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(54) **Title:** A METHOD OF MANUFACTURING AND INSTALLATION OF HIGH PRESSURE LIQUID LPG FUEL SUPPLY AND DUAL OR MIXED FUEL SUPPLY SYSTEMS

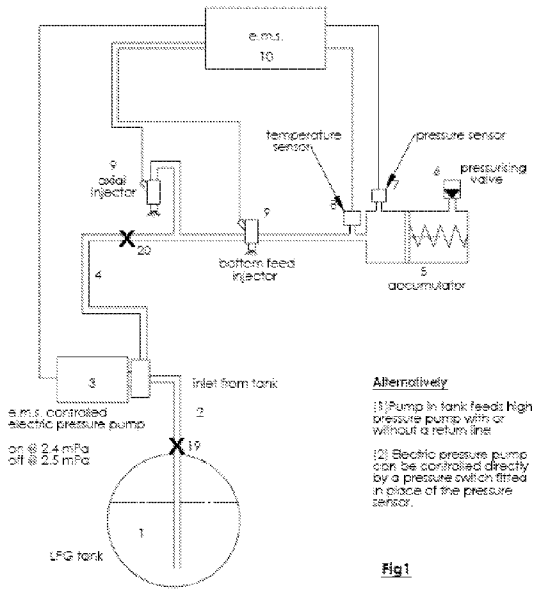

Fig1

(57) **Abstract:** A high vapour pressure liquid fuel (*eg* LPG) injection system keeps the fuel liquid at all expected operating temperatures by use of a high pressures pump capable of at least 2.5 MPa pressures. The fuel can be injected directly into the cylinder or into the inlet manifold of an engine via axial or bottom feed injectors and also could be mixed with a low vapour pressure fuel (*eg* diesel) to be injected similarly. The fuel, mixed or unmixed, can be stored in an accumulator under high pressure assisting in keeping the engine running during fuel changeovers and injection after a period of time as in re-starting the engine. The same injectors can be used to inject any of the fuels or mixtures of them.

WO 2008/141390 A1

A METHOD OF MANUFACTURE AND INSTALLATION OF HIGH PRESSURE LIQUID LPG FUEL SUPPLY AND DUAL OR MIXED FUEL SUPPLY SYSTEMS

FIELD OF THE INVENTION

This invention relates to a system of injection for a high vapour pressure fuel, such as LPG or injecting a mix of fuels and a changeover from one fuel to another.

TECHNICAL FIELD

This invention provides a method, employing a high pressure pump and accumulator, of ensuring a constant and adequate high pressure fuel supply of LPG alone, or in a fuel mixture, as with a lower vapour pressure fuel such as petrol or diesel, maintained in a liquid state, supplied to axial or bottom feed liquid fuel injectors injecting into the inlet manifold or cylinders of a spark ignition internal combustion engine, or directly into the cylinders of a diesel or compression engine, to keep said engine running at its critical usable power output levels.
In a spark ignition engine the invention allows for a seamless changeover from a high vapour pressure fuel to another fuel of lower vapour pressure of which a change from LPG to petrol is an example.
The system, as configured, is controlled by electronic means.

BACKGROUND AND DESCRIPTION OF THE INVENTION

It is most advantageous if liquid petroleum gas (LPG) can be fed to an engine in liquid form so gaining the advantage of the better combustion provided by the volumetric effect, the phase change from liquid to gas.
Prior art (Granted Australian Patents 647561, 647857,) has disclosed energy efficient low pressure methods of delivering liquid LPG into the inlet manifold of a spark ignition (SI) engine.
An advantageous alternative is to overcome the high vapour pressure of the LPG so enabling the delivery of the LPG to the inlet manifold or direct into the cylinder in the highly desirable liquid state. A means of doing so is shown in Drawing 1.

It is highly advantageous to be able to simplify the installation by deleting the return of fuel to the tank. An additional benefit is not raising the tank temperature of the LPG.

Whereas this description concentrates upon the use of LPG as the fuel it is possible to utilize mixed fuels of which LPG may be a constituent, utilizing a mixer prior to the inlet of the high pressure pump. Alternatively, the pump and fuel measuring device may be one unit with a mixer prior to or integral with the accumulator, as in Drawing 2.

An economical method to manufacture and install a high pressure liquid LPG fuel supply system for an internal combustion engine is described. The LPG is fed from an LPG tank, either vapour pressure fed, or with the aid of a low pressure submerged pump in the tank, providing a LPG feed at tank vapour pressure, plus up to 250 kPa from the submerged pump, to a high pressure pump capable of delivering at least 2.5 MPa pressure. The purpose behind the use of the low pressure pump is the avoidance of cavitation on the inlet side of the high pressure pump.
The pumping of the LPG in liquid form from the tank to the inlet side of the high pressure pump may include a return line to the LPG tank and a pressure regulation device in the form of a one way valve, such valve having a fixed spring of a certain cracking pressure and located at the return inlet to the tank, as disclosed in the prior art quoted, Granted Australian Patents 647561, 647857. A similar system of a return line for diesel can be utilized.

