



## (51) International Patent Classification:

*F02M 37/08* (2006.01) *F02M 37/18* (2006.01)  
*B60K 15/077* (2006.01)

## (21) International Application Number:

PCT/SE2015/050971

## (22) International Filing Date:

17 September 2015 (17.09.2015)

## (25) Filing Language:

Swedish

## (26) Publication Language:

English

## (30) Priority Data:

1451087-9 17 September 2014 (17.09.2014) SE

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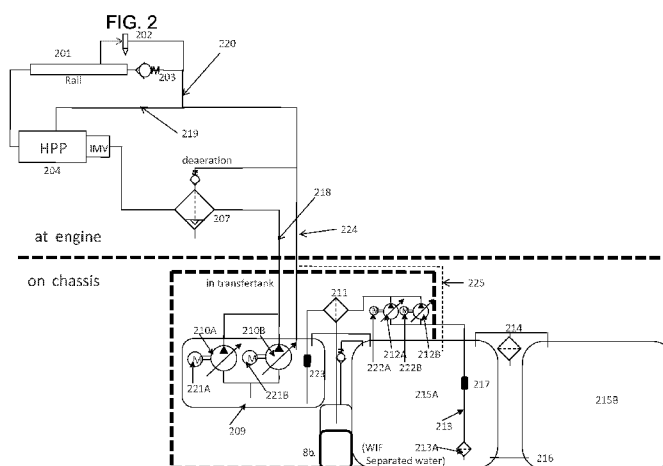
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, 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, 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))

## (54) Title: METHOD AND SYSTEM FOR FUEL PUMP REGULATION



(57) Abstract: The present, invention relates to a method to control a fuel pump in a fuel system of a vehicle (100), wherein said vehicle (100) comprises a combustion engine (101) and a fuel supply system (204) associated with said combustion engine (101), wherein the vehicle (100) also comprises a first main tank. (215A) for drawing up fuel and a first fuel pump (212A; 210A) for use in connection with transfer of fuel between said first main tank (215A) and said fuel supply system (204), A second fuel pump (212B; 210B) is arranged to operate in parallel with said first fuel pump (212A; 210A) in connection with transfer of fuel between said first main tank (215A) and said fuel supply system (204), and the method comprises: - controlling the transfer of fuel with said first (212A; 210A) and second (212B; 210B) fuel pump, at least partly based on a representation of a total efficiency for said, first (212A; 210A) and second (212B; 210B) fuel pump, wherein said transfer of fuel also is controlled, based, on at least one parameter relating to the life span of said fuel pumps.

**METHOD AND SYSTEM FOR FUEL PUMP REGULATION****Field of the invention**

The invention relates to a method for fuel pump control in a fuel system according to the preamble of claim 1. The invention  
5 also relates to a system and a vehicle, as well as a computer program and a computer program product, which implement the method according to the invention.

**Background of the invention**

The present invention relates to fuel systems in vehicles, and  
10 in particular to heavy goods vehicles such as trucks, buses and machines. These types of vehicles are often relatively heavy, and also travel long distances. In summary, this entails a requirement that the vehicles be equipped with relatively large fuel tanks. For example, such vehicles may be equipped with a  
15 fuel tank holding in the range of 500 - 1000 litres, where such volume may also be divided over two fuel tanks arranged in the vehicle.

The fuel tanks thus consist of relatively large volumes, which entails, when the fuel level drops, that any remaining fuel is  
20 moved around in the fuel tank as a result of the vehicle's movements. Fuel transfer from the fuel tank to the vehicle's combustion engine is usually carried out with the use of a fitting, submerged in the fuel tank, with an inlet through which the fuel is sucked up with the help of a pump. In order  
25 for fuel to be sucked up with said pump, however, the inlet of the fitting must be surrounded by fuel, and not by air.

In relation to fuel systems in general, in many vehicles today, a fuel pump arranged in connection with the combustion engine draws up fuel, the fuel pump being mechanically connected to  
30 the combustion engine and operated by the driving shaft of the combustion engine. This solution entails that the fuel pump

must be able to pump a relatively large amount of fuel already at low rotational speeds, i.e. lower rotational speeds than the idling speed of the combustion engine, in order to be able to pump a sufficient amount of fuel to the combustion engine when the start engine is working, in order for the combustion engine to be able to start at all. This in turn means that the fuel pump will be over dimensioned during progress, and will thus continuously pump a large amount of fuel, which then must be diverted and returned to the fuel tank. This excess pumping obviously leads to unwanted losses.

Furthermore, a fuel pump operated by the combustion engine's output shaft may, if it begins to draw up air, e.g. because of a low fuel level, begin to cavitate, and as a consequence the pump may not begin to draw up fuel again without first being stopped, which thus also means that the vehicle must be stopped before the fuel supply may be resumed. With the objective of avoiding such situations, a fuel reserve may be applied, which at least partly reduces the risk of the fuel pump starting to draw air.

The above disadvantages may be reduced with the use of a fuel pump that is electrically operated, i.e. operated with an electric motor, which means that the speed of the fuel pump may be controlled independently of the speed of the output shaft of the combustion engine.

#### **Summary of the invention**

One objective of the present invention is to provide a method to control the fuel pump in a fuel system. This objective is achieved with a method according to claim 1.

The present invention relates to a method

to control a fuel pump in a fuel system of a vehicle, wherein said vehicle comprises a combustion engine and a fuel supply

system associated with said combustion engine, wherein the vehicle also comprises a first main tank for drawing up fuel and a first fuel pump for use in connection with transfer of fuel between said first main tank and said fuel supply system.

5 A second fuel pump is arranged to operate in parallel with said first fuel pump in connection with transfer of fuel between said first main tank and said fuel supply system, and the method comprises:

10 - controlling transfer of fuel with said first and second fuel pump, at least partly based on a representation of a total efficiency for said first and second fuel pump, wherein said transfer of fuel also is controlled based on at least one parameter relating to the life of said fuel pumps.

15 According to the above, there are disadvantages with using fuel pumps operated by the combustion engine's output shaft. Such problems may be mitigated with the use of an electrically operated fuel pump, wherein the electrically operated pump may be started/stopped as and when needed. Furthermore, dependability is a very important parameter, in particular in  
20 relation to heavy goods vehicles, and obviously a functioning fuel supply is also a very important parameter for dependability. For this reason, according to the present invention a system is used, wherein two electrically operated fuel pumps operating in parallel are used to transfer fuel from  
25 the vehicle's fuel tank to said fuel supply system, such as e.g. a fuel injection system. The fuel pumps are arranged for individual control by way of individual control of the respective associated electric motors. Through the use of fuel pumps operating in parallel, e.g. a redundancy is obtained,  
30 which facilitates that fuel may be transferred even when one of the fuel pumps is malfunctioning.

However, the present invention relates to a method which, in addition to improving dependability, results in an economical operation of the parallel fuel pumps, in respect of economical consumption, and according to a preferred embodiment as set out below, a method which may also additionally improve dependability.

In relation to economical operation of the fuel pumps, this is achieved according to the invention by way of controlling the total operation of the fuel pumps based on a representation of the efficiency of the fuel pumps, wherein the fuel pumps are controlled based on their total efficiency. Thus, the total efficiency may e.g. be maximised. The efficiency of a fuel pump may vary greatly over its operating area, and with the use of the present invention the fuel pumps may be controlled towards as good a joint efficiency as possible. Accordingly, the manner in which the fuel pumps are controlled will depend on the specific operating point that must be achieved, such as with respect to the resulting flow and pressure difference over the fuel pumps.

