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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 December 2019 (26.12.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/243221 A1

(51) International Patent Classification:
F02M 59/46 (2006.01)

(21) International Application Number:
PCT/EP2019/065810

(22) International Filing Date:
17 June 2019 (17.06.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1809989.5 18 June 2018 (18.06.2018) GB

(71) Applicant: **DELPHI TECHNOLOGIES IP LIMITED** [BB/BB]; Erin Court, Bishop's Court Hill, St. Michael (BB).

(71) Applicant *(for GH only)*: **DELPHI FRANCE SAS** [FR/FR]; c/o Delphi Technologies, Campus Saint Christophe, Bâtiment Galilée 2, 10, avenue de l'Entreprise, 95863 Cergy Pontoise CEDEX (FR).

(72) Inventor: **WILLMOTT, James**; 4 Newgardens Road Teynham, Sittingbourne, Kent ME9 9SG (GB).

(74) Agent: **DELPHI FRANCE SAS**; Delphi Technologies, Campus Saint Christophe, Bâtiment Galilée 2, 10, avenue de l'Entreprise, 95863 Cergy Pontoise CEDEX (FR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

(54) Title: FUEL PUMP VALVE

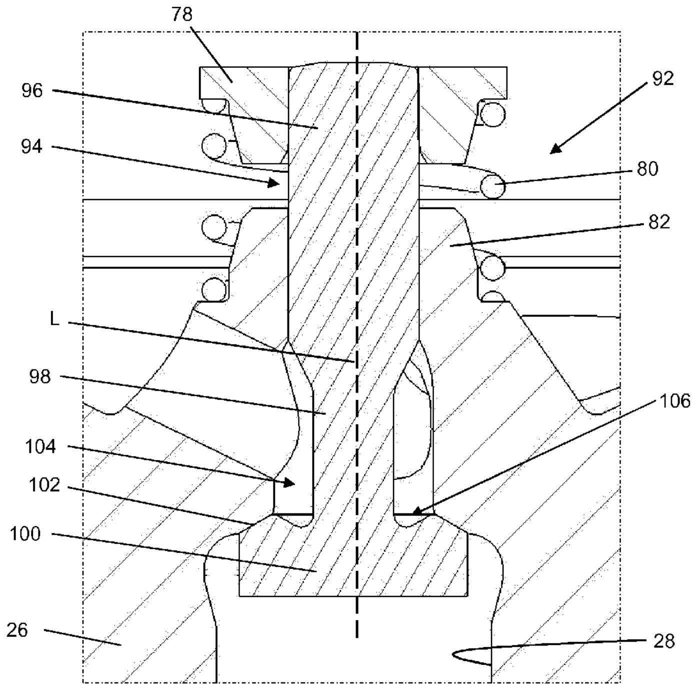

Fig. 6

(57) Abstract: A valve member (94) of an automotive fuel pump valve (92), the valve member (94) comprising: an elongate body (96); a head (100) disposed at a longitudinal end of the body (96), the head (100) comprising an engagement surface (102) extending radially from the body (96), the engagement surface (102) being configured to engage a valve seat (68) of the fuel pump valve (92); and a recess (106) extending longitudinally into the head (100) to act as a particle trap, in use.

WO 2019/243221 A1

[Continued on next page]

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

FUEL PUMP VALVE

FIELD OF THE INVENTION

This invention relates to automotive fuel pump valves and in particular, but not exclusively, to an inlet valve of a high-pressure fuel pump and its valve member.

BACKGROUND TO THE INVENTION

In some automotive high-pressure fuel pumps, debris can accumulate under gravity in a v-shaped crevice that forms around a seal where a valve member engages a valve seat in an inlet valve. This debris then drops into a clearance between the sealing faces of the valve member and the valve seat when the valve member lifts, becoming trapped between those faces and preventing the valve from closing again. This in turn prevents the fuel pump from reaching a normal fuel pressure, which may be around 200 bar at engine cranking, for example. In this event, an engine that depends on fuel supplied by the pump will fail to start.

For a passive arrangement that relies on generation of pressure differentials to operate the inlet and outlet valves of the pump, the absence of a seal in the inlet valve caused by debris entrapment can preclude generation of a sufficient pressure differential to open the outlet valve and therefore deliver fuel. This is particularly the case at engine start, when the cranking speed is relatively low. The problem may be further exacerbated if an auxiliary lift pump that supplies fuel to the high-pressure fuel pump is of low power.

Conversely, if the engine starts successfully debris is cleared each time the valve lifts and so does not accumulate around the valve member, and so the problem tends not to arise during subsequent engine operation.

In pump arrangements subject to this problem, the valve member may only lift by around 40 microns or less on engine start-up, and so it is only debris of this size that contributes to the problem. Such debris originates from various sources, including metal fragments from manufacture or wear of the pump components, and small particles present in fuel.

As the debris involved is so small, the use of a fine mesh filter as a solution is not feasible as wax crystals can form in the fuel in cold conditions, which could block such a filter. Also, although it is known to include particle traps in pump housings to collect particles of this size, in some arrangements packaging constraints are such that this is not possible.

It is against this background that the invention has been devised.

SUMMARY OF THE INVENTION

An aspect of the invention provides a valve member of an automotive fuel pump valve. The valve member comprises an elongate body and a head disposed at a longitudinal end of the body. The head comprises an engagement surface extending radially from the body, the engagement surface being configured to engage a valve seat of the fuel pump valve. The valve member also comprises a recess extending longitudinally into the head to act as a particle trap, in use.

By extending longitudinally into the head, at least to some extent, the recess extends generally downwardly when the valve member is oriented vertically with the head lowermost. This means that debris suspended in fuel will settle in the recess under gravity while the fuel pump is idle, and will be held in the recess when the valve initially opens, thereby preventing particle entrapment and the associated problems.

Notably, a recess that extends longitudinally into the head is counter to convention, since it will have a negative impact on fluid dynamics. However, by preventing particle entrapment, this arrangement provides a net benefit.

The recess is optionally formed in or adjacent to the engagement surface of the head. This arrangement ensures that debris that might otherwise accumulate around the engagement surface is instead collected in the recess.