The high pressure pump in the preferred embodiment delivers liquid LPG at 2.5 MPa pressure to the fuel line and to an accumulator having a suggested capacity capable of fuelling the engine in question for one minute at peak revolutions.

This period of one minute is ample time in which to achieve a changeover from one fuel type to another. The engine management system will calculate the time required for the first fuel to be almost exhausted from the fuel lines and accumulator, gauging the fuel pressure and temperature in the lines, before changing to the second fuel at the optimum pressure for that fuel to be injected through the same injectors delivering the liquid fuel.

The high pressure pump and accumulator can be set at any pressure which will guarantee that the LPG remains in a liquid state for injection, directly into the engine or into the engine intake manifold.

Upon demand, the liquid LPG is fed to injectors, axial or bottom feed injectors on the engine, via a distribution manifold and flexible high pressure fuel lines, providing the LPG to each injector. An alternative is to utilize a common rail system as found in modern diesel engines which method is suitable for direct into the cylinder fuel injection.

A pressure switch, acting in accordance with the pressure in the accumulator turns the high pressure pump off, either directly or through the engine management system (EMS) when the set pressure (here 2.5 MPa) is reached. Upon the pressure in the accumulator falling by one hundred kPa, or other preferred pressure difference, a switch will turn on the high pressure pump to restore the set pressure.

Alternately the speed of the high pressure pump can be modulated by the EMS to match the delivery rate to engine requirement thereby maintaining a constant pressure.

The accumulator may be used to ensure constant delivery of LPG in liquid form to the injectors at all operating times and to assist starting of the engine following a period of shut down of the engine or, by choice, the accumulator may be dispensed with, which would reduce the time needed to exhaust the old fuel in the accumulator when

changing from one fuel to another and reliance will rest upon the high pressure pump to provide sufficient high pressure fuel at all operating moments to ensure smooth operation of the engine. The absence of an accumulator may be aided by elasticity in the tubing used to conduct the liquid LPG from the pump to the injectors.
Hot starts may not be instantaneous due to vapourisation of the LPG in the fuel lines whilst the engine is stopped.
In this invention the high pressure accumulator is used to keep LPG in the liquid state ready for an instant start, or re-start of the engine.

The injectors are designed to deliver LPG at pressures up to and over 20 MPa with a preference to operating around 2.5 MPa so limiting the energy needed to drive the system, but still allowing for direct into the cylinder injection or injection into the engine manifold.
The pressure of injection is such as to keep liquid fuel at the tip of the injector for injection into the inlet manifold of the engine or directly into the cylinders of the engine.
The system is aided by heat shielding of components and cooling, via the air conditioning system of the vehicle or other means, of the high vapour pressure fuel.
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Experience with the prior art has encountered the heating up of the LPG by its continuous recirculation through the injectors and fuel lines of the engine.

It is preferable that the LPG can be supplied from the high pressure pump to the engine without a return line to the LPG tank so as to avoid raising the temperature of the LPG in the tank, which heat can raise the vapour pressure and affect the time taken for filling the LPG tank, plus incurring the added cost and complexity of return tubing.

The invention will be generally discussed in relation to the operation of a liquefied petroleum gas fuelled vehicle, as an example of a high vapour pressure fuel system, but the invention is not restricted to this fuel.
This present invention provides an arrangement whereby such an engine can be supplied to advantage with high pressure bottom feed or axial feed injectors of a size equal to or smaller than commonly used petrol injectors. The bottom feed injectors discussed by this invention do not require to be placed in a housing or pod, the outer shell of the injector serving that function. They do not sit in a series of pods, constituting a fuel rail, but are connected, in the preferred embodiment, by flexible high pressure fuel lines from pump or accumulator to injector. A common rail system, or plastic coated steel fuel lines may be used to feed the injectors.

It is of assistance and is specified as the desired option in this invention that to deliver liquid LPG to the injecting orifice of the injector, adequate pressure is exerted by the high pressure pump to keep the LPG liquid in all normal circumstances of motoring and the desired pressure is 2.5 MPa.
Utilising an axial injector the fuel is fed through the top of the injector in the common embodiment. With a bottom feed injector, the fuel is fed to the bottom of the injector

and removed therefrom if so required via arms which are rigid and to which the flexible tubing used is connected or a common rail is used.
The nozzle of the injector can be relatively small at 8 or 9 mm in diameter and can be fitted with a collar to ensure that the injector is a snug fit in the holes provided in the inlet manifold by the engine manufacturer. This aids rapidity and economy of assembly.