Since dependability is of very great significance, apart from efficiency, regard is also had to additional parameters when determining how the fuel pumps should be controlled.

When controlling the fuel pumps, regard is also had to at least one parameter with respect to the durability/life of the pumps. This parameter may e.g. consist of the number of starts, stops and/or operating cycles, i.e. the number of times each respective pump has started and stopped. In general, starting/stopping entails wear, and by e.g. distributing the operation between the pumps in operating modes where only one pump needs to be in operation, the wear may be kept even. Likewise, the total operating time may be used as a parameter, wherein the pumps may e.g. be controlled in such a manner that

the total pumping operation over time is distributed evenly between the pumps.

According to one embodiment, efficiency is weighted with a first weight, and the respective of said at least one parameter with respect to life is weighted with a second weight.

Thus, e.g. the number of starts/stops may be included as a parameter at the determination of weight, since the pump's/electric machine's life is often directly related to the number of operating cycles. Likewise, the total operating time may e.g. be used as a parameter, as may temperature, operating time, load etc. Changes relating to how the pumps are controlled may also be included as a factor. For example, large control changes, e.g. transient changes in control may be "punished" at control based on life, in order to reduce the occurrence of such events. Thus, a trade-off between life and efficiency may be applied to obtain an overall economical operation of the fuel pumps.

The weights used at the control may also be arranged to change over time. For example, the pumps may be controlled more based on efficiency when the pumps are new, while life may be prioritised increasingly as the pumps age.

Another parameter that may be included in the calculation when controlling the pumps consists of the prevailing temperature, wherein e.g. a temperature sensor arranged in/at the respective pump/electric motor, or alternatively a modelled temperature, e.g. based on an ambient temperature for the pump or electric motor and a model of temperature changes during operation/out of operation may be used to control the pumps' cooperation, so that unwanted high temperatures, with an associated risk of damage, in particular with respect to the windings of the electric motor, may be avoided to the extent possible.

According to one embodiment, arranged between said fuel supply system and said first at least one main tank, a transfer tank is applied, also called a "catch-tank" or "tech-tank", but referred to herein as a transfer tank, whereat the method  
5 comprises supply of fuel to said transfer tank from said first main tank before a transfer is effected to said fuel supply system from said transfer tank, and whereat said transfer tank preferably consists of a smaller tank, compared with said first fuel tank. The volume of the transfer tank may e.g. be a volume  
10 within the interval 1-10%, or 1-5%, of the total volume of said at least one main tank.

The transfer tank is thus substantially smaller than the main tank, which means that it is also less sensitive to the movements of the fuel in the tank, resulting from movement and  
15 road gradients. When the transfer tank is full, it therefore functions as a buffer on occasions when fuel may not be drawn out of the main tank, e.g. because of a low fuel level combined with an incline, so that fuel may be transferred to the fuel supply system from the transfer tank even when fuel in said  
20 first main tank is not available, and so that the transfer tank may be refilled when conditions so allow and the main tank's fuel is available again. Such a solution thus allows that an even larger proportion of the main tank's fuel may be used before a refill is required. According to one embodiment, said  
25 first and second fuel pump, respectively, is used for transfer of fuel to said transfer tank from said at least one main tank. According to another embodiment, said first and second fuel pump, respectively, is used for transfer of fuel from said transfer tank to said fuel supply system. According to one  
30 embodiment, a first pair of fuel pumps operating in parallel is used to transfer fuel to said transfer tank from said at least one main tank, and a second pair of fuel pumps operating in parallel is used for transfer of fuel from said transfer tank

to said fuel supply system. According to the invention the first and/or the second pair of pumps operating in parallel may be arranged to be controlled according to the invention.

Further characteristics of the present invention and advantages thereof will be described in the detailed description of example embodiments set out below and in the enclosed drawings.

#### **Brief description of the drawings**

Fig. 1A schematically shows a vehicle, in which the present invention may advantageously be used.

Fig. 1B shows a control device in a vehicle control system.

Fig. 2 schematically shows a fuel system, in which the present invention may be applied.

Fig. 3 schematically shows an example method according to one embodiment of the present invention.

Fig. 4 shows an example of the appearance of the efficiency for a fuel pump.

Fig. 5 shows an example of the total efficiency's appearance for a pair of fuel pumps operating in parallel.

#### **Detailed description of preferred embodiments**

Fig. 1A schematically shows a powertrain in a vehicle 100, according to an embodiment of the present invention. The vehicle 100 shown schematically in Fig. 1A comprises a powertrain with a combustion engine 101, which in a customary manner, via an output shaft on the combustion engine 101, usually via a flywheel 102, is connected to a gearbox 103 via a clutch 106. The combustion engine 101 is controlled by the control system of the vehicle 100 via an engine control device 115. Likewise, in the present example, the clutch 106 and the gearbox are controlled by a control device 116.

Further, an output shaft 107 from the gearbox 103 drives the driving wheels 113, 114 via a final gear 108, e.g. a customary differential, and the drive shafts 104, 105 connected to said final gear 108. Fig. 1A thus shows a powertrain of a specific type, but the invention is applicable at all types of powertrains, and also at all types of vehicles, as long as these are operated by a combustion engine.

The displayed vehicle also comprises a fuel system, where Fig. 1A shows two main fuel tanks 215A, 215B from which fuel is supplied to a fuel supply system arranged at a combustion engine 101, in the present example an injection system 204, via a transfer tank 209. The fuel system's functions are controlled by a control device 230. Additional details in the exemplified fuel system are displayed in Fig. 2, and described below.

According to the above, the present invention relates to control of fuel pumps for transfer of fuel from one or several fuel tanks to a fuel supply system, with the use of fuel pumps operating in parallel. The method according to the invention may be arranged to be carried out by some applicable control device in the vehicle's control system, and may e.g. be arranged to be carried out by the control device 230 or alternatively by another applicable control device in the vehicle, such as e.g. the engine control device 115. The control device may thus consist of any suitable control device in the vehicle's control system. The invention may also be implemented in a control device dedicated to the present invention.

Generally, such control systems consist of a communications bus system, consisting of one or several communication buses to connect a number of electronic control devices (ECUs), or controllers, and different components arranged in the vehicle 100. Such a control system may thus comprise a large number of

control devices, and the responsibility for a specific function may be distributed among more than one control device. For the sake of simplicity, in Fig. 1A only a very limited number of control devices are displayed.

5 The function of the control device 230 (or the control device(s) at which the present invention is implemented) according to the present invention, may, e.g. depend on signals from different sensors, examples of which are described below in connection with Fig. 2. Furthermore, the function according  
10 to the invention may depend on signals from the fuel pump(s) that ensure transfer of fuel from a fuel tank to the injection system as set out below. The control may also depend on signals from one or several other control devices, such as data relating to the vehicle's road ahead of the vehicle, received  
15 from the control device 117.

Furthermore, the control is often carried out by programmed instructions. These programmed instructions typically consist of a computer program, which, when executed in a control  
20 device, causes the control device to carry out the desired control action, such as a method step according to the present invention.

The computer program is usually a part of a computer program product, where the computer program product comprises an applicable storage medium 121 (see Fig. 1B), with the computer  
25 program stored on said storage medium 121. The computer program may be stored in a non-volatile way on said storage medium. Said digital storage medium 121 may e.g. consist of any from the following group: ROM (Read-Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable PROM), Flash, EEPROM  
30 (Electrically Erasable PROM), a hard disk unit, etc., and may be set up in or in combination with the control device, where the computer program is executed by the control device. By

changing the computer program's instructions, the vehicle's behaviour may thus be adjusted in a specific situation.