In some embodiments, the recess has a radial extent such that it spans the width of a closed volume formed between the valve member and a bore in which the valve member is received, in use. In such arrangements, the recess defines the lower surface of the closed volume when the valve member is oriented vertically, meaning that there is nowhere for debris to settle other than in the recess. Thus, the recess effectively collects all debris in such arrangements.

The recess may be annular, which both aids its performance as a particle trap and eases manufacture.

The engagement surface may be generally conical.

The recess may be disposed at a junction between the head and the body of the valve member.

The valve member may have multiple orders of rotational symmetry about its longitudinal axis, and may have circular symmetry about its longitudinal axis.

The invention also extends to a valve of an automotive fuel pump, the valve comprising the valve member of the above aspect. Such a valve may be configured as a fuel inlet valve, for example.

Another aspect of the invention provides an automotive fuel pump comprising the valve member or the valve of the above aspects. The fuel pump may be a configured as a high-pressure fuel pump.

A further aspect of the invention provides a method of preventing debris entrapment in an automotive fuel pump valve, the valve comprising a valve member having an elongate body and a head disposed at a longitudinal end of the body, the head comprising an engagement surface extending radially from the body, the engagement surface being configured to engage a valve seat of the fuel pump valve. The method comprises forming a recess that extends longitudinally into the head so that the recess acts as a particle trap, in use.

It will be appreciated that preferred and/or optional features of the first aspect of the invention may be incorporated alone or in appropriate combination in the second aspect of the invention also.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more readily understood, preferred non-limiting embodiments thereof will now be described, by way of example only, with reference to the accompanying drawings, in which like features are assigned like reference numbers, and in which:

Figure 1 is a side view of a known fuel pump in longitudinal cross-section;

Figure 2 is shows the fuel pump of Figure 1 in transverse cross-section;

Figure 3 is a detail view of a pumping head of the fuel pump of Figure 1;

Figure 4 is a detail view of an inlet valve arrangement of the pumping head of Figure 3;

Figure 5 is a detail view of a crevice that forms around a valve seat of the inlet valve arrangement of Figure 4 when closed;

Figure 6 shows an inlet valve arrangement comprising a valve member according to an embodiment of the invention that is suitable for use in the fuel pump of Figure 1; and

Figure 7 is a detail view of a valve seat region of the inlet valve arrangement of Figure 6.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

To provide context for the invention and to explain the above noted problem of debris entrapment in more detail, a known automotive fuel pump 10 is now described with reference to Figures 1 and 2, which show the pump 10 in longitudinal and transverse cross-section respectively. The skilled reader will be familiar with the construction of such a pump, and so the below description focusses on the details that are relevant to the present invention.

The fuel pump 10 includes a pump housing 12 that supports a pumping head 14 and a longitudinally-extending camshaft 16 carrying a cam 18. In the pictured arrangement, the cam 18 is oval defining a pair of opposed lobes 19, and has two axes of symmetry in transverse cross-section, as is visible in Figure 2.

The pumping head 14 is disposed radially outboard of the camshaft 16 to align with the cam 18. An elongate cylindrical rod defining a plunger 20 extends radially from the pumping head 14 to engage the cam 18 through a cam roller arrangement 22, the plunger 20 being biased into contact with the cam roller arrangement 22 by a plunger return spring 24. Thus, rotation of the camshaft 16 is translated into reciprocating linear motion of the plunger 20 in a radial direction into and outwardly from the pumping head 14.

The plunger 20 reaches an upper position within the pumping head 14 when the cam roller arrangement 22 aligns with the widest region of the cam 18, and sinks to occupy a lower position when the cam 18 rotates through a right angle so that the cam roller arrangement 22 aligns with the narrowest region of the cam 18.

As shown more clearly in Figure 3, the pumping head 14 has a pumping head body 26 having a main bore 28 extending radially with respect to the camshaft 16 through the entire pumping head body 26, and a secondary bore 30 that is orthogonal to the main bore 28.

A dome-like lid 32 covers an opening 34 of the main bore 28 at an upper surface 36 of the pumping head body 26, so that a cavity 38 is formed between the lid 32 and the upper surface 36 of the pumping head body 26, sealed by an o-ring 40. In use, this cavity 38 acts as a reservoir for fuel to be fed into the main bore 28. Fuel held in the reservoir is typically at approximately four bar.

The secondary bore 30 extends between a proximal end 42 that connects with the main bore 28 and a distal end 44 that is formed within a tubular protrusion of the pumping head body 26 extending parallel to the camshaft 16, to define a pump outlet 46. It is noted that the orientation of the pump outlet can be varied to suit each application.

The proximal end 42 of the secondary bore 30 comprises a narrowed region 48 where it connects with the main bore 28. A conical surface provides an interface between the narrowed region 48 and the remainder of the secondary bore 30, that conical surface defining an outlet valve seat 50 for a spherical outlet valve member 52 that controls fluid flow from the main bore 28 to the secondary bore 30 and on to the pump outlet 46. The outlet valve seat 50 and the outlet valve member 52 therefore together define an outlet valve 54 of the pumping head 14.

The outlet valve member 52 is biased into engagement with the outlet valve seat 50 by an outlet valve spring 56, defining a closed position for the outlet valve 54. Accordingly, the outlet valve 54 is configured as normally-closed.

A portion of the main bore 28 is defined in a tubular protrusion defining a turret 58 of the pumping head body 26 that extends towards the camshaft 16 to receive the plunger 20 in a telescopic arrangement.

The main bore 28 includes a narrowed portion 60 at its upper end, as viewed in Figure 3, which is of reduced diameter relative to the majority of the main bore 28 and is shaped to accommodate an inlet valve member 62 to create an inlet valve 64 generally in the form of a poppet valve.

The narrowed portion 60 of the main bore 28 communicates with a set of feed channels 66 extending through the pumping head body 26 at an angle of approximately 60° with respect to the main bore 28, to supply fuel from the cavity 38 to the main bore 28. In this embodiment there are three feed channels 66 equi-angularly spaced around the main bore 28, only one of which is visible in Figure 3 as the other two feed channels 66 lie outside of the section plane.