The pressure and temperature of the LPG is taken at closely located points to determine, via the EMS, from look up charts the composition of the LPG. This knowledge is then used to set the base injection pulse width and ignition timing specific to the fuel composition, is the readings for which are then modified by the oxygen sensor and other inputs required for the effective running of the engine by the EMS in the normal manner, as disclosed in Australian Patent 647857.

DUAL FUEL SYSTEM
With dual fuel systems that inject the fuel in the liquid state via bottom feed injectors as in Australian Patents 647561 "A Method of Fuel Injection" and 647857 "Dual Fuel Injection System" there exists a problem in sizing the required injectors, relatively low flow injectors for high pressure LPG, and relatively high flow injectors for low pressure petrol injection.

Using one high pressure pump and one set of high pressure injectors eliminates the need for a second set of low pressure injectors when running solely on petrol or other low vapour pressure fuel.

This problem is overcome in this invention by injecting both fuels at the relatively high pressure of 2.5MPa. The fuel to be used can be selected by use of lock off solenoids on the fuel lines with care being taken to ensure that there is no flowing of one fuel to the tank of the alternative.

A mixed charge of differing fuels can be used employing the aid of a mixer which can mix the fuels in set proportions and such proportions can be varied.
In the preferred embodiment, shown in Drawing 2, the pressurizing of the fuels or fuel is shown with integral measuring of the relative volume of the fuels.
A system of integral measuring by the use of two pumps mounted on a common shaft is shown in Drawing 3.
Adequate mixing of the fuels may also be achieved with a mixer prior to or being an integral part of the accumulator.

Economy is served if the pump in the LPG tank can be dispensed with and this will depend on the ability to avoid cavitation at the inlet of the high pressure pump and therefore depend on operating conditions encountered.

Prior to this invention a common method of switching from the high vapour pressure fuel to the low vapour pressure fuel is to allow the pressure in the fuel rail to subside after switching off the high vapour pressure fuel, mainly LPG in Australia or Europe and propane in the United States of America. For the pressure in the fuel rail to subside to a level of less than 250 kPa or such level as the fuel pump will normally pump

the low vapour pressure fuel such as petrol may take 2 minutes of time during which the engine will not run in an effective manner.
If the engine is in a motor vehicle, the vehicle is normally stationary during the fuel changeover and this can be a source of irritation and inconvenience, even danger.
This problem is avoided as all fuels are injected at similar pressures thereby requiring no time for pressure adjustment

An inventive step is the use of the high pressure pump for the injection of a mixture of both fuels, or other suitable alternative fuels, for injection through the one set of injectors, otherwise petrol or LPG as a single fuel, with solenoid control over the fuel selected.
In such a system the alteration to the power output will be a minimum in any changeover of fuels and both fuels can successfully be injected at high pressure.
For LPG or petrol, or a petrol LPG mix, the engine will be a spark ignition engine and for diesel, or a diesel LPG mix, the engine will be a compression ignition engine, however a variable compression engine fitted with spark ignition such as that disclosed in UK Patent cover Family 4, EPA Number 03792495.8, PCT No. PCT/GB2003/003643 can utilize all of the above fuels.

Using the computing facilities of the engine management system into which the temperature and pressure of the fuel are fed the appropriate pulse width for the injectors can be calculated
for which verification of the fuel mix being used by the engine can come from the exhaust sensors which also read back to the engine management system and compensate for fuel metering errors.
Accordingly, the present invention is directed to a high pressure single fuel injection, or a dual fuel system employing high and low vapour pressure fuels which will be capable of being switched from one fuel to the other, or operating with mixed fuels, without interrupting the effective functioning of the engine.

Whereas the mixed fuels may commonly be LPG and petrol, or ethanol, it is possible to use a mix of LPG and diesel, including biodiesel where the engine is a compression ignition engine and in which case the injection of the fuel mix for maximum efficiency, could be direct into the cylinder.

Although various forms of the invention have been described it is to be noted the invention is not limited thereto but can include variations and modifications falling within the spirit and scope of the invention.

BEST MODE
The best mode is that shown in Drawings 2 and 3 if viewed as a combined system.

MODE FOR INVENTION
The mode is mechanical for the automotive industry so as to reduce emissions and make the best use of available fuels giving the user greater economy and satisfaction

INDUSTRIAL APPLICABILITY

The foremost use is in transport, predominantly personal transport and trucks, but important uses exist in areas such as forklifts, sweepers, polishers and power generation units.

CLAIMS

1. A high vapour pressure liquid fuel injection system whereby a high vapour pressure fuel such as LPG is kept liquid at all expected operating temperatures by use of a high pressure pump capable of at least 2.5 MPa pressures.

2. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein an accumulator is employed to retain the fuel at the 2.5 MPa approximate pressures for the purposes of constant metering for smooth running or easy starting of an engine.

3. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the high vapour pressure fuel is delivered to the high pressure pump in a manner which avoids cavitation in the high pressure pump by locating the said pump below the fuel tank outlet line or having a pump in the tank so as to circulate liquid fuel to the high pressure pump with a return line to the tank.

4. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the pump can operate intermittently according to the pressure recorded in the accumulator leaving sufficient fuel in the accumulator for one minutes operation of the engine at all times.

5. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the system can be operated without an accumulator and be aided by elasticity in the fuel lines to keep relatively constant fuel pressures at the injectors.

6. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the high vapour pressure fuel can be delivered by axial flow or bottom feed injectors from a common rail.

7. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the high vapour pressure fuel can be delivered by axial flow or bottom feed injectors from fuel lines of plastic or plastic coated steel construction

8. A high vapour pressure liquid fuel injection system as defined in claim 1 wherein the pressure pump, electric or mechanical can be intermittently operated according to the pressure in the accumulator as sensed and transmitted to the engine management system which controls the operation of the said pump.

9. A high pressure liquid fuel injection system capable of keeping LPG in liquid form at operating pressures which can be varied, but not expected to exceed 2.5 MPa and of mixing a second low vapour pressure fuel such as diesel with LPG or another high vapour pressure fuel, via a mixer operating with a high pressure pump.

10. A high pressure liquid fuel injection system utilising a high pressure pumping system having at least two gear pumps or similar positive displacement pumps operated by the same power shaft, such pumps can operate adjacent to each other or by utilising different volumes created by set bore and stroke sizes in one block and operated by a single shaft.

11. A high pressure liquid fuel injection system utilising a high pressure pumping system wherein the positive displacement pumps have a set volume relative to each other, enabling mixing of the fuels in those relative proportions.

12. A high pressure liquid fuel injection system wherein the fuels are mixed in the proportions set by the pump sizes utilising a mixing means operating between the pump and the accumulator in the preferred embodiment, but the mixer may operate prior to the pump.

13. A high pressure liquid fuel injection system wherein the fuels are mixed in the proportions set by the pump sizes utilising a mixing means and allowed to fill an accumulator the pressure of which can be varied by a pressurising gas, a spring loaded diaphragm, or by other means.

14. A high pressure liquid fuel injection system wherein the mixed fuels are stored in an accumulator of sufficient volume for the engine being fed with fuel to operate for a set period on that fuel stored under pressure in the accumulator.

15. A high pressure liquid fuel injection system wherein the pre-mixed fuels are stored under pressure in an accumulator which has a pressure sensor connected to the engine management system allowing the high pressure pump to be selectively operated to maintain the desired pressure in the accumulator.

16. A high pressure liquid fuel injection system wherein the mixture of fuels is stored in the accumulator at a pressure which enables easy starting of the engine, under heat soak conditions or not, after a period during which the engine has not run.

17. A high pressure liquid fuel injection system wherein the fuel may be drawn from one tank only utilising solenoid operated lock off valves to select said tank and delivered under pressure to the accumulator as an unmixed single fuel.

18. A high pressure liquid fuel injection system wherein the fuel may be drawn from a selected tank only utilising solenoid operated lock off valves to select said tank and delivered to the accumulator at a selected pressure as an unmixed single fuel giving the ability to switch fuels according to instructions from the engine management system including instructions as to exhausting one fuel via the injectors prior to the introduction of the alternative fuel and changed operating instructions to the engine to accommodate the optimum use of that newly introduced fuel.

19. A high pressure liquid fuel injection system wherein the mixture of fuels is delivered from the accumulator to a common rail in-cylinder injection system utilising bottom feed or axial feed injectors, the timing and volume of injection being controlled by electronic signals from the engine management system in accordance with information from sensors recording the circumstances of the engine, the engine operating at optimum levels of power during the changeover of fuels.

20. A high pressure liquid fuel injection system wherein the mixture of fuels is delivered from the accumulator to an axial or bottom feed injector via rigid steel or flexible plastic tubing connecting the accumulator to the injector or injectors.

21. A high pressure liquid fuel injection system wherein the mixture of fuels is delivered from the accumulator to an axial or bottom feed injector via thermally efficient plastic coated rigid metal tubing or reinforced plastic tubing.

22. A high pressure liquid fuel injection system wherein the mixture of fuels is delivered to the injector or injectors from the accumulator, or direct from the pump, after having been mixed by the mixing means, this controlled by the engine management system via solenoid operated isolation valves.

23. A high pressure liquid fuel injection system wherein the mixture of fuels is delivered from the accumulator at a pressure selected by the engine management system, which pressure may be varied via the pressurising valve or other means to a set of injectors the injection timing and pulse width being controlled by the engine management system which can alter parameters of injection by reference to the pressure and temperature of the fuel and the readings from the oxygen sensor in the exhaust of the engine so as to obtain maximum efficiency during the changeover in fuel types or in constant running of the engine.

