as described above all provide an additional flow path between the high pressure line 20 and the second control chamber 68, which in
each embodiment enables the second control chamber 68 to refill and re-
pressurise more quickly than in prior art embodiments. All embodiments
therefore avoid steep gain curves for small injections, particularly where a large
inter-valve volume is present.

The above embodiments are provided by way of example only, further
alternative embodiments comprising a combination of the above features, which
enable an additional flow path between the high pressure line 20 and the second
control chamber 68, are included within the scope of the present invention.
REFERENCES

fuel injector 10
control valve arrangement 12
5 needle guide housing 14
needle 16
bore 18
high pressure supply line 20
valve housing 22
10 vertical valve axis A2
main vertical axis A1
first control chamber 24
first valve seat 26
filling chamber 28
15 wall 30
guide portion 32
second valve seat 34
low pressure chamber 36
low pressure line 38
20 filling valve 40
disc-plug portion 42
stem 44
groove 43
coil spring 46
25 communication channel 48
upper section 48a
lower section 48b
stem top surface 50
spill orifice 52
30 lift stop 54
control valve 56
disc-plug portion 58
stem 60
spring 62
actuator 66
second control chamber / inter-valve volume 68
filling channel 70
5 restriction orifice 72
additional flow path 100, 300, 400, 500
circumferential groove 205
flat 306, 406, 406a, 406b, 506, 606, 706
ridge 407
10 bypass orifice 510, 610, 710, 810, 910
groove 620
CLAIMS

1. A control valve arrangement (12) of a fuel injector (10) comprising a valve housing (22) wherein are arranged a filling channel (70) extending from a high pressure fuel supply line (20) to a filling chamber (28), the filling chamber being in a first fluid communication with a first control chamber (24), wherein the first fluid communication is controlled by a filling valve (40) normally biased open by a first spring (46), away from a first seat (26) arranged in the valve housing (22), and a communication channel (48) extending from the first control chamber (24) to a second control chamber (68) which is in a second fluid communication with a low pressure outlet line (38), wherein the filling valve (40) comprises a stem (44), a guiding section of which is located within a guide portion (32) of the valve housing (22); wherein the second fluid communication is controlled by a control valve (56) normally biased in a closed position by a second spring (62), in complementary abutment against a second seat (34) arranged in the housing (22), the control valve (56) cooperating with an actuator (66) to move from the normally closed position to an open position and, a bore (18) in which a piston (16) is slidably arranged, the piston (16) piloting the injection of the fuel into a compression chamber; wherein the bore (18) is in a third fluid communication with the first control chamber (24), and wherein the bore (18) opens into the first control chamber (24) such that the third fluid communication is unrestricted; wherein a fourth fluid communication is provided between the high pressure supply line (20) and the second control chamber (68).

2. A control valve arrangement as claimed in claim 1 wherein the fourth fluid communication comprises a channel provided between the stem (44) of the filling valve (40) and the guide portion (32) of the valve housing (22).

3. A control valve arrangement as claimed in claim 1 wherein the stem (44) of the filling valve (40) additionally comprises an elongate groove (205), and wherein a close clearance is maintained between the guiding section of the stem...
(44) and the guide portion (32) of the valve housing (22) at regions (230) either 
side of the groove (205), and wherein the fourth fluid communication comprises 
clearance between the groove (205) and the guide portion (32) of the valve 
housing (22) and leak paths between the regions (230) either side of the groove 
(205) and the guide portion (32) of the valve housing (22).

4. A control valve arrangement as claimed in claim 1 wherein the filling 
valve (40) is provided with at least one flat (206, 306, 406, 406a, 406b, 506, 606, 
706), wherein the fourth fluid communication at least partially comprises a 
clearance between the flat (206, 306, 406, 406a, 406b, 506, 606, 706) and the 
guide portion (32) of the valve housing (22).

5. A control valve arrangement as claimed in claim 4 wherein the at least one 
flat (206) extends along an axial length of the stem (44) of the filling valve (40).

6. A control valve arrangement as claimed in claim 4 or claim 5 wherein a 
ridge (107) is provided on at least one flat (406).

7. A control valve arrangement as claimed in claim 1 wherein the fourth fluid 
communication comprises a bypass orifice (510, 610, 710, 810, 910) provided in 
the filling valve, wherein the bypass orifice (510, 610, 710, 810, 910) opens into 
the communication channel (48).

8. A control valve arrangement as claimed in claim 7, wherein the bypass 
orifice (510, 610, 710, 810, 910) opens into the communication channel (48) at a 
point between a spill orifice (52) and the second control valve (68).

9. A control valve arrangement as claimed in claims 4 and 7, wherein the 
bypass orifice (510, 710) extends from the flat (506, 706).

10. A control valve arrangement as claimed in claims 4 and 7 wherein a 
groove (620) is provided on the stem (44) of the filling valve (40) adjacent the flat 
(606), and wherein the bypass orifice (610) is extends from the groove (620).
11. A control valve arrangement as claimed in claim 7 wherein the bypass orifice (710, 810, 910) extends from the stem (44) at a point of the of the stem (44) which does not comprise the guide portion.

12. A control valve arrangement as claimed in claim 11 wherein the bypass orifice (710, 810, 910) is provided between the filling chamber (28) and the communication channel (48).

13. A control valve arrangement as claimed in claim 12 wherein the bypass orifice (810, 910) is angled relative to a radial axis (Rl) of the control valve arrangement.

14. A control valve arrangement as claimed in claim 12 wherein the bypass orifice (910) is drilled into a groove section (43) of the filling valve (40), the groove section (43) being adjacent the stem (44) and the remote the second control chamber (68).

15. A fuel injector (10) wherein a movable needle cooperates with a nozzle to enable or prohibit fuel injection, the needle being hydraulically piloted by a control valve arrangement (12) in accordance with any one of the preceding claims.
FIG. 4a
FIG. 9a
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M47/02
ADD. F02M63/00

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)
F02M

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>EP 2 093 410 A1 (DELPHI TECH INC [US]) 26 August 2009 (2009-08-26)</td>
<td>1,2,15</td>
</tr>
<tr>
<td>A</td>
<td>paragraphs [0036], [0040]; figure 1</td>
<td>3-14</td>
</tr>
<tr>
<td>A</td>
<td>figures 1,2</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>EP 2 628 940 A1 (BOSCH GMBH ROBERT [DE]) 21 August 2013 (2013-08-21)</td>
<td>1,15</td>
</tr>
<tr>
<td>A</td>
<td>figure 1</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>DE 10 2011 089130 A1 (BOSCH GMBH ROBERT [DE]) 20 June 2013 (2013-06-20)</td>
<td>1,15</td>
</tr>
<tr>
<td>A</td>
<td>figures</td>
<td></td>
</tr>
</tbody>
</table>

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
  * "A" document member of the same patent family

Date of the actual completion of the international search
2 October 2015

Date of mailing of the international search report
14/10/2015

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
Landriscina, V
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CN 103644055 A</td>
<td>19-03-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2093410 Al</td>
<td>26-08-2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2743490 Al</td>
<td>18-06-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES 2464451 T3</td>
<td>02-06-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 5236018 B2</td>
<td>17-07-2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2011512486 A</td>
<td>21-04-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PT 2093410 E</td>
<td>26-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2011017844 Al</td>
<td>27-01-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2009103819 Al</td>
<td>27-08-2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 102013112227 Al</td>
<td>15-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 103807069 A</td>
<td>21-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 102013112227 Al</td>
<td>15-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 5641035 B2</td>
<td>17-12-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2014098323 A</td>
<td>29-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2014131483 Al</td>
<td>15-05-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 102012202538 Al</td>
<td>22-08-2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2628940 Al</td>
<td>21-08-2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 102011089130 Al</td>
<td>20-06-2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>

Form PCT/ISA/210 (patent family annex) (April 2005)