Below a junction with the feed channel 66, the main bore 28 includes a conical surface that connects the narrowed portion 60 to the remainder of the main bore 28, that conical surface defining an inlet valve seat 68 of the inlet valve 64.

The inlet valve 64 is shown in detail in Figure 4, which shows that the inlet valve member 62 generally takes the form of an elongate rod having circular symmetry about its longitudinal axis L. In axial succession along the central longitudinal axis L of the inlet valve member 62, from top to bottom as viewed in Figure 4, the inlet valve member 62 comprises three generally cylindrical portions: a main body 70; a neck 72 of reduced diameter relative to the main body 70; and a relatively short head 74 of greater diameter than the main body 70.

A generally conical surface joining tubular outer surfaces of the head 74 and the neck 72 defines an engagement surface 76 of the inlet valve member 62, which is configured to engage the inlet valve seat 68 to create a high-pressure seal and thereby close the inlet valve 64, in use.

As Figure 4 shows, a junction between the engagement surface 76 and the outer surface of the neck 72 is filleted. Similarly, a junction between the neck 72 and the main body 70 is defined by a conical surface. Profiling the outer surface of the inlet valve member 62 in this way optimises hydrodynamics around the inlet valve member 62, as is conventional.

When assembled, the main body 70 of the inlet valve member 62 is telescopically received in the uppermost part of the narrowed portion 60 of the main bore 28 so that an upper end of the main body 70 protrudes into the cavity 38 beneath the lid 32 of the pumping head 14. A collar 78 is fixed to the upper end of the main body 70 of the inlet valve member 62, typically by press-fitting. The collar 78 is arranged to receive an inlet valve spring 80 that acts between the collar 78 and an upwardly extending cylindrical protrusion 82 formed around the opening 34 of the main bore 28 in the upper surface 36 of the pumping head body 26, to bias the inlet valve member 62 upwardly as viewed in Figure 4.

As Figure 4 shows, the diameter of the main body 70 of the inlet valve member 62 is approximately equal to that of the narrowed portion 60 of the main bore 28 of the pumping head body 26 so that a close fit is formed.

Below this, the neck 72 of the inlet valve member 62 resides at the junction between the feed channel 66 and the narrowed portion 60 of the main bore 28. Accordingly, the reduced diameter of the neck 72 creates an annular space 84 within the narrowed portion 60 of the main bore 28 within which fuel can flow past the inlet valve member 62 towards the inlet valve seat 68.

The head 74 of the inlet valve member 62 is disposed beneath the inlet valve seat 68, so that the inlet valve member 62 moves upwardly to close the inlet valve 64, and moves downwardly to open the inlet valve 64.

As noted above, the inlet valve spring 80 is configured to provide a retraction force that acts to bias the inlet valve member 62 upwardly, as viewed in Figure 4. The engagement surface 76 of the inlet valve member 62 is therefore biased into engagement with the inlet valve seat 68, defining a closed position for the inlet valve 64. Accordingly, the inlet valve 64 is configured as normally-closed. As shall become clear in the description that follows, in operation the pump 10 relies on pressure differentials across the inlet valve member 62 to switch the inlet valve 64 between the closed position and an open configuration in which the inlet valve member 62 is displaced from the inlet valve seat 68.

Returning to Figure 3, even when occupying its upper position the plunger 20 does not occlude the entrance to the secondary bore 30 and is spaced from the underside of the inlet valve member 62, leaving a portion of the main bore 28 unoccupied. This unoccupied portion defines a pumping chamber 86 in which fuel is pressurised before being expelled through the pump outlet 46.

When the plunger 20 is in its lower position, the pumping chamber 86 has a maximum volume. In operation, as the cam 18 rotates to urge the plunger 20 upwardly, fuel in the pumping chamber 86 is compressed as the volume of the pumping chamber 86 decreases. The resulting rise in fuel pressure generates a force on the underside of the inlet valve member 62 that, together with the retraction force provided by the inlet valve spring 80, presses the inlet valve member 62 into engagement with the inlet valve seat 68 to close the inlet valve 64. Simultaneously, the rising fuel pressure creates a force on the outlet valve member 52 that urges it away from the outlet valve seat 50 to open the outlet valve 54, allowing fuel to flow into the main part of the secondary bore 30 and thereby delivering fuel through the pump outlet 46.

As the plunger 20 completes its upward stroke, the pressure in the pumping chamber 86 equals the pressure of fuel in the secondary bore 30. This allows the outlet valve spring 56 to overcome the force generated by fuel pressure on the outlet valve member 52, and therefore return the outlet valve member 52 into engagement with the outlet valve seat 50 to close the outlet valve 54.

As the cam 18 rotates further, the plunger 20 begins to fall in a downward stroke under the action of the plunger return spring 24. This increases the volume of, and so reduces fuel pressure in, the pumping chamber 86. This pressure reduction creates a pressure differential across the inlet valve member 62 between fuel at supply pressure in the feed channel 66 and the increasingly low pressure fuel held in the pumping chamber 86. A resultant downwardly-acting force therefore arises on the inlet valve member 62, which overcomes the retraction force of the inlet valve spring 80 to open the inlet valve 64 and draw fuel into the pumping chamber 86.

This continues until the plunger 20 reaches its lowest position, at which point the pumping chamber 86 is once more at its maximum volume and is filled with fuel. The plunger 20 then commences another upward stroke, which increases pressure in the pumping chamber 86 to reiterate the pumping cycle.

It is during the downward stroke of the plunger 20 when the inlet valve 64 opens that the problem of debris entrapment described earlier can arise. In this respect, Figure 5 shows the inlet valve seal in detail, with the inlet valve 64 in its closed position. As noted previously, when closed a v-shaped crevice 88 forms around the inlet valve seal, and Figure 5 shows accumulated debris 90 within the crevice 88, said debris 90 having settled within stagnant fuel under gravity while the pump 10 and the engine were not operating. In this respect, the surface of the inlet valve member 62, which as already noted is contoured for optimised fluid flow around the inlet valve member 62 when the inlet valve 64 is open, acts to guide debris 90 into the crevice 88 when the inlet valve 64 is closed.