An example control device (control device 230) is shown schematically in Fig. 1B, and the control device in turn may  
5 comprise a calculation unit 120, which may consist of e.g. a suitable type of processor or microcomputer, e.g. a circuit for digital signal processing (Digital Signal Processor, DSP), or a circuit with a predetermined specific function (Application Specific Integrated Circuit, ASIC). The calculation unit 120 is  
10 connected to a memory unit 121, which provides the calculation unit 120 with e.g. the stored program code and/or the stored data that the calculation unit 120 needs in order to be able to carry out calculations, e.g. to determine whether an error code should be activated. The calculation unit 120 is also set up to  
15 store interim or final results of calculations in the memory unit 121.

Further, the control device is equipped with devices 122, 123, 124, 125 for receiving and sending of input and output signals. These input and output signals may contain waveforms, pulses or  
20 other attributes which, by the devices 122, 125 for the receipt of input signals, may be detected as information for processing by the calculation unit 120. The devices 123, 124 for sending output signals are arranged to convert the calculation result from the calculation unit 120 into output signals for transfer  
25 to other parts of the vehicle's control system and/or the component(s) for which the signals are intended. Each one of the connections to the devices for receiving and sending of input and output signals may consist of one or several of the following: a cable; a data bus, such as a CAN (Controller Area  
30 Network) bus, a MOST (Media Oriented Systems Transport) bus, or any other bus configuration; or of a wireless connection.

An example embodiment for control of fuel pumps according to the invention is displayed in Fig. 3, and the invention will be exemplified in connection with the fuel system displayed in Fig. 2. The present invention is applicable in all types of fuel systems, i.e. also in fuel systems without a transfer tank, and is especially applicable in fuel systems of the type displayed in Fig. 2, and the versions of the fuel system described in connection with Fig. 2.

In relation to the method 300 in Fig. 3, this begins at step 301, where it is determined whether fuel transfer with fuel pumps should be carried out. When fuel transfer must be carried out, the method continues to step 302. According to one embodiment, control of the fuel pumps at fuel transfer may be arranged to be carried out continuously according to the present invention, as soon as a fuel pump must be activated. Furthermore the method may, in cases where more than one pair of parallel fuel pumps is used, be arranged to be controlled individually. The method displayed may thus be used individually for the pairs of fuel pumps arranged in parallel displayed below.

Fig. 2 shows the fuel system in Fig. 1 in more detail. In the system illustrated in Fig. 2, two main tanks 215A, 215B are used, each of which holds a relatively large amount of fuel, such as e.g. a fuel amount in the interval 300-1000 litres. By using several tanks, it is possible to obtain a greater total fuel capacity than what might otherwise be possible while using only a single tank, as there may be a shortage of large, connected spaces in vehicles and as it may thus be difficult to find a possible location for a single tank of the desired size. The two main tanks 215A, 215B are connected with each other via a passage 216 in the lower part of the tanks 215A, 215B, so that fuel may flow from one of the tanks to the other.

Likewise, the tanks are connected with each other at the upper edge via a deaeration filter 214.

Fuel is drawn from the main tank 215A, to which the fuel in the main tank 215B also flows, via a fuel armature 213. The inlet  
5 213A of the fuel armature 213 is preferably arranged deep in the tank, i.e. near the bottom of the tank, in order to ensure that as a great a volume as possible may be drawn. A certain distance from the bottom of the tank may be advantageous, e.g. in order to avoid that gravel, debris and other objects that  
10 may have entered the tank be drawn up. The fuel level in the tank may be determined with the use of a level sensor 217. The fuel is sucked up by at least one of a pair of fuel pumps 212A, 212B arranged in parallel, and the fuel drawn up by the fuel pumps 212A, 212B is pumped, in the present example, via a pre-  
15 filter 211 for separation of water in a customary manner, to an intermediate tank 209, a transfer tank, as set out above, which is substantially smaller than the main tanks 215A, 215B. The size of the transfer tank 209 may e.g. be in the range of 15-50 litres, or e.g. have a size which, in relation to the total  
20 volume of the main tanks, constitutes a volume in the range of 1-10%, or 1-5%, of the total volume of the main tanks.

Furthermore, the geometry of the transfer tank is preferably such that it has a height which exceeds, or preferably substantially exceeds, the width and the depth, respectively.

25 The transfer tank is thus preferably relatively high and relatively narrow, in order to reduce negative impact of slushing to the extent possible.

The pumps 212A, 212B for transfer of fuel from the main tanks 215A, 215BB to the transfer tank 209 may advantageously be  
30 arranged inside the transfer tank 209, which is indicated with dashed lines in Fig. 2. Obviously, this is not necessarily the case, and obviously, Fig. 2 is an entirely logical diagram of

the fuel system, where no proportionate comparisons may be made between various component parts of the fuel system. For example, all fuel pumps displayed may be of the same type. Neither may any conclusions be drawn regarding the physical  
5 placement of the respective component parts, other than it being indicated explicitly in the figure that the fuel pumps in the example displayed may be arranged in the transfer tank. According to another embodiment of the present invention, this is not the case, however. The fuel pumps 212A, 212B, as well as  
10 the fuel pumps 210A, 210B described below, are electrically operated fuel pumps, where a respective electric motor 222A, 222B, 221A, 221B is used to operate the respective fuel pumps as set out below. A fuel pump with an associated electric motor may in practice consist of an integrated part.

15 The fuel pumps 210A, 210B, which are arranged for parallel operation in a manner corresponding to the pumps 212A, 212B, are used to transfer fuel from the transfer tank 209 to the combustion engine's 101 injection system. These electrically operated fuel pumps 210A, 210B may also be arranged in the  
20 transfer tank 209, as well as the fuel filter 211. In the system displayed, two pairs of fuel pumps 210A-B, 212A-B for transfer of fuel from the main tank to the injection system are thus displayed. By arranging the fuel pumps 210A, 210B, 212A, 212B, and electric motors associated therewith, in the transfer  
25 tank 209, the fuel in the transfer tank may be used to cool components, while, in the reverse, the fuel may be heated with excess heat from electric motors/fuel pumps. The respective fuel pumps, as well as the fuel filter 211 may alternatively be arranged in another applicable place, such as e.g. in one of  
30 the main tanks or entirely outside the fuel tanks.

The fuel is moved, in the present example, from the transfer tank 209, via a conduit 218 and a second fuel filter 207, to an

injection system, where a high pressure pump (or another mechanical pressure increasing device such as e.g. a unit injector) 204 pressurises the fuel to a very high pressure for supply to a common rail 201, in order to supply it to the combustion engine's combustion chamber via the respective injectors 202.

The injection system displayed in Fig. 2 thus consists of a so-called Common Rail System, which thus entails that all injectors (and thus combustion chambers) are supplied by the common rail 201. The pressure in the fuel conduit 201 may be controlled with the use of a valve 203. The function of the fuel filters is not described herein, since such function constitutes prior art.

Excess fuel from the high pressure pump 204 may be returned to the transfer tank 209 (according to the present example), or alternatively to the main tanks 215A, 215B (indicated with a dashed line 225) via a conduit 219, 224. Likewise, excess fuel from injectors 202 and/or from the fuel conduits 201 may be returned in a corresponding manner from an overflow conduit 220, 224. The returned fuel may also consist of a lubricant for, respectively, the high pressure pump 204 and the injectors 202, etc. The returned fuel is usually heated, so that such excess heat may be used to heat the fuel by way of returning the fuel to the applicable fuel tank, as described above.