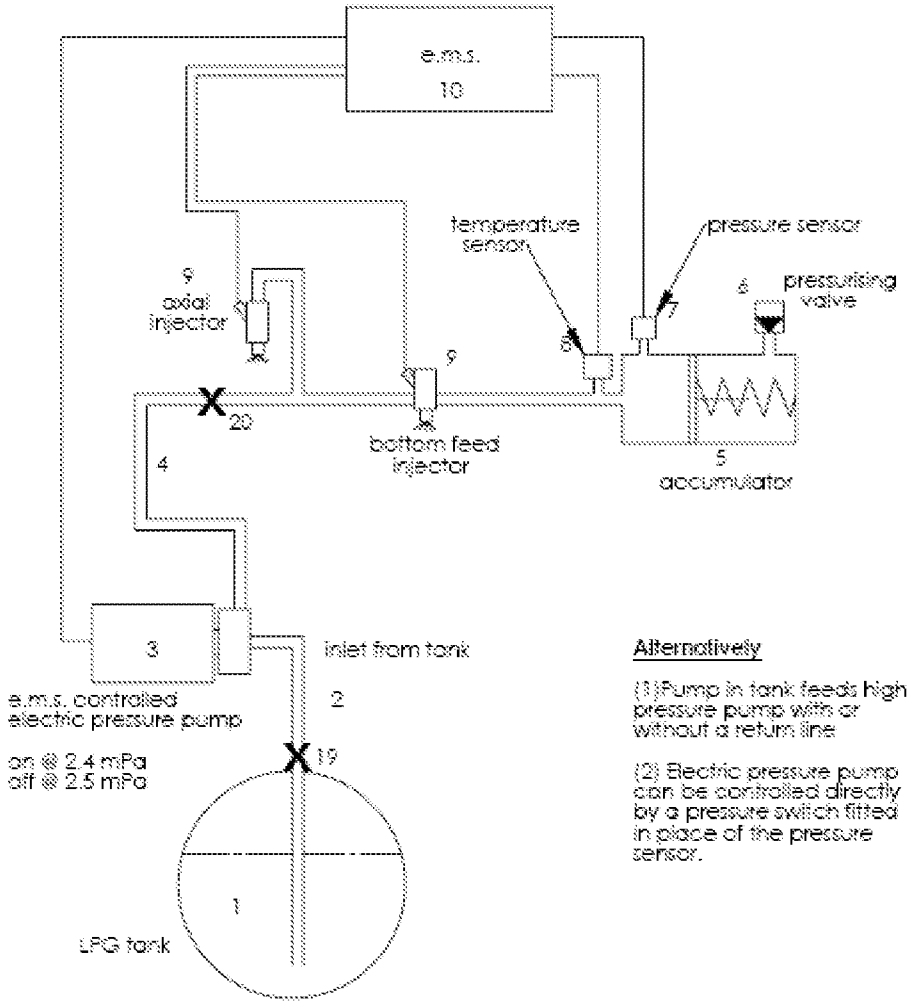
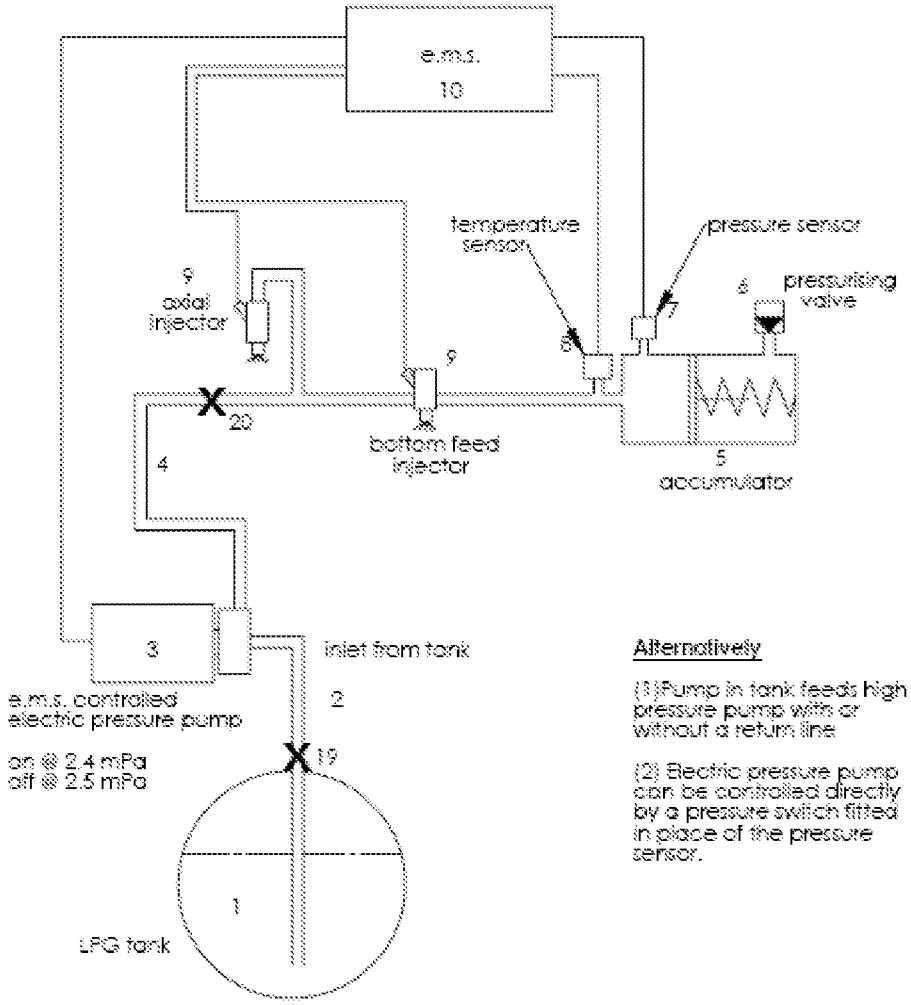