From the starting conditions shown in Figure 5, when the inlet valve 64 opens the downward slope of the engagement surface 76 of the inlet valve member 62 guides debris 90 into a space between the engagement surface 76 and the inlet valve seat 68.

In practice, the pump camshaft 16 typically rotates at the same speed as the vehicle engine. Noting that the cam 18 includes two lobes, two pumping cycles occur for each full rotation of the pump camshaft 16. Accordingly, pumping cycles may occur at around 30Hz when the vehicle engine idles, and at up to 200Hz in operation, for example.

So, the inlet valve 64 only remains open for a very short time on each pumping cycle. It follows that the debris 90 does not have time to travel beyond the point of engagement between the inlet valve member 62 and the inlet valve seat 68 before the inlet valve 64 starts to close again. This is particularly so where a relatively high amount of debris 90 that has accumulated while the pump 10 was not operating must be cleared and the flow rate of fuel across the valve is relatively low, as is the case at engine start-up.

As the inlet valve 64 closes, any debris 90 remaining between the engagement surface 76 and the valve seat becomes trapped and therefore prevents full closure of the inlet valve 64. This creates a leak path around the inlet valve member 62, which prevents fuel in the pumping chamber 86 from reaching a sufficient pressure to open the outlet valve 54. Thus, the pump 10 cannot dispense fuel and the engine does not start.

In this context, embodiments of the invention propose alternative inlet valve members that can be substituted for that shown in Figures 1 to 5 and described above. The inlet valve members of these embodiments include integral particle traps that collect debris and hold it during initial opening of the inlet valve 64 at engine start-up, thereby preventing the above described problem of debris entrapment. Accordingly, inlet valve members of such embodiments are particularly suited to compact pump arrangements lacking the space for accommodating a particle trap elsewhere.

Figures 6 and 7 show an inlet valve 92 comprising an inlet valve member 94 according to an embodiment of the invention. The inlet valve member 94 is configured as a direct replacement for the known inlet valve member 62 of the pump 10 shown in Figures 1 to 5, to be used in the same pumping head body 26. Accordingly, other features of the inlet valve 92 visible in Figures 6 and 7 are substantially identical to their counterparts of the known pump 10 already described, and for the sake of simplicity are not described again.

As for the known inlet valve member 62 of Figures 1 to 5, the inlet valve member 94 of the embodiment shown in Figures 6 and 7 generally takes the form of an elongate rod having circular symmetry about its longitudinal axis L. Accordingly, the inlet valve member 94 may, for example, be machined from a length of steel bar in a series of lathe operations as part of a CNC process.

In axial succession along the central longitudinal axis L of the inlet valve member 94, from top to bottom as viewed in Figure 6, the inlet valve member 94 comprises three generally cylindrical portions: a main body 96; a neck 98 of reduced diameter relative to the main body 96; and a relatively short head 100 of greater diameter than the main body 96.

As in the conventional inlet valve member 62, the inlet valve member 94 of this embodiment has a conical engagement surface 102 configured to engage the inlet valve seat 68 to create a high-pressure seal, that engagement surface 102 being defined by a generally conical surface joining tubular outer surfaces of the head 100 and the neck 98 of the inlet valve member 94. Accordingly, the engagement surface 102 extends radially from, and is inclined relative to, the neck 98. In a further similarity, a junction between the neck 98 and the main body 96 of the inlet valve member 94 is bridged by a conical surface.

When assembled in the known pumping head body 26, the main body 96 of the inlet valve member 94 is telescopically received in the uppermost part of the narrowed portion 60 of the main bore 28 so that an upper end of the main body 96 protrudes into the cavity 38 beneath the lid 32 of the pumping head 14. A collar 78 is fixed to the upper end of the main body 96 of the inlet valve member 94, typically by press-fitting. The collar 78 is arranged to receive an inlet valve spring 80 that acts between the collar 78 and the upwardly extending cylindrical protrusion 82 formed around the opening 34 of the main bore 28 in the upper surface 36 of the pumping head body 26, to bias the inlet valve member 94 upwardly as viewed in Figure 4.

As Figure 4 shows, similarly to the known inlet valve member, the diameter of the main body 96 of the inlet valve member 94 of this embodiment is approximately equal to that of the narrowed portion 60 of the main bore 28 of the pumping head body 26 so that a close fit is formed.

Below this, the neck 98 of the inlet valve member 94 resides at the junction between the feed channel 66 and the narrowed portion 60 of the main bore 28.

Accordingly, the reduced diameter of the neck 98 creates an annular space 104 within the narrowed portion 60 of the main bore 28 within which fuel can flow past the inlet valve member 94 towards the inlet valve seat 68.

The head 100 of the inlet valve member 94 is disposed beneath the inlet valve seat 68, so that the inlet valve member 94 moves upwardly to close the inlet valve 92, and moves downwardly to open the inlet valve 92.

As noted above, the inlet valve spring 80 is configured to provide a retraction force that acts to bias the inlet valve member 94 upwardly, as viewed in Figure 4. The engagement surface 102 of the inlet valve member 94 is therefore biased into engagement with the inlet valve seat 68, defining a closed position for the inlet valve 92. Accordingly, the inlet valve 92 is configured as normally-closed. As for the conventional arrangement, in operation the pump 10 relies on pressure differentials across the inlet valve member 94 to switch the inlet valve 92 between the closed position and an open configuration in which the inlet valve member 94 is displaced from the inlet valve seat 68.

Having considered the similarities between the conventional inlet valve 64 and the inlet valve 92 of this embodiment, it is now noted that the inlet valve member 94 of this embodiment differs from the conventional inlet valve member 62 in that an annular recess 106 or groove is formed at a junction between its engagement surface 102 and the outer surface of its neck 98, the recess 106 being arranged to act as a particle trap positioned directly adjacent to the inlet valve seat 68 that collects and holds debris that accumulates while the pump 10 is idle.

In this respect, Figure 7 shows the region of the inlet valve seat 68 in more detail, in which it is clear that the recess 106 extends longitudinally into the head 100 of the inlet valve member 94, the recess 106 being bounded by a circular rim 108 at its radially outer extremity, and the surface of the recess 106 blending into the tubular outer surface of the neck 98 at the radially innermost part of the recess 106.