The solution displayed has the advantage that, with the use of the substantially smaller transfer tank described above, which is therefore also substantially less sensitive to slushing fuel and the incline of the vehicle, jointly with the use of electrically operated fuel pumps, various advantages may be achieved, such as e.g. improved range, since a larger withdrawal from the main tanks is permitted before refilling is required. Furthermore, the use of electrically operated pumps

entails advantages with respect to e.g. energy consumption, compared with a fuel pump operated with an output shaft of the combustion engine.

When fuel thus has to be pumped, the parameters that are to be  
5 used in determining the control of the fuel pumps are determined in step 302, and the method continues to step 303, in order to determine how the fuel pumps should be controlled, following which the control is carried out in step 304. The method may then resume to step 301, wherein continuous control  
10 of the fuel pumps may be performed. The method displayed may be arranged to be carried out separately for the respective pairs of fuel pumps 210A-B; 212A-B.

In relation to the determination of parameters that are to be used in the determination of the control of the fuel pumps in  
15 step 302, these may consist of parameters of various types. As mentioned above, control according to the invention is based at least on the fuel pumps' total efficiency. Regarding efficiency, this is often available for fuel pumps of the type displayed, where efficiency may depend on e.g. pressure and  
20 flow. Such data may be available from the supplier or alternatively may e.g. be measured, and in Fig. 4, an example of efficiency characteristics for an example fuel pump is displayed. The X-axis represents flow, the y-axis represents pressure difference over the fuel pump, and the graph specifies  
25 efficiency, where a corresponding pump rotation speed is also specified. Such data is preferably stored for the respective pumps, either in tabled form, or alternatively a model of the fuel pump's efficiency may be applied, whereat such modelling may be carried out in an applicable prior art manner with the  
30 use of e.g. a pump model from prior art.

With the use of such data in relation to the two pumps in a pair operating in parallel, a total efficiency for the two

pumps may be determined. This may be determined in an applicable manner, and may e.g. be calculated with the use of the following equations:

$$q_T = q_1 + q_2 \quad (\text{equation 1})$$

5 where  $q_T$  is the total pumped flow and  $q_1, q_2$  is the flow for the respective pump.

$$\Delta P_T = \Delta P_1 = \Delta P_2 \quad (\text{equation 2})$$

I.e. the pressure difference over the pumps is the same at parallel connection.

10 The efficiency may then be rewritten as:

$$\eta_T = \frac{q_1 \Delta P_1}{q_T \Delta P_T} \eta_1 + \frac{q_2 \Delta P_2}{q_T \Delta P_T} \eta_2 = \frac{q_1}{q_T} \eta_1 + \frac{q_2}{q_T} \eta_2 \quad (\text{equation 3})$$

Where  $\eta_T$  is the total efficiency and  $\eta_1, \eta_2$  is the efficiency for the respective pump. Fig. 5 shows an example of a resulting diagram for a certain pressure  $\Delta P_T$ , determined with the use of the above equations, wherein the total efficiency is displayed as a function of pump speed and wherein the total flow is also specified. Such representations of the total efficiency may thus be obtained for applicable pressure differences over the fuel pumps.

20 In step 302, e.g. a control of the fuel pumps entailing a maximisation of the total efficiency for the fuel pumps may be determined, so that the respective pumps may be controlled based on this result. This may be achieved e.g. by way of looking up tabled values, or with a solution of an optimisation problem, which may be carried out in an applicable prior art manner and with e.g. boundary conditions in the form of maximum pumping speeds etc. Depending on the total efficiency's appearance, the result may be that one pump at a time is

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activated at e.g. minor flows, or alternatively that the pumps are activated at the same time but with different loads.

Thus, the operation of the parallel fuel pumps may be optimised for each moment/change in pressure/flow, and as a consequence the long-term energy consumption is optimised. According to the above, this optimisation may be carried out individually for each respective pair of fuel pumps in systems of the type displayed in Fig. 2.

According to the invention, however, the present invention is not used only to optimise energy consumption, but also for optimisation from the point of view of dependability. This is achieved by way of, in addition to optimisation based on efficiency, also including additional parameters.

There is a number of factors impacting the life span of an electrically operated fuel pump. In particular, the life is determined by the life of its component parts, and regarding an electrically operated pump, these parts consist primarily of bearings and the electric motor. The component with the shortest life will determine the life of the pump. The life of the component parts is affected by various factors, and according to one embodiment, empirical tests are performed to determine the impact of various factors on the life span. Such data may also be available, at least partly, e.g. from the pump manufacturer. In connection with the determination, regard may be had to various factors, and a cost function may advantageously be applied to minimise the "cost" with respect to the operation of the pump, wherein the operation of the pump may thus be optimised based on set criteria, including efficiency and life related parameters.

Examples of factors impacting the components of the fuel pump consist, e.g. in relation to bearings, of the load of the pump, the rotational speed, the number of operating cycles, the

lubrication and the operating temperature. In relation to the electric motor, the factor with the greatest impact on the life span is the temperature of the motor windings. If insufficient cooling is obtained, the temperature of the windings will rise, with a consequential risk of damage. The factors primarily impacting the temperature of the windings are the current applied and the ambient temperature.

From a control point of view, the factors that may be directly impacted are load and rotational speed. The lower these are, the lower the resulting temperature of the pump/electric motor will be, and the need for lubrication also decreases.

According to the present invention, a cost function may be applied, wherein various factors are weighted. Generally, cost functions are often applied on motor vehicles such as cars, trucks, buses or similar, in different optimisation algorithms with the objective of determining control parameters for control of various vehicular functions, and such methods may thus also be applied in this case, wherein weights included may be calculated and/or determined empirically. Thus, e.g. the number of starts/stops may be included as a parameter, since the pump's/electric machine's life is often directly related to the number of operating cycles. Likewise, the total operating time may e.g. be used as a parameter, as well as the temperature, the operating time, the load etc. and changes in how the pumps are controlled may also be included as a factor, wherein e.g. large control changes may be "punished" to reduce the occurrence of such events.

Control may thus be performed as a cost function, wherein a number of factors are weighted when determining how the fuel pumps should be controlled. The cost may e.g. be calculated with the use of a square cost function or another applicable cost function, wherein the control may be carried out as a

weighting of the pumps' total energy consumption, wear etc. expressed as pumping speed, measured/calculated pump temperature etc. start/stop and risk of failure, wherein such risk may be arranged to rise with age/operating time etc. The  
5 resulting control of the pumps may thus vary over time, e.g. the resulting cost function may be such that a poorer efficiency may be accepted when the pumps are worn, if this reduces the risk of a failure.

In principle, the control may be arranged to follow a "valley"  
10 in the cost room, and e.g. occur continuously. In systems of the type displayed in Fig. 2 the pumps may be arranged to be controlled in various ways, wherein 210A, 210B, which supply the engine with fuel, may be arranged to be in operation continuously, while the pumps 212A, 212B filling the transfer  
15 tank may be arranged to operate either continuously or in a non-stationary/intermittent manner.