e.m.s.
10
temperature sensor
pressure sensor
9
axial injector
6
pressurising valve
7
8
9
20
bottom feed injector
4
5
accumulator
3
inlet from tank
e.m.s. controlled electric pressure pump
2
on @ 2.4 mPa
off @ 2.5 mPa
19
1
LPG tank
Alternatively
(1) Pump in tank feeds high pressure pump with or without a return line
(2) Electric pressure pump can be controlled directly by a pressure switch fitted in place of the pressure sensor.

Fig1


e.m.s.
10
temperature sensor
pressure sensor
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axial injector
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pressurising valve
7
8
9
20
bottom feed injector
4
5
accumulator
3
inlet from tank
e.m.s. controlled electric pressure pump
on @ 2.4 mPa
off @ 2.5 mPa
2
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(1) Pump in tank feeds high pressure pump with or without a return line
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Fig1

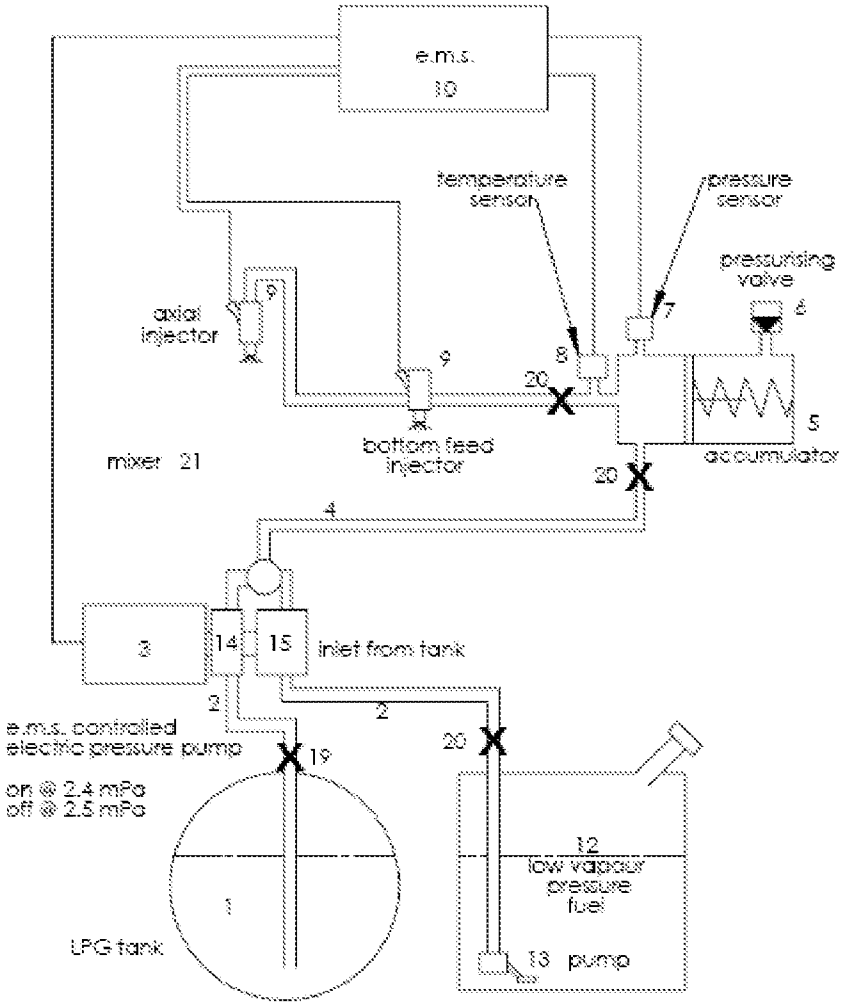
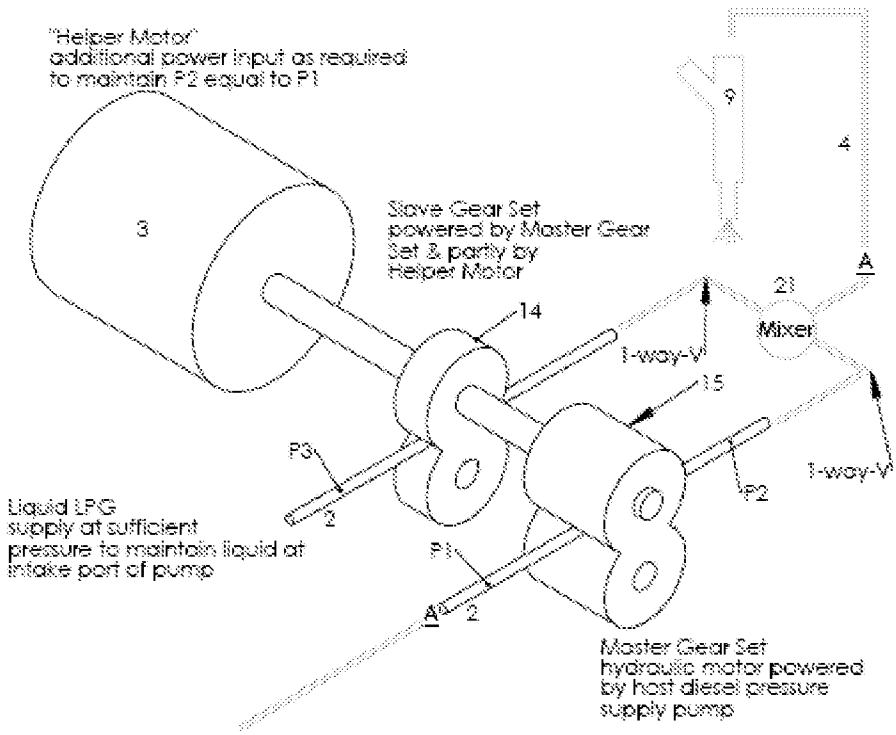

e.m.s.
10
temperature sensor
pressure sensor
pressurising valve
6
7
8
9
axial injector
9
20
5
accumulator
bottom feed injector
mixer 21
20
4
3
14
15
inlet from tank
2
e.m.s. controlled electric pressure pump
on @ 2.4 mPa
off @ 2.5 mPa
19
20
12
low vapour pressure fuel
1
LPG tank
13 pump

Fig 2

MASTER/SLAVE FIXED METERING PUMP

Motor control.....power up motor to make P1=P2

P1 will be less than P2 by the power required to raise P3 to equal P2



The pressure loss P1 to P2 is due to energy lost in driving slave pump, additional electrical energy is required to raise P2 to equal P1

Fig 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000726

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

F02M 21/02 (2006.01) ***F02B 43/00*** (2006.01) ***F02M 37/04*** (2006.01)