The radial width of the recess 106 is configured so that the rim 108 generally coincides with an internal junction between the engagement surface 102 and the inlet valve seat 68. Thus, the v-shaped crevice 88 of the known arrangement shown in Figures 1 to 5 is eliminated by the recess 106 of the Figure 6 embodiment, ensuring that debris cannot accumulate at the junction between the engagement surface 102 and the inlet valve seat 68.

It is also possible for the recess 106 to be wider than the annular space 104 between the neck 98 and the narrowed portion 60 of the main bore 28 of the pumping head body 26, so that the conical surface of the main bore 28 that defines the inlet valve seat 68 overhangs the recess 106 to some extent when the inlet valve 92 is closed.

Consequently, the recess 106 spans the entire radial width of the annular space 104 around the neck 98 within the narrowed portion 60 of the main bore 28, so that when the inlet valve member 94 is oriented vertically the recess 106 defines a bottom surface of a closed volume around the neck 98 when the inlet valve 92 is closed. Thus, there is nowhere for debris settling under gravity within that closed volume to accumulate other than in the recess 106.

Accordingly, debris settling under gravity while the pump 10 is idle will fall into the recess 106 and therefore accumulates away from the point of contact between the engagement surface 102 and the inlet valve seat 68. Thus, when the inlet valve 92 opens relatively slowly in the first pumping stroke when the pump 10 is started, the accumulated debris is held in the recess 106 and does not fall into the space between the engagement surface 102 of the inlet valve member 94 and the inlet valve seat 68, thereby preventing debris entrapment.

Subsequently, when the engine starts and the pump 10 operates at its normal pressure, the high suction generated by the downward stroke of the plunger 20 is sufficient to suck the debris out of the recess 106 and therefore clear the debris while the inlet valve 92 is open.

It is noted that the shape of the cross-section of the recess 106 of the embodiment shown in Figures 6 and 7 is simply one possible example. Many different suitable shapes exist, provided that they achieve the function of trapping and holding debris during opening of the inlet valve 92 to prevent debris entrapment between the sealing faces of the inlet valve 92. In practice, this typically entails that the recess 106 extends longitudinally into the head 100 of the inlet valve member 94, at least to some extent.

Preferably, as in the Figure 6 embodiment the lowest extent of the recess 106 lies below the junction between the engagement surface 102 and the inlet valve seat 68 that is exposed to fuel within the narrowed portion 60 of the main bore 28 when the inlet valve 92 is closed. In other words, the recess 106 is configured such that, when oriented generally vertically as in Figure 6, it defines the lowest point in the closed volume within the narrowed portion 60 of the main bore 28 when the inlet valve 92 is closed, so that debris will naturally accumulate in the recess 106 under gravity.

Even more preferably, the recess 106 extends generally downwardly from the junction between the engagement surface 102 and the inlet valve seat 68, as in the Figure 6 embodiment. This optimises guidance of debris into the recess 106 and away from the junction between the engagement surface 102 and the inlet valve seat 68.

However, other shapes are possible for the recess 106, and the precise cross-section adopted may vary for each specific application.

Indeed, the recess need not necessarily be annular as in the embodiment shown in Figure 6. Instead, a series of recesses could be included around the head 100 adjacent to the engagement surface 102. For example, the recesses could take the form of a ring of longitudinal drillings around the head 100. In this case, the valve member would not have circular symmetry about its longitudinal axis as for embodiments having an annular recess, but would nonetheless have multiple orders of rotational symmetry about its longitudinal axis.

It is noted that the provision of a recess 106 in the inlet valve member 94 to solve the problem of debris entrapment runs counter to convention, as it entails a valve member offering poor fluid dynamics insofar as the recess 106 will create turbulence and/or a dead zone having stagnation points when fuel flows around the inlet valve member 94. This sits in stark contrast with the conventional design having a contoured surface leading towards the inlet valve seat 68 for optimised hydrodynamics.

It will be appreciated by a person skilled in the art that the invention could be modified to take many alternative forms to that described herein, without departing from the scope of the appended claims.

REFERENCES USED:

10 - pump
12 - pump housing
14 - pumping head
16 - camshaft
18 - cam
19 - cam lobe
20 - plunger
22 - cam roller arrangement
24 - plunger return spring
26 - pumping head body
28 - main bore of pumping head body
30 - secondary bore of pumping head body
32 - lid
34 - opening of the main bore
36 - upper surface of pumping head body
38 - cavity
40 - o-ring
42 - proximal end of secondary bore
44 - distal end of secondary bore
46 - pump outlet
48 - narrowed region of secondary bore
50 - outlet valve seat
52 - outlet valve member
54 - outlet valve
56 - outlet valve spring
58 - turret of pumping head body
60 - narrowed portion of main bore
62 - known inlet valve member
64 - known inlet valve
66 - feed channel
68 - inlet valve seat
70 - main body of known inlet valve member
72 - neck of known inlet valve member
74 - head of known inlet valve member

76 - engagement surface of known inlet valve member

78 - collar

80 - inlet valve spring

82 - protrusion around opening of main bore

84 - annular space around neck of known inlet valve member

86 - pumping chamber

88 - crevice

90 - debris

92 - inlet valve according to invention

94 - inlet valve member according to invention

96 - main body of inlet valve member according to invention

98 - neck of inlet valve member according to invention

100 - head of inlet valve member according to invention

102 - engagement surface of valve member according to invention

104 - annular space around neck of inlet valve member according to invention

106 - recess

108 - rim

CLAIMS:

1. A valve member (94) of an automotive fuel pump valve (92), the valve member (94) comprising:

an elongate body (96);

a head (100) disposed at a longitudinal end of the body (96), the head (100) comprising an engagement surface (102) extending radially from the body (96), the engagement surface (102) being configured to engage a valve seat (68) of the fuel pump valve (92); and

a recess (106) extending longitudinally into the head (100) to act as a particle trap, in use.

2. The valve member (94) of claim 1, wherein the recess (106) is formed in or adjacent to the engagement surface (102) of the head (100).

3. The valve member (94) of claim 1 or claim 2, wherein the recess (106) has a radial extent such that it spans the width of a closed volume (104) formed between the valve member (94) and a bore (28) in which the valve member (94) is received, in use.