For example, the operation of the pumps 212A, 212B may be arranged, to the extent possible, so that the transfer tank is filled at engine braking, e.g. when the fuel supply to said  
20 combustion engine is turned off, as energy for operation of the fuel pumps is then available without any cost from the generator. In this respect, the control device 230 may be arranged to continuously receive data regarding the road ahead of the vehicle, from the control device that handles such  
25 information. This information may e.g. consist of map data together with positioning data, or alternatively another applicable description of the nature of the road ahead of the vehicle. For example, it is increasingly common for vehicles to comprise a so-called Look Ahead (LA) function that controls  
30 various vehicular functions such as cruise control, based on the appearance of the road ahead of the vehicle. This Look Ahead function, or a similar function, may thus be used to

supply the control device 230 with information about the appearance of the road ahead of the vehicle, wherein operation of the pumps to fill the transfer tank may, when possible, be controlled to road sections where this may be carried out without any cost. In the present example, this functionality is provided by a control device 117 (Fig. 1A).

As mentioned above, however, the present invention is not limited to fuel systems with a transfer tank, but the invention is applicable in all types of fuel systems, wherein electrically operated fuel pumps operating in parallel may be arranged.

Other embodiments of the method and the system according to the invention are available in the claims enclosed hereto. It should also be noted that the system may be modified according to various embodiments of the method according to the invention (and vice versa) and that the present invention is in no way limited to the above embodiments of the method according to the invention, but relates to and comprises all embodiments within the scope of the enclosed independent claims.

**Claims**

1. Method for fuel pump control in a fuel system in a vehicle (100), wherein said vehicle (100) comprises a combustion engine (101) and a fuel supply system (204) associated with said combustion engine (101), wherein the vehicle (100) also comprises at least one first main tank (215A) for receipt of fuel and a first fuel pump (212A; 210A) for use when transferring fuel between said first main tank (215A) and said fuel supply system (204), **characterised in that** a second fuel pump (212B; 210B) is arranged to operate in parallel with said first fuel pump (212A; 210A) in connection with transfer of fuel between said first main tank (215A) and said fuel supply system (204), wherein in the method comprises:
  - controlling the transfer of fuel with said first (212A; 210A) and second (212B; 210B) fuel pump, at least partly based on a representation of a total efficiency for said first (212A; 210A) and second (212B; 210B) fuel pump, wherein said transfer of fuel also is controlled based on at least one parameter relating to the life span of said fuel pumps.
2. Method according to claim 1, further comprising, at said control:
  - weighting efficiency with a first weight and the respective of said at least one parameter with respect to life span with a second weight.
3. Method according to claim 1 or 2, further comprising, at said control:
  - weighting efficiency with a first weight and the respective of said at least one parameter with respect to life span with a second weight, wherein said first and

second weight, respectively, is arranged to change over time.

4. Method according to claim 2 or 3, wherein said weights are arranged in such a manner that control is carried out increasingly less based on efficiency, compared to based on life span, with a rising total operating time and/or a rising number of operating cycles for said first and/or second fuel pump.
5. Method according to any of claims 1-4, further comprising:  
- controlling said first (212A; 210A) and second (212B; 210B) fuel pumps, based on a total efficiency, determined based on an individual efficiency for said first (212A; 210A) and second (212B; 210B) fuel pump, respectively.
6. Method according to any of claims 1-5, also comprising determining said total efficiency for said first (212A;210A) and second (212B;210B) fuel pump, based on a modelled and/or tabled representation of the efficiency for said first (212A;210A) and second (212B;210B) fuel pump, respectively.
7. Method according to any of the previous claims, wherein said efficiency consists of an efficiency dependent on speed and/or flow and/or pressure difference.
8. Method according to any of the previous claims, also comprising control of the operation of said first (212A; 210A) and second (212B; 210B) fuel pump with the use of a cost function, wherein said cost function is a function of at least efficiency and at least one parameter relating to the life span of said first (212A; 210A) and second (212B; 210B) fuel pump, respectively.
9. Method according to any of the previous claims, wherein said at least one parameter relating to the life span of

said first and/or second fuel pump comprises one or more of:

- a prevailing temperature and/or a temperature expected during operation for said first and/or second fuel pump;

- completed starts and/or stops and/or operating cycles for said first and/or second fuel pump;

- an operating time, such as an accumulated operating time, for said first and second fuel pump, respectively;

- speed during operation of said first and/or second fuel pump.

10. Method according to any of the previous claims, wherein said vehicle (100) also comprises a transfer tank (209), arranged between said fuel supply system (204) and said at least one first main tank (215A), wherein the method comprises supplying fuel to said transfer tank (209) from said first main tank (215A) and from said transfer tank to said fuel supply system (204), wherein said transfer tank (209) is a smaller tank than said first main tank (209A), and wherein said first and second fuel pumps are used to transfer fuel from said first main tank (215A) to said transfer tank (209), or from said transfer tank to said fuel supply system (204).

11. Method according to claim 10, wherein said transfer tank (209) consists of a tank with a height that is greater than its width and its depth, respectively.

12. Method according to claim 10 or 11, wherein the size of the transfer tank (209) is in the range of 15-50 litres, or a size which represents a volume, in relation to the total volume of one or several of the main tanks (215A, 215B), in the interval 1-10%, or 1-5%, of the total volume of said main tanks (215A, 215B).

13. Method according to any of claims 10-12, wherein a first pair of pumps arranged for parallel operation is used to transfer fuel from said at least one first main tank (209A) to said transfer tank, and wherein a second pair of pumps arranged for parallel operation is used to transfer fuel from said transfer tank to said fuel supply system (204), wherein each pair of fuel pumps is controlled according to any of claims 1-12.
14. Method according to any of the previous claims, also comprising control of the transfer of fuel from said main tank to said transfer tank, at least partly based on data relating to the road ahead of the vehicle (100), wherein fuel is transferred when the fuel supply to said combustion engine is turned off.
15. Method according to any of the previous claims, wherein said fuel supply system (204) consists of a fuel injection system.
16. Computer program comprising a program code which, when said program code is executed in a computer, achieves that said computer implements the method according to any of claims 1-15.
17. Computer program product comprising a computer-readable medium and a computer program according to claim 14, said computer program being comprised in said computer-readable medium.
18. System for fuel pump control in a fuel system in a vehicle (100); wherein said vehicle (100) comprises a combustion engine (101) and a fuel supply system (204) associated with said combustion engine (101), wherein the vehicle (100) also comprises at least one first main tank (215A) for receipt of fuel and a first fuel pump (212A; 210A), for use when transferring fuel between said first main

tank (215A) and said fuel supply system (204),  
**characterised in that** the vehicle comprises a second fuel  
pump (212B; 210B) arranged to operate in parallel with  
said first fuel pump (212A; 210A) in connection with  
5 transfer of fuel between said first main tank (215A) and  
said fuel supply system (204), and wherein the system  
comprises elements to:

- control the transfer of fuel between said first (212A;  
210A) and second (212B; 210B) fuel pump, at least partly  
10 based on a representation of a total efficiency for said  
first (212A; 210A) and second (212B; 210B) fuel pump,  
- elements to control said transfer of fuel, based also on  
at least one parameter relating to the life span of said  
fuel pumps.

15 19. Vehicle (100), **characterised in that** it comprises a system  
according to claim 17.