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)
see below under "Electronic databases searched"

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)
DWPI: IPC: F02M, F02B, F02D with keywords ; (a) LPG, pressur+ , liquid+; (b) LPG, pressur+, inject+
(c) Epoque : WPI : EPODOC: IC: TEXTE: F02M, F02B, F02D with keywords LPG inject+ , diesel and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 5690078 A (OFNER) 25 November 1997	
X	the whole document	1-4, 6-8
Y	the whole document	5, 7
	US 5967126 A (OFNER) 19 October 1999	
X	the whole document	1, 3, 6
	US 5592924 A (AUDISIO et al.) 14 January 1997	
Y	Figures 2 , 3 and accompanying description	5, 7
	GB 2407620 A (MA) 4 May 2005	
Y	Figure 3 and the accompanying description	9

[X] Further documents are listed in the continuation of Box C [X] 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
30 September 2008	13 OCT 2008

Name and mailing address of the ISA/AU

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000726

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5377645 A (MOORE) 3 January 1995 the whole document .	9
A	DD 219054 A3 (DREVS et al.) 20 February 1985 the whole document	9
A	NL 8300163 A (POLYGAS B.V.) 16 August 1984	9
A	US 5887574 A (SMITH) 30 March 1999	1-9
A	US 3406666 A (STEIGER) 22 October 1968	1-9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000726

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See the Supplemental Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-9**

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000726

Supplemental Box
(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to potentially distinguish the claimed combination of features from the prior art. Where different claims have different distinguishing features they define different inventions.