4. The valve member (94) of any preceding claim, wherein the recess (106) is annular.

5. The valve member (94) of any preceding claim, wherein the engagement surface (102) is conical.

6. The valve member (94) of any preceding claim, wherein the recess (106) is disposed at a junction between the head (100) and the body (96) of the valve member (94).

7. The valve member (94) of any preceding claim, having multiple orders of rotational symmetry about its longitudinal axis

8. The valve member (94) of claim 7, having circular symmetry about its longitudinal axis.

9. A valve (92) of an automotive fuel pump (10), the valve (92) comprising the valve member (94) of any preceding claim.

10. The valve (92) of claim 9, configured as a fuel inlet valve.

11. An automotive fuel pump (10) comprising the valve member (94) of any of claims 1 to 8, or the valve (92) of claim 9 or claim 10.

12. A method of preventing debris entrapment in an automotive fuel pump valve (92), the valve (92) comprising a valve member (94) having an elongate body (96) and a head (100) disposed at a longitudinal end of the body (96), the head (100) comprising an engagement surface (102) extending radially from the body (96), the engagement surface (102) being configured to engage a valve seat (68) of the fuel pump valve (92); the method comprising forming a recess (106) that extends longitudinally into the head (100) so that the recess (106) acts as a particle trap, in use.

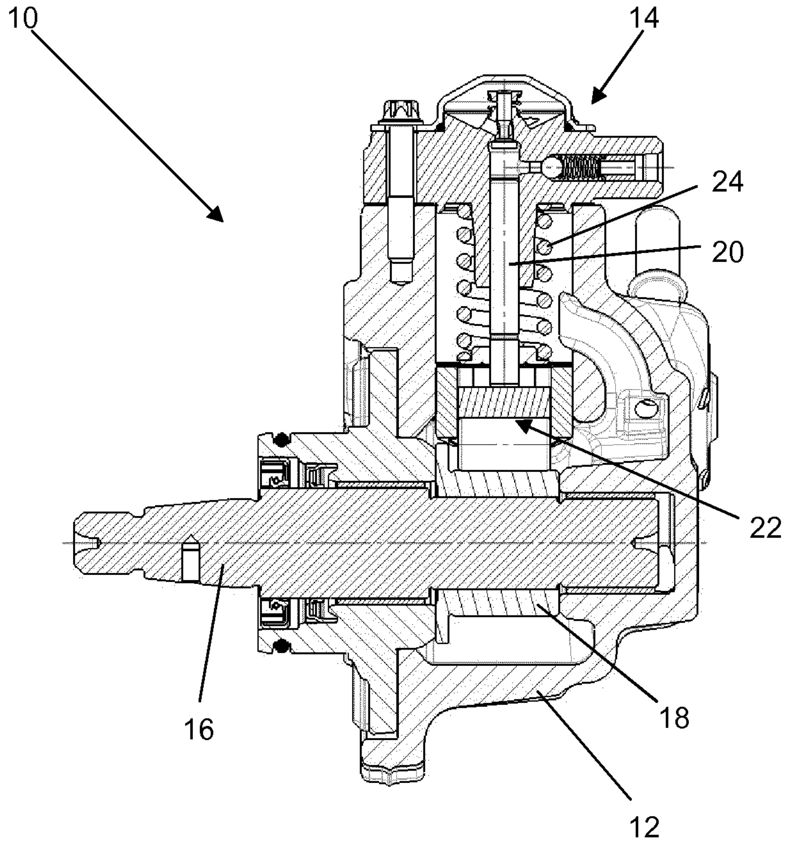

Fig. 1
(prior art)

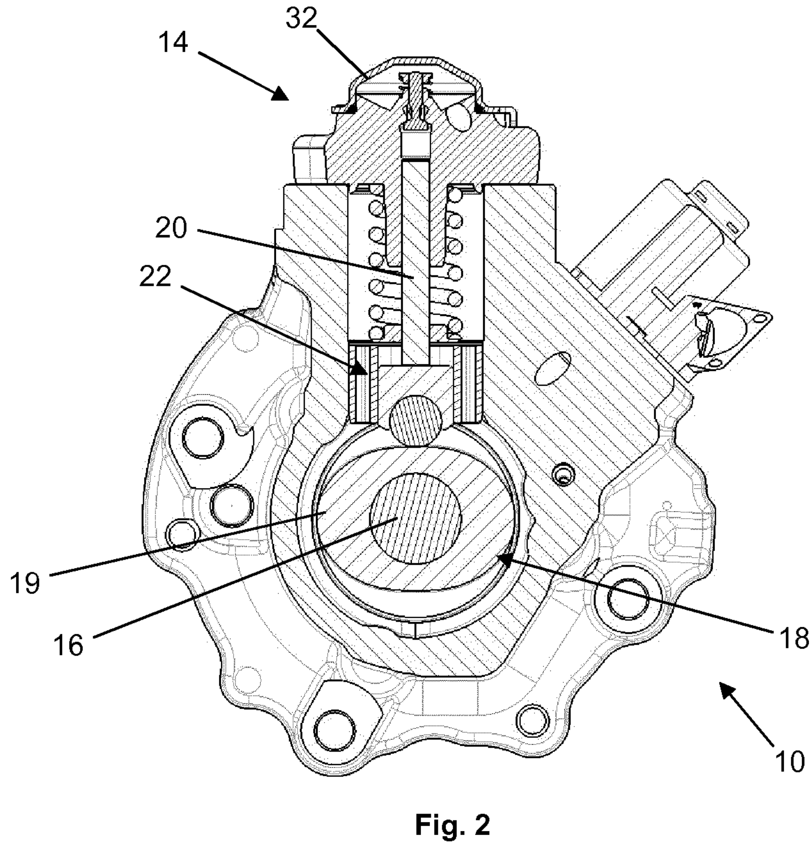

Fig. 2
(prior art)

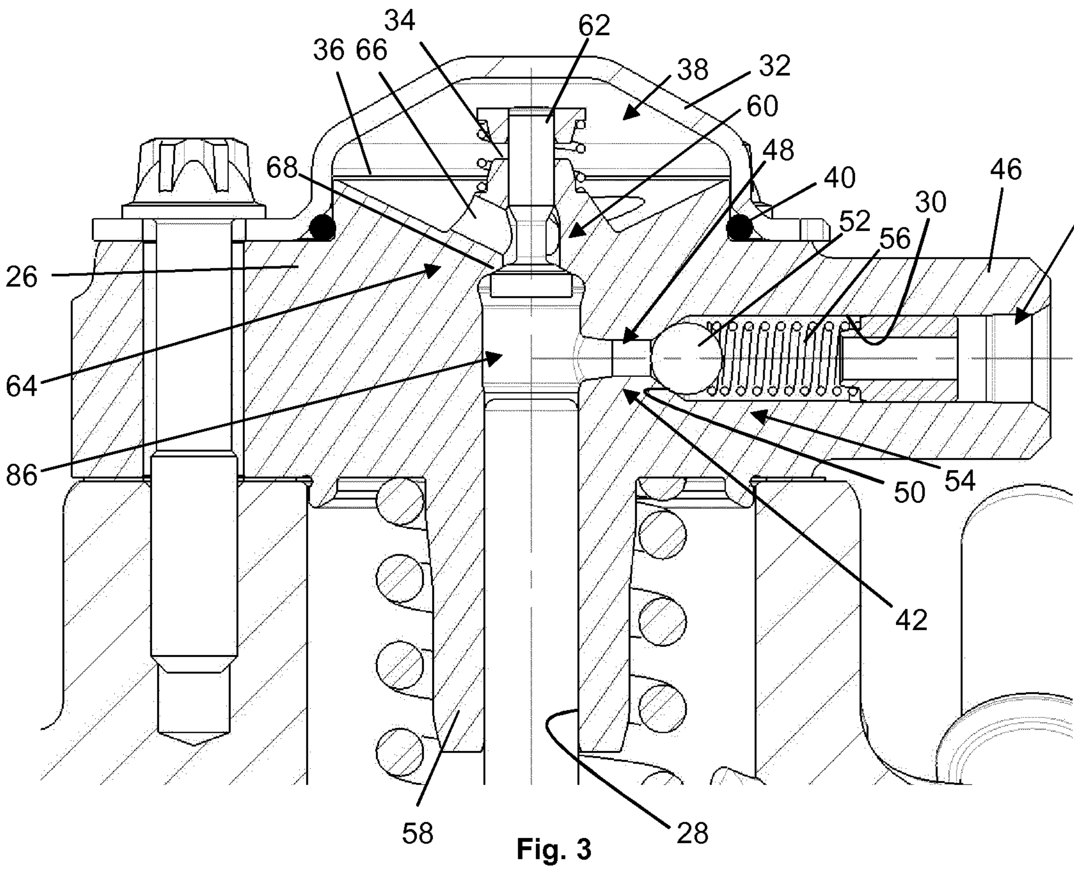

Fig. 3
(prior art)

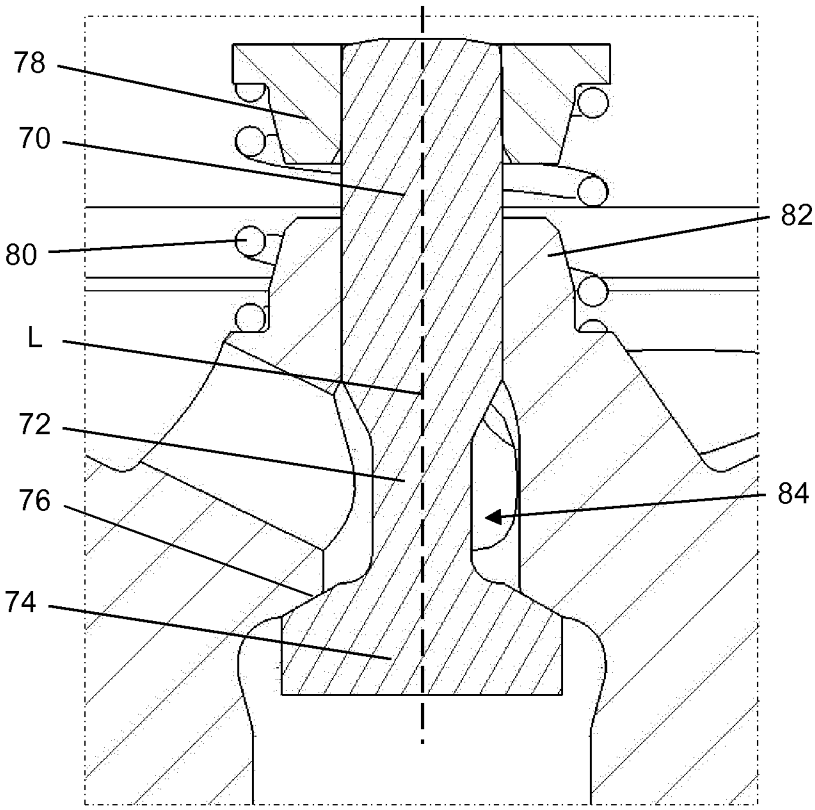

Fig. 4
(prior art)

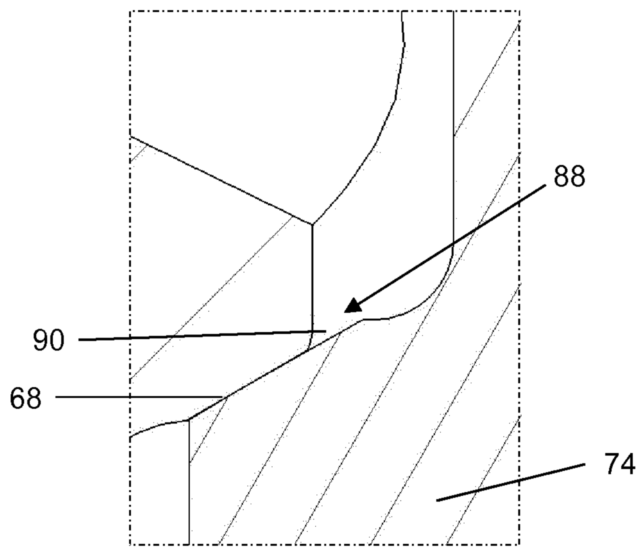

Fig. 5
(prior art)

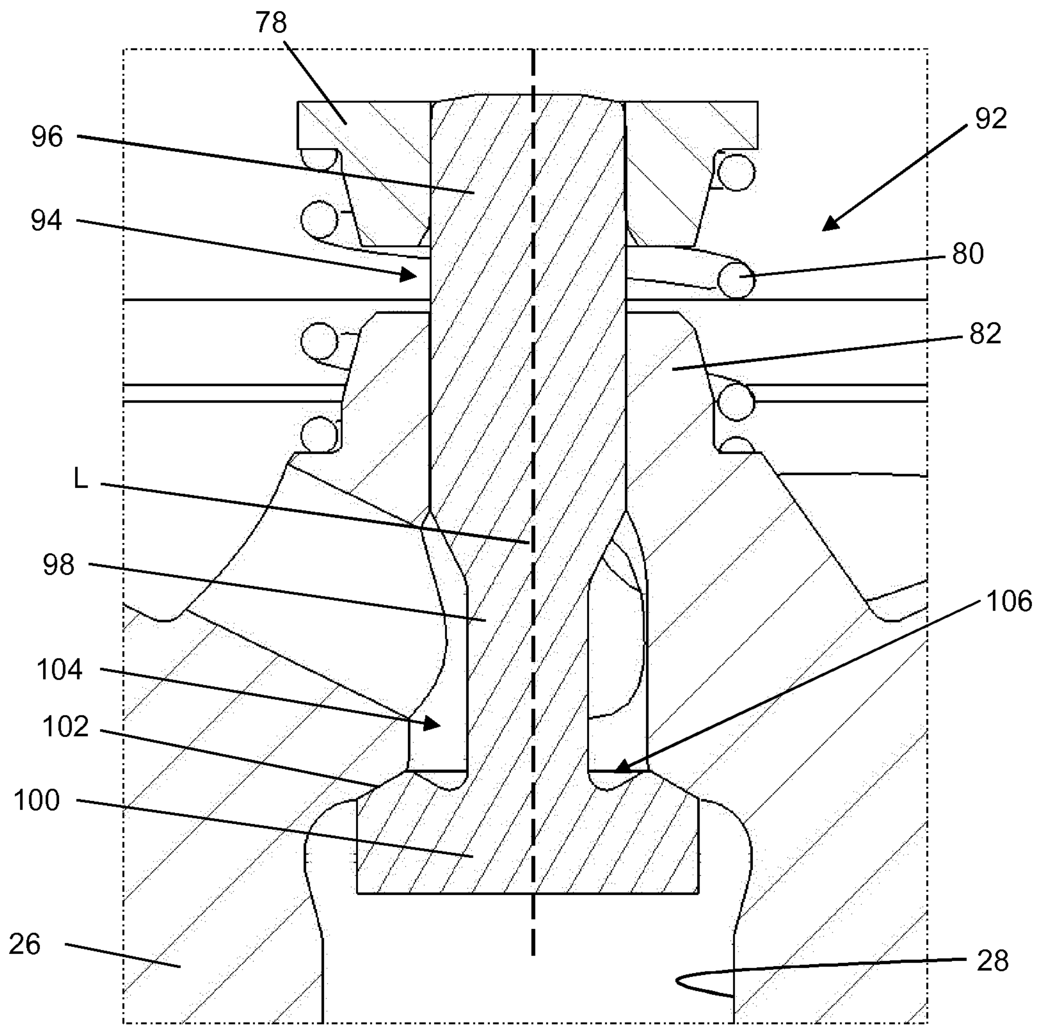

Fig. 6

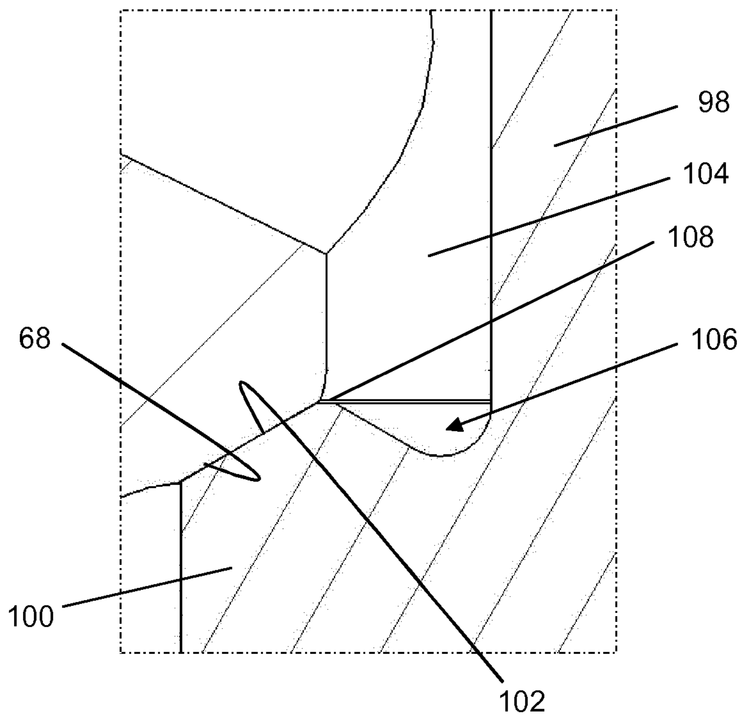

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/065810

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M59/46
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)
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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 6 045 120 A (TARR YUL J [US] ET AL) 4 April 2000 (2000-04-04) figures 1,1b -----	1-4,6-12 5
Y	DE 10 2013 210957 A1 (BOSCH GMBH ROBERT [DE]) 18 December 2014 (2014-12-18) figure 1 -----	5

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 August 2019	27/08/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Morales Gonzalez, M

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/065810

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6045120 A	04-04-2000	DE 19900883 A1	30-09-1999
		GB 2333348 A	21-07-1999
		JP 3044697 B2	22-05-2000
		JP H11270732 A	05-10-1999
		US 6045120 A	04-04-2000
DE 102013210957 A1	18-12-2014	NONE	