FIG. 1A

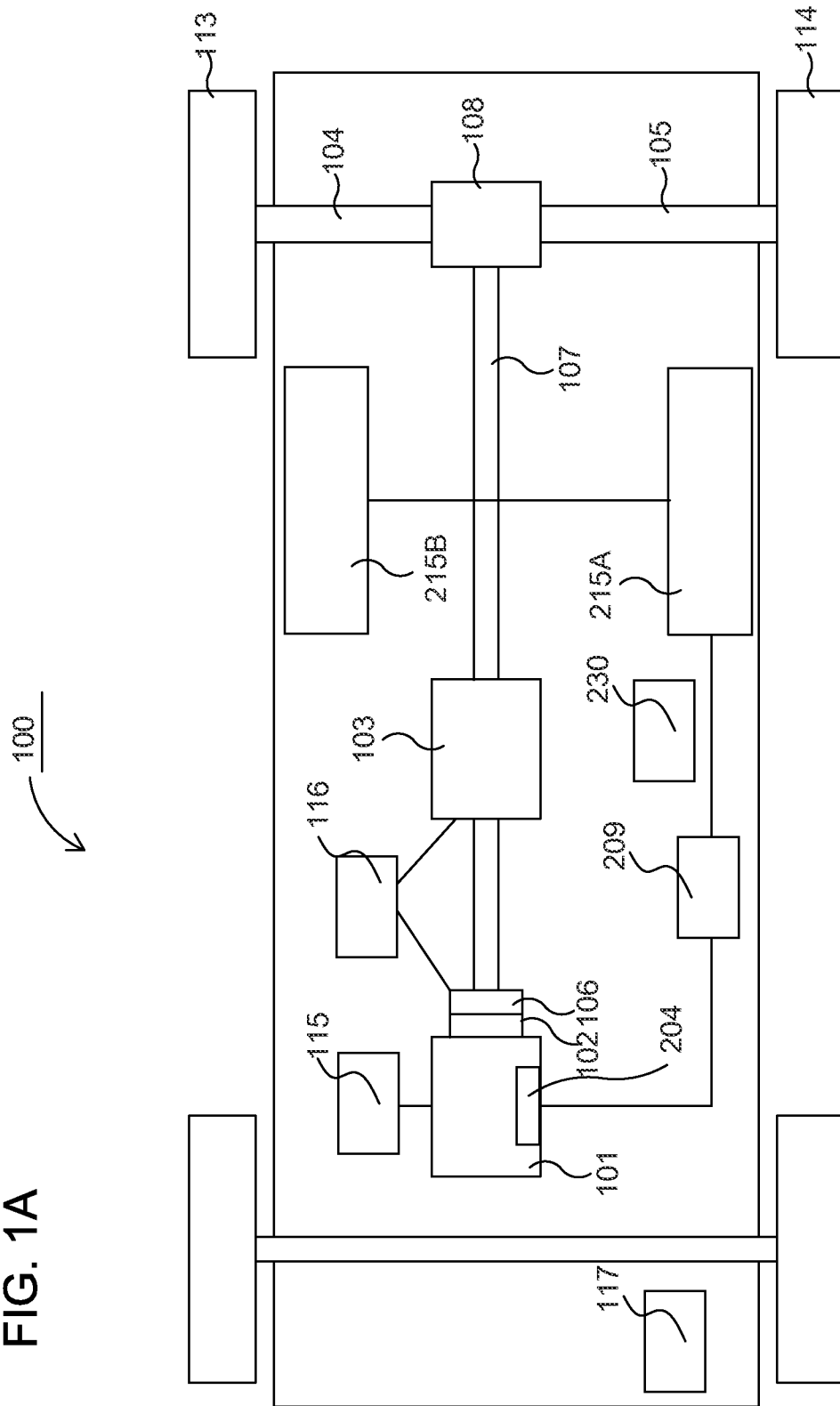


FIG. 1B

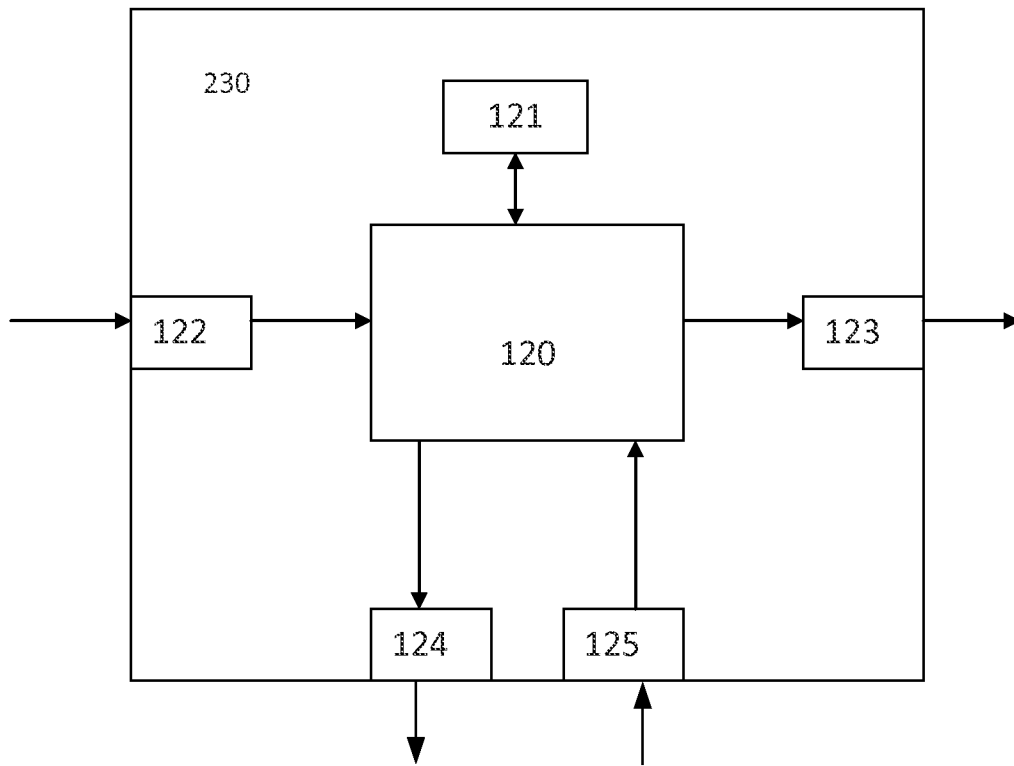
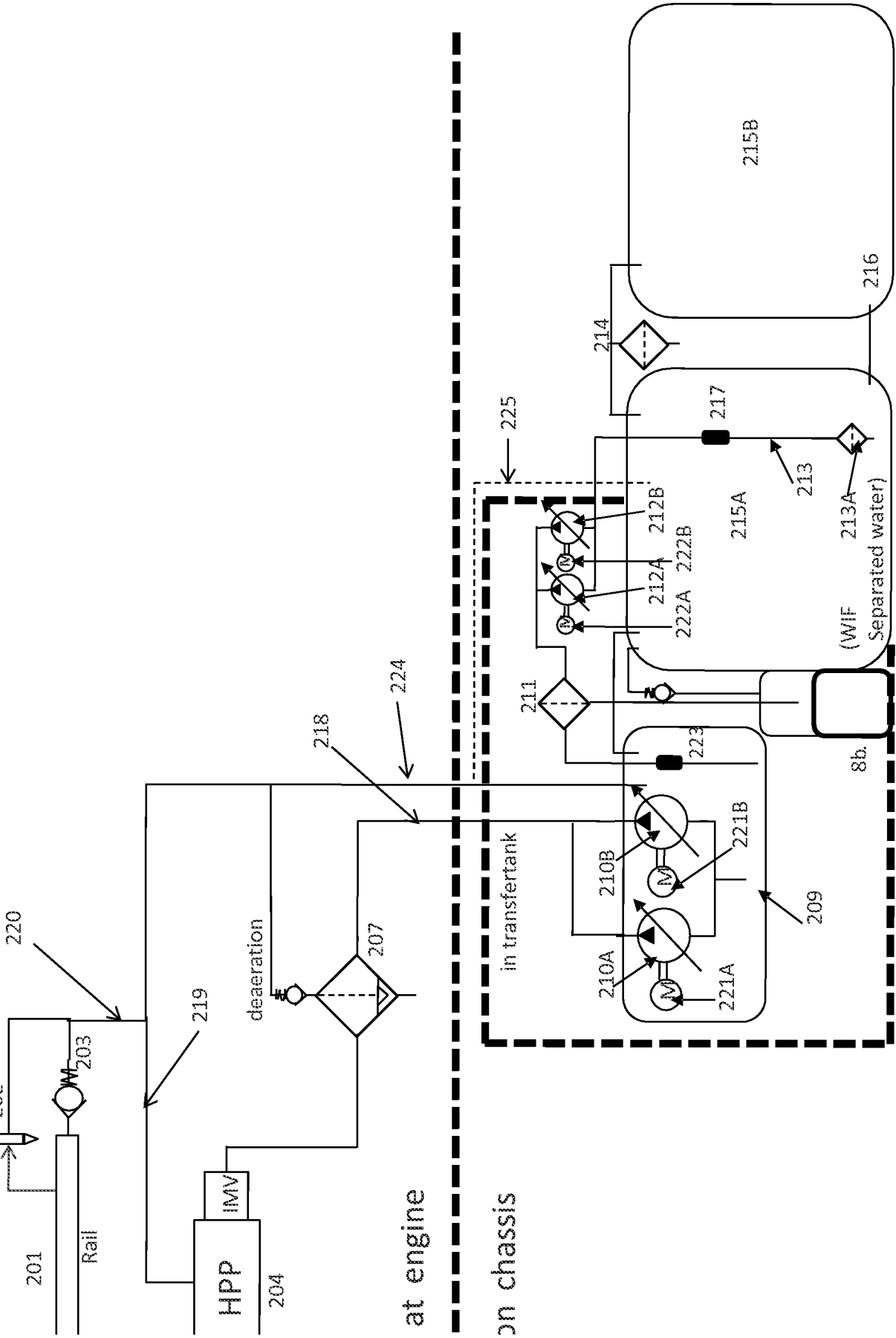
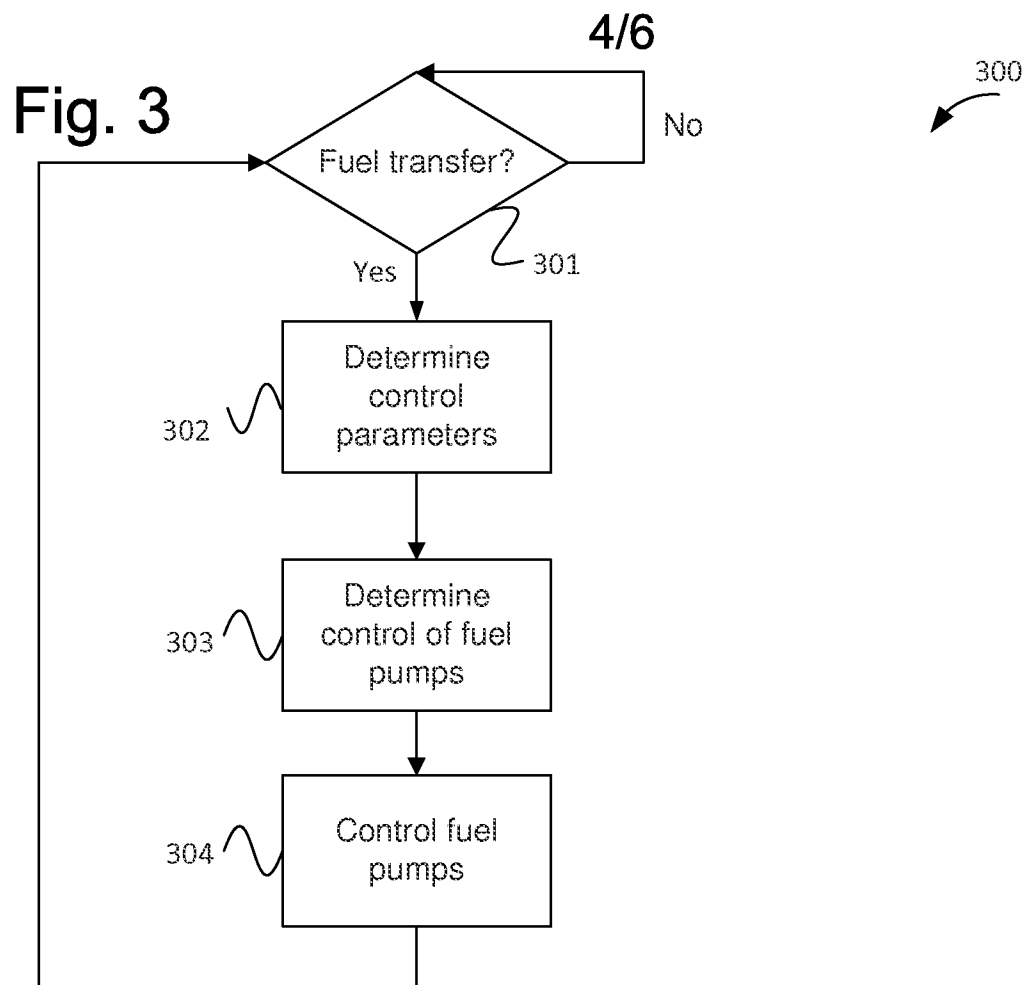


FIG. 2





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Fig. 4

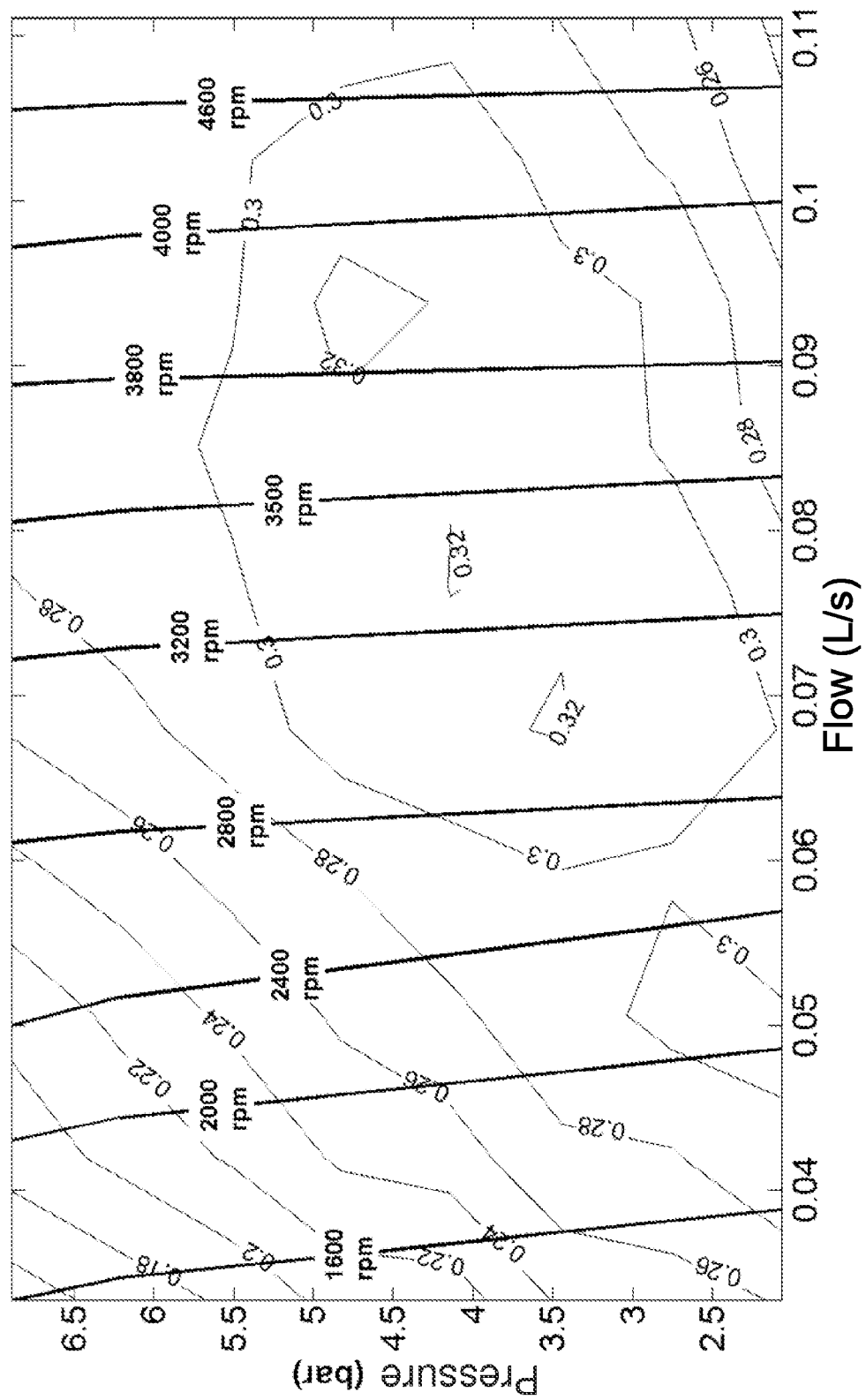
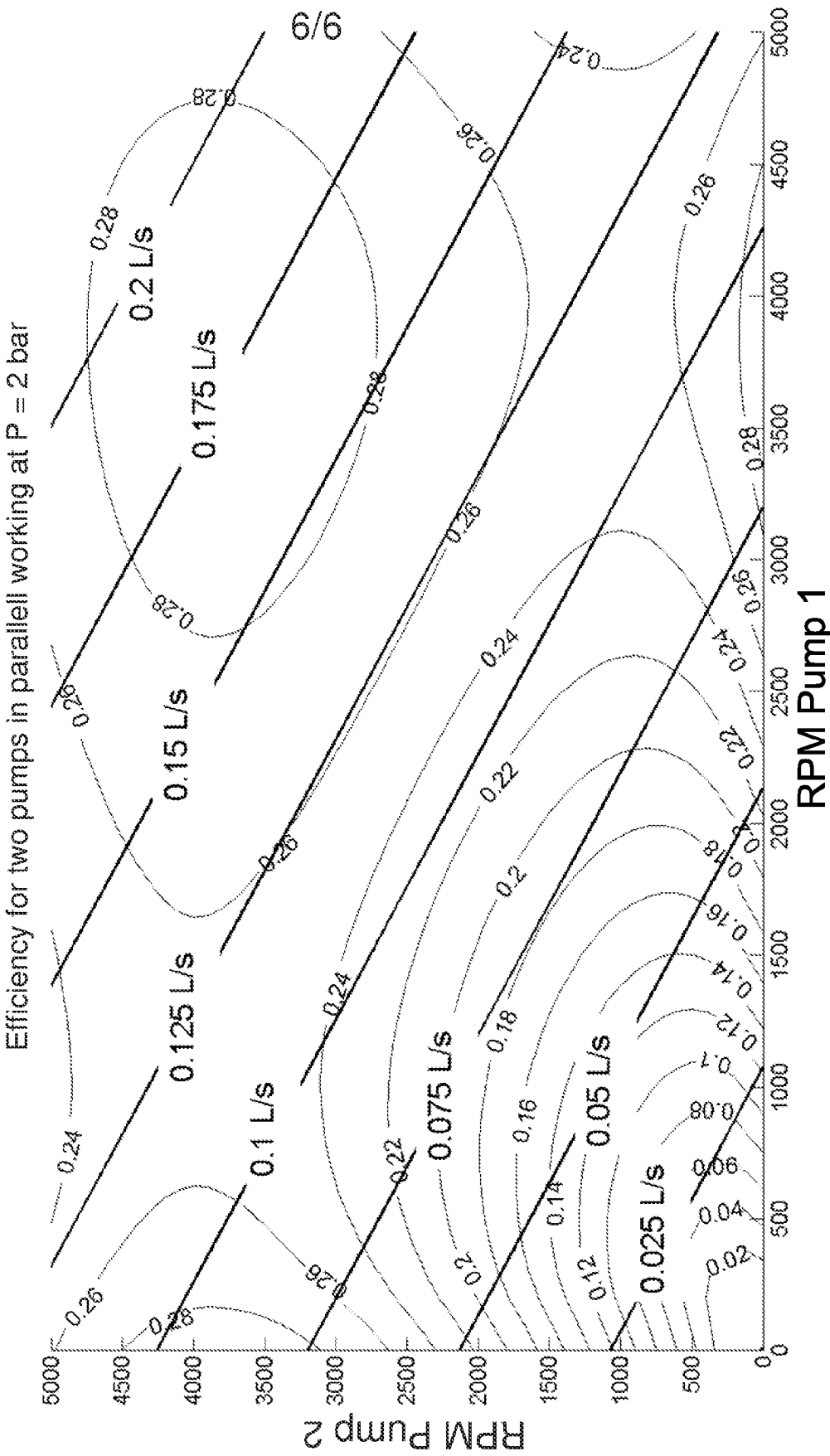


Fig. 5



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/SE2015/050971

## A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B60K, F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                       | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | DE 10335698 A1 (BAYERISCHE MOTOREN WERKE AG), 24 February 2005 (2005-02-24); abstract; paragraphs [0007]-[0017]; figure 1; claims 1-3<br>--              | 1-19                  |
| A         | JP 2007211623 A (MITSUBISHI ELECTRIC CORP), 23 August 2007 (2007-08-23); abstract; paragraphs [0006], [0011]-[0015]; figures 1-2; See PAJ abstract<br>-- | 1-19                  |
| A         | US 20130108473 A1 (TAMMINEN JUSSI ET AL), 2 May 2013 (2013-05-02); abstract; paragraphs [0027], [0037]; figures<br>--<br>-----                           | 1-19                  |

☐ 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

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“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

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Date of the actual completion of the international search

02-12-2015

Date of mailing of the international search report

02-12-2015

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**Continuation of:** second sheet**International Patent Classification (IPC)***F02M 37/08* (2006.01)*B60K 15/077* (2006.01)*F02M 37/18* (2006.01)

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

PCT/SE2015/050971

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|----|----------------|------------|------|------------|------------|--|
| DE | 10335698 A1    | 24/02/2005 | NONE |            |            |  |
| JP | 2007211623 A   | 23/08/2007 | NONE |            |            |  |
| US | 20130108473 A1 | 02/05/2013 | FI   | 20116080 A | 03/05/2013 |  |
|    |                |            | US   | 9091259 B2 | 28/07/2015 |  |