This International Searching Authority has found that there are 11 different inventions as follows:

- Claims 1-9 are directed to a high vapour pressure/high pressure liquid fuel injection system. It is considered that keeping a high vapour pressure fuel such as LPG liquid at all expected operating temperatures or at operating pressures which can be varied by use of a high pressure pump capable of at least or not expected to exceed 2.5 MPa pressures comprises a first distinguishing feature.

- Claims 10 and 11 are directed to a high pressure liquid fuel injection system. It is considered that utilising a high pressure pumping system wherein least two positive displacement pumps having different volumes created by set bore and stroke sizes in one block operated by a single shaft or set volumes relative to each othercomprises a second distinguishing feature.

- Claims 12 and 13 are directed to a high pressure liquid fuel injection system. It is considered that fuels are mixed in the proportions set by pump sizes utilising a mixing means operating between the pumps and an accumulatorcomprises a third distinguishing feature.

- Claim 14 is directed to a high pressure liquid fuel injection system. It is considered that mixed fuels are stored in an accumulator of sufficient volume for the engine to be fed with fuel to operate for set period on that fuel stored under pressure in the accumulator comprises a fourth distinguishing feature.

- Claim 15 is directed to a high pressure liquid fuel injection system. It is considered that pre-mixed fuels are stored under pressure in an accumulator which has a pressure sensor connected to an engine management system allowing a high pressure pump to be selectively operated to maintain desired pressure in the accumulator comprises a fifth distinguishing feature.

- Claim 16 is directed to a high pressure liquid fuel injection system. It is considered that mixed fuels stored in an accumulator at a pressure which enables easy starting of the engine, under heat soak conditions or not, after a period during which the engine has not run comprises a sixth distinguishing feature.

- Claims 17 and 18 are directed to a high pressure liquid fuel injection system. It is considered that a fuel may be drawn from one tank only utilising solenoid operated lock off valves to select said tank and delivered to an accumulator as an unmixed single fuel comprises a seventh distinguishing feature.

- Claim 19 is directed to a high pressure liquid fuel injection system. It is considered that a mixture of fuels is delivered from an accumulator to a common rail in-cylinder injection system utilising bottom feed or axial feed injectors, the timing and volume of injection being controlled by electronic signals from an engine management system in accordance with information from sensors recording the circumstances of the engine, the engine operating at optimum levels of power during the changeover of fuels comprises a eighth distinguishing feature.

(Continued in the next sheet)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000726

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: III

(Continued from the previous sheet)

- Claims 20 and 21 are directed to a high pressure liquid fuel injection system. It is considered that a mixture of fuels is delivered from an accumulator bottom feed or axial feed injectors via rigid steel, flexible plastic tubing, thermally efficient plastic coated rigid metal tubing or reinforced plastic tubing comprises a ninth distinguishing feature.
- Claim 22 is directed to a high pressure liquid fuel injection system. It is considered that a mixture of fuels is delivered to injectors from an accumulator, or direct from a pump after having been mixed by a mixing means, this controlled by an engine management system via solenoid operated isolation valves comprises a tenth distinguishing feature.
- Claim 23 is directed to a high pressure liquid fuel injection system. It is considered that a mixture of fuels is delivered from an accumulator at a pressure selected by an engine management system, which pressure may be varied via the pressurising valve or other means to a set of injectors, the injector timing and pulse width being controlled engine management system which can alter parameters of injection by reference to the pressure and temperature of the fuel and the readings from the oxygen sensor in a exhaust of the engine so as to obtain maximum efficiency during the changeover in fuel types or in constant running of the engine comprises an eleventh distinguishing feature.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

The only feature common to all of the claims is a high pressure liquid fuel injection system and the only feature common to all of the claims 12-23 is the use of an accumulator for storing mixed or unmixed fuels prior to injection. However both of these concepts are not novel in the light of GB 2407620 A (MA) 4 May 2005 .

This means that the common feature can not constitute a special technical feature within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art.

Because the common feature does not satisfy the requirement for being a special technical feature it follows that it cannot provide the necessary technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention *a posteriori*.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2008/000726

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5690078	AT	92095	DE	19611434		
US	5967126	DE	19827439	JP	11022590		
US	5592924	EP	0725208	IT	TO950064	IT	TO950405
GB	2407620	GB	2415966				
US	5377645	AU	90192/91	CA	2096648	EP	0558592
		WO	1992008886				
DD	219054	CS	8305557	HU	35052		
NL	8300163	NONE					
US	5887574	AU	54917/96	CA	2220492	CN	1183826
		EP	0879346	WO	1996035863		
US	3406666	CH	431190	GB	1114610	NL	6502991

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX