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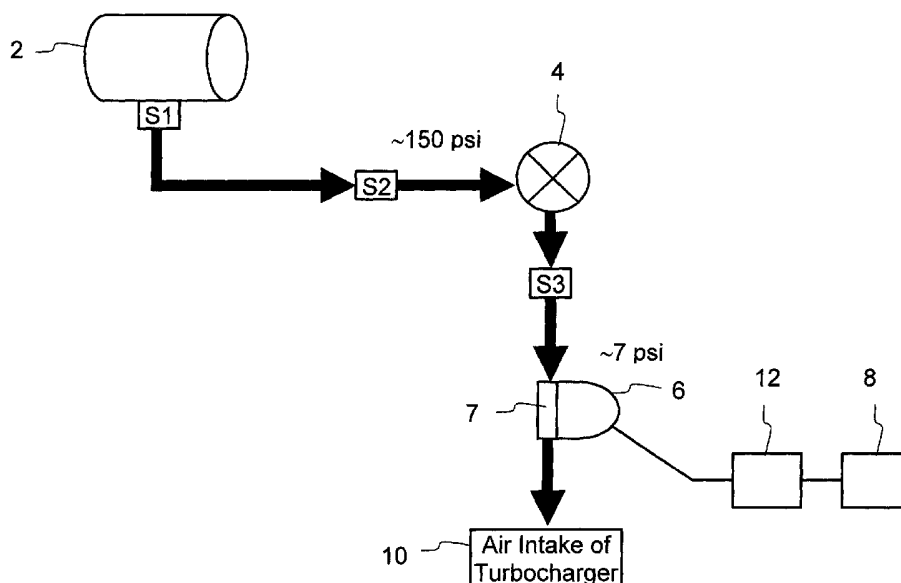
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(54) Title: FUEL CONTROL SYSTEM AND METHOD



(57) Abstract: A fuel control system for controlling supply of a mixture to a combustion engine, the mixture comprising air and at least one other combustible material such as liquefied petroleum gas (LPG), the system comprising a controller (8), a source (2) of combustible material, a first valve (S1) allowing egress of combustible material from the source in response to a first activation signal, a metering valve (7) regulating supply of the combustible material into an air supply of the combustion engine, a phase converter (4) located between the first valve (S1) and the metering valve (7), the controller (8) regulating supply of combustible material to the air supply via the metering valve in response to an engine speed signal received by the controller.



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## TITLE

## FUEL CONTROL SYSTEM AND METHOD

## FIELD OF THE INVENTION

5           The invention relates to a fuel control system and method. In particular, although not exclusively, the invention relates to a system and method for controlling the injection of a combustible material, particularly liquefied petroleum gas (LPG), into an air supply for a diesel combustion engine to improve performance. However, it is envisaged that other combustible materials may be  
10 employed.

## BACKGROUND TO THE INVENTION

One problem with conventional combustion engines is that of incomplete and therefore inefficient combustion of the fuel. This is a particular problem with  
15 compression ignition (diesel) engines. The problem is exacerbated under load because more diesel is delivered to the combustion chamber. The relatively slow-burning nature of the diesel fuel further compounds the problem because a significant amount of energy is lost due to exhaust ports opening prior to complete combustion of the diesel. This results in fuel burning in the exhaust manifold,  
20 which contributes nothing to the power developed by the engine. Additionally, the exhaust fumes comprise black smoke and/or soot, which are detrimental to the environment.

One known method of attempting to solve this problem is to introduce a gas, such as liquefied petroleum gas (LPG) into the fuel supply to achieve more  
25 complete combustion. The ignition of the diesel under compression provides the spark for the LPG, which, having a higher flash point than diesel, speeds the burn rate of the diesel and results in more complete combustion. The process is known

as fumigation and the LPG-accelerated combustion reduces diesel consumption and improves efficiency.

Despite the process of fumigation being known for many years, a commercially viable, efficient system and/or method for controlling the injection and mixture of the LPG into the air supply has not been achieved. Previous attempts have resulted in over-fuelling of the engine and poor performance especially at idle. Hence, there is a long felt need for a system and/or method that achieves the benefits of fumigation whilst overcoming or at least ameliorating the aforementioned problems.

10

#### DISCLOSURE OF THE INVENTION

In one form, although it need not be the only or indeed the broadest form, the invention resides in a fuel control system for controlling supply of a mixture to a combustion engine, said mixture comprising air, a first fuel and at least one other combustible material, said system comprising:

- a controller;
- a first valve allowing egress of said other combustible material from a source in response to a first activation signal;
- a metering valve regulating supply of said combustible material into an air supply of said combustion engine;
- a phase converter located between, and being in fluid communication with, said first valve and said metering valve, said phase converter allowing passage of said other combustible material therethrough;
- wherein, in response to an engine speed signal received by said controller, said controller regulates supply of said other combustible material into said air supply via said metering valve.

Preferably, the fuel control system further comprises a second valve

located between said first valve and the phase converter and a third valve located between the phase converter and the metering valve, said second and third valves allowing passage of the combustible material therethrough respectively in response to detection by the controller of a second activation  
5 signal and the engine speed signal.

Suitably, the combustion engine is a diesel engine.

Suitably, the first activation signal is a voltage signal detected when an ignition is switched on and the second activation signal is a voltage signal detected from the alternator.

10 Suitably, the first, second and third valves are electrically operated solenoid valves.

Preferably, the phase converter is a negative (gas-on-demand) first stage regulator and heat exchanger.

Suitably, the first fuel for the combustion engine is passed through the  
15 phase converter. In this case, the phase converter preferably includes a diaphragm comprising fuel-impervious material, which may be nitrile rubber.

Preferably, the metering valve is connected to the controller via an electrically operated stepper motor, said stepper motor operating the metering valve. Preferably, the stepper motor is re-zeroed and recalibrated each time an  
20 engine ignition is switched on.

Suitably, the controller is a programmable logic controller (PLC).

The fuel control system preferably further comprises a plurality of sensors to enable the controller to detect signals from one or more of: a foot brake, an engine brake, cruise control activation/deactivation, cruise control resumption,  
25 an idle validation signal.

Preferably, the combustible material is liquefied petroleum gas (LPG). Alternatively, the combustible material is methane.

Preferably, the fuel control system further comprises a turbocharger and a sensor to monitor a temperature of the turbocharger.

Suitably, the fuel control system further comprises an oxygen sensor to monitor levels of oxygen in emissions from said engine.

5           Suitably, the fuel control system further comprises a wireless communication device coupled to the controller to enable at least remote calibration of the fuel control system. The wireless communication device may preferably also enables remote monitoring of parameters associated with the fuel control system.

10           In another form, the present invention resides in a method of controlling a combustion engine comprising the fuel control system, said method including the step of increasing the supply of the combustible material to the air supply in accordance with an increasing magnitude of the engine speed signal.

15           The method may further include the step of limiting supply of the combustible material to the air supply upon detection by the controller of a prescribed engine speed.

The method may further include the step of only supplying the combustible material to the air supply upon detection of boost from a turbocharger of the combustion engine.

20           The method may further include the step of preventing supply of the combustible material to the air supply upon detection of a prescribed upper temperature of a turbocharger of the combustion engine.

25           The method may further include the step of permitting supply of the combustible material to the air supply when the turbocharger has cooled to a prescribed lower temperature.

The method may further include the step of measuring oxygen levels in emissions from the combustion engine and adjusting the supply of the

combustible material to the air supply in response to said oxygen levels.

The method may further include the step of remotely adjusting a level of the first fuel supplied to the combustion engine depending on the supply of combustible material to the air supply.

5        According to a further form, the invention resides in a method of calibrating the fuel control system of claim 1 installed in a vehicle, wherein said calibration is executed over a communication network via the controller and a wireless communication device coupled to said controller, said vehicle situated in a first location and a processor performing said calibration situated in a second  
10    location remote from said first location.

The calibration method may further comprise deactivating a disabling device of said fuel control system prior to performing said calibration.

Further aspects of the present invention will become apparent from the following detailed description.

15

#### BRIEF DESCRIPTION OF THE DRAWINGS

To assist in understanding the invention and to enable a person skilled in the art to put the invention into practical effect preferred embodiments of the invention will be described by way of example only with reference to the  
20    accompanying drawings, wherein:

FIG 1 shows a schematic diagram of a first embodiment of the fuel control system of the present invention;

FIG 2 shows a schematic diagram of an air supply line for the fuel control system shown in FIG 1;

25        FIG 3 shows a simplified schematic diagram of the connectivity of a controller used in the present invention;

FIG 4 shows a table of measured engine and vehicle performance

parameters for a conventional truck engine not employing the system of the present invention;

FIG 5 shows a table of performance parameters measured for the same engine and vehicle as in FIG 4, but employing the system of the present invention;

FIG 6 shows the variation of wheel horsepower with engine speed for a conventional truck engine not employing the system of the present invention; and

FIG 7 shows the variation of wheel horsepower with engine speed for the same truck engine yielding the results shown in FIG 6, but employing the system of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention, a combustible material such as liquefied petroleum gas (LPG) is injected into an air supply line of a conventional diesel engine system to achieve improved engine performance and fuel consumption. The following description of the present invention is in the context of a fuel system and diesel engine typically found in trucks. However, it will be appreciated that the present invention may be applied to other types of combustion engines and fuel systems found in other vehicles, particularly vehicles employed in other heavy duty applications.

A schematic representation of a first embodiment of the system of the present invention is shown in FIG 1. The system comprises a source of combustible material in the form of a tank 2, a phase converter 4, a stepper motor 6, a metering valve 7, a controller in the form of a programmable logic controller (PLC) 8 (shown in further detail in FIG 3) and a plurality of valves, S1, S2 and S3.



In the case where the combustible material is LPG, the tank 2 stores a supply of international standard LPG, such as HD5, which comprises at least 95% propane. Alternatively, the tank 2 may store AAA grade marine quality propane. The LPG is to be mixed with a supply of air to the engine combustion chambers. The tank 2 comprises a standard, float-operated, auto fill-limiting valve (AFL), which is not shown in FIG 1, but is familiar to one skilled in the art. The AFL prevents the tank 2 from being filled beyond approximately 80% of its capacity. The AFL thus prevents over-filling of the tank 2 and allows for expansion of the LPG with increasing temperature. In the case of a truck application, at the approximately 80% fill level, the tank 2 may typically hold 250 litres of LPG. The tank 2 also comprises a standard gauge valve, which is not shown, but is familiar to one skilled in the art. The level of LPG in the tank 2 at any instant may be indicated to a driver in the truck cab by a standard LED indicator, the connection and operation of which is familiar to a person skilled in the art. The tank 2 further comprises a standard, mechanical pressure relief valve (not shown), which relieves any tank pressure in excess of a prescribed safe limit such as, for example, approximately 140 psi.

Valves S1-S3 may be standard solenoid valves used in vehicle applications. It should be appreciated that valves S2 and S3 are desirable, at least from a safety viewpoint. However, valves S2 and S3 are not essential for the functioning of the system and are therefore optional features of the present invention.

Delivery valve S1 controls flow of LPG from the tank 2 and its operation is dependent on the vehicle ignition. Valve S1 is closed and therefore prevents egress of the LPG from the tank unless the vehicle ignition is on. With the ignition on, valve S1 opens to allow the flow of LPG from the tank 2.

Operation of valves S2 and S3 are dependent on the controller PLC 8

detecting both a signal from the alternator (signal A in FIG 3) and an engine speed signal (signal ES in FIG 3). As described hereinafter in detail, the quantity of LPG injected into the air supply line 9 shown in FIG 2 is dependent on the engine speed. The engine speed may be determined by, for example, detecting the position of the accelerator pedal, although it will be appreciated by those skilled in the relevant art that engine speed may be determined in other ways. For example, the engine speed may be determined by detecting signals associated with a flywheel of the engine. Alternatively, the engine speed may be determined using a suitable positional sensor associated with a crankshaft of the engine.

In the absence of, for example, depression of the accelerator pedal, such as at idle, although an alternator signal (A) may be present, valves S2 and S3 are closed, thus preventing the flow of LPG beyond valve S2. At idle, it is desired that no LPG be injected into the air supply line 9. Depression of the accelerator pedal, irrespective of the amount of depression, produces an engine speed signal (ES) indicative of an above-idle engine speed that may determine a quantity of LPG to be injected into the air supply line 9. An engine speed signal (ES), in the presence of the alternator signal (A), opens valves S2 and S3 allowing flow of LPG therethrough.

Valve S2 also comprises a fine copper mesh filter, typically cylindrical in shape, of length approximately 2cm and of diameter approximately 1cm, through which the LPG passes. The LPG is unlikely to be clean and needs to be filtered to minimize impurities entering the phase converter 4. The LPG undergoes various chemical reactions with different materials it encounters at a refinery level, prior to introduction to the vehicle system. For example, the LPG reacts with materials from which LPG storage facilities are made, hoses, and other conduits through which the LPG passes, which produces various by-products

that separate during the change of state of the LPG from a liquid to a vapour. The impurities and by-products, which manifest themselves as a wax type residue, must be removed to prevent reductions in converter efficiency and engine damage.

5           With valve S2 open, LPG in the liquid phase, typically at a pressure of 150 psi, flows into the phase converter 4. The phase converter is preferably a negative (gas-on-demand) first stage regulator and heat exchanger that converts the LPG from the liquid phase to a vapour typically at 7 psi, by virtue of coolant at radiator temperature passing through a dedicated channel of the converter. A  
10   suitable negative converter would be an Elko E420 negative converter, but other models may be equally suitable. A positive converter could potentially be employed, although with a positive converter there is the possibility of vapour leakage when the LPG is not required. Overcoming this problem may require unfeasible valving, since by their nature, positive converters force gas into the  
15   engine.

          With the engine running at idle, when the accelerator pedal is depressed, valves S1-S3 are open allowing the passage of LPG vapour at 7 psi to a standard conical solenoid metering valve 7. A stepper motor 6 is connected to the conical solenoid metering valve 7, which moves an approximate distance of  
20   20mm from a fully closed to a fully open position. The stepper motor 6 has up to 256 steps/increments in which to traverse this distance, which takes the order of milliseconds. Alternative suitable stepper motor/valve arrangements capable of the same performance may be implemented in the present invention.

          Movement of the stepper motor 6 and therefore the metering valve 7 is  
25   controlled by the PLC 8 via a stepper motor interface, such as a driver controller 12 shown in FIG 3 and described in more detail hereinafter. The stepper motor/metering valve is re-zeroed and self-calibrated each time the ignition is

switched on. The stepper motor/metering valve regulates the flow of LPG vapour into the air supply line 9 prior to the turbocharger 10, shown in FIG 2, and thus regulates the percentage of LPG vapour in the air-LPG vapour mixture entering the combustion chambers of the diesel engine. Generally, as the accelerator is further depressed, thus increasing the engine speed, more LPG vapour is introduced into the air supply line 9.

A schematic ambient air intake 5 and air supply line 9 is shown in FIG 2. The LPG vapour is shown as being introduced via input 13 to the air supply line 9 after the vacuum intakes 11 (used, for example, for the braking system of the truck), but just before the compressor ambient air inlet 15 of the turbocharger 10. The LPG vapour easily mixes with air when drawn into the compressor of the turbocharger 10. Because of the density of the LPG compared with that of air and the point of introduction of the LPG in the air supply line 9, the LPG vapour does flow back along the air supply line 9, toward, for example, the vacuum intakes 11 and therefore does not contaminate any of the air dependent systems of the vehicle.

A schematic representation of the PLC 8 and its connections according to a first embodiment is shown in FIG 3. A suitable PLC is a 24v PLC manufactured by Mitsubishi, but other PLCs may be equally suitable for this application. Trucks used in various countries usually have 12v, 24v or 36v electrical systems and a 24v PLC makes the present invention easily adaptable to the various alternative voltages used. FIG 3 shows the inputs to, and outputs from, the PLC 8, which are as follows: (P) power; (ES) engine speed; (FB) foot brake; (IV) idle validation; (A) alternator; (CC) cruise control on/off; (CR) cruise control resume; (S1-S3) valves S1-S3; and (EB) engine brake (also known as a Jacob's brake). The outputs of the PLC 8 include four to the stepper motor driver controller 12 and control signals to the valves S2-S3.

In addition to the PLC 8 detecting a voltage representative of engine speed, such as the accelerator position, the alternator and the valves S1-S3, the PLC also monitors the various brakes, any cruise control activations/deactivations and an idle validation signal. The PLC repeatedly  
5 cycles to continually monitor each parameter.

The presence of an idle validation signal (IV) detected by the PLC confirms that no acceleration is taking place. This may be verified by the absence of an engine speed signal (ES) above idle.

Some, but not all trucks also have a cruise control setting. With cruise  
10 control activated, the driver is no longer required to depress the accelerator to maintain engine speed. However, according to one embodiment of the present invention, the amount of LPG vapour introduced to the air supply line 9 may be dependent on determining the accelerator position. Therefore, once activation of cruise control is detected, the percentage of LPG vapour being introduced to  
15 the air supply is fixed temporarily until cruise control is deactivated. Cruise control may be deactivated by an on/off switch in the truck cab, or by depressing the foot brake, or by activating the engine brake, any of which will be detected by the PLC 8. Once cruise control is deactivated, determination of the level of LPG vapour to be introduced is once again dependent on accelerator position.  
20 Detection of cruise control being resumed will also be detected by the PLC, which will again fix the LPG vapour percentage temporarily.

Four of the outputs from the PLC 8 are inputs to the stepper motor driver controller 12. The driver controller acts as the interface between the PLC and the stepper motor and tailors the signals from the PLC for control of the stepper  
25 motor 6, as would be familiar to a person skilled in the relevant art. It will be appreciated that if a different PLC is selected, the driver controller, or an equivalent control module, for the stepper motor may be incorporated in or

integrated with the PLC 8.

As previously stated, the amount of LPG vapour introduced into the air supply to the combustion chambers of the engine is metered by the stepper motor/metering valve in response to instructions from the PLC 8. As described  
5 above, metering is generally dependent on the engine speed, which may be determined by accelerator position (i.e. in the absence of cruise control). The accelerator position may be measured by a conventional switch or rheostat and the measured voltage is communicated to the PLC. The manner of achieving such accelerator position monitoring will be familiar to one skilled in the relevant  
10 art.

Engine speed may be detected by means of a voltage signal, the magnitude of which is representative of the engine speed. For example, at an idle engine speed of approximately 800 r.p.m., the voltage may be 0.5v. At approximately 1800 r.p.m., the voltage may be 5v. This will, of course, vary  
15 between different types of engines and between the same types of engines in different vehicles due to, for example, differences in engine performance and calibration. The PLC 8 may monitor the engine speed signal, for example, every 10 r.p.m.

For a typical truck diesel engine, in each cycle, approximately 14 litres of  
20 air are taken into the combustion chamber and compressed into which the diesel fuel is injected. At idle the engine is not under load and no LPG is introduced into the air supply line 9. At the other end of the engine operating range, for example, in the 1800-2000 r.p.m. range, the engine will be under substantially maximum load and a maximum percentage of LPG will be introduced into the air  
25 supply line. A maximum percentage of LPG in the air supply may be approximately 6-18%, but this will vary depending on the vehicle, the type of engine and the application. Therefore, with the present invention, at, for

example, 1800 r.p.m., approximately 10% of the supply may be LPG.

To avoid over-fuelling the engine, which could severely damage the engine and potentially be very dangerous, beyond approximately 1800 r.p.m. up to the maximum engine speed, the percentage of LPG introduced to the air supply does not increase with engine speed. In one embodiment, the percentage of LPG is reduced beyond 1800 r.p.m. as a safety measure to ensure the engine is not over-fuelled. This is controlled by the PLC 8, but may also be achieved with a conventional limiting switch, the installation and operation of which is familiar to one skilled in the art. At approximately 1800 r.p.m., for example, the engine may be consuming the maximum amount of diesel and no further increase in air/LPG is required.

Between idle and approximately 1800 r.p.m., the percentage of LPG introduced to the air supply may increase linearly with the increase in engine speed. As the voltage detected from, for example, the accelerator pedal increases, the stepper motor 6 increases the conical valve aperture proportionally and precisely by virtue of the 256 increments that it may utilize between fully open and fully closed positions, thus proportionally increasing the LPG flow. As the accelerator pedal voltage decreases, the reverse occurs. However, it is envisaged that under certain driving conditions, the relationship between engine speed and LPG percentage may be non-linear.

Since the response time of the system of the present invention is of the order of milliseconds, the percentage of LPG being introduced to the air supply is synchronized with the demand therefor. The stepper motor/metering valve are positioned as close as possible to the end of the LPG supply line, as shown in FIG 1, to ensure that when the LPG supply is cut off, there is minimal LPG remaining in the conduit between the metering valve 7 and the turbocharger intake 15.

The present invention improves the performance of a vehicle by improving volumetric and thermal efficiency and the combustion rate. (Other benefits include the eradication of localized burning (spotting) and the minimization of fuel burning in the manifold.) The result is that a higher engine  
5 horsepower is achievable, by virtue of the combustion of the fuel being closer to complete than conventional diesel engines. Therefore, to achieve the same power as an engine without the system of the present invention, less diesel is required, thus improving diesel fuel efficiency. Furthermore, the power band of the engine is reached sooner than would be the case with only air being  
10 introduced to the combustion chambers. The result is a torque curve with a steeper slope, indicating that the power band is reached sooner, and a flatter curve to the right the slope, indicating that higher engine horsepower is reached sooner and thus maintained for a longer period.

A more quantitative comparison between the same engine and vehicle  
15 with and without the present invention will now be described.

FIGS 4 and 5 show tables of measured engine and vehicle performance parameters without and with the present invention respectively. The engine tested was a Caterpillar® C-15 air to air after-cooled, direct injection diesel engine and the vehicle configuration was a Fuller – RTLQ20918B manual  
20 transmission with two drive axles and an axle ratio of 4.56. The weight on the axles was 8000 kg and radial tires with a highway tread were used.

It can be seen from, for example, the corrected wheel horsepower values, that, at a given engine speed, the corrected wheel horsepower is increased by virtue of the present invention and the fuel consumption rate figures are  
25 decreased for a number of engine speeds. The wheel horsepower variations with engine speeds are depicted in FIGS 6 and 7.

Further features of the present invention will now be described.



Combustion of the diesel is more efficient when the diesel is at a cooler temperature. At cooler temperatures the diesel is denser than at higher temperatures, causing improved combustion per injection cycle. Temperature and viscosity of the diesel are also relevant factors in relation to the spray  
5 pattern of the diesel achieved by injector nozzles of the engine and the avoidance of injector seizure.

In many diesel engines, the engine body will heat any excess diesel not injected into the combustion chamber and the heated excess diesel is re-circulated back to the diesel tank. The energy of the heated excess diesel is  
10 transferred to the diesel in the tank, thus raising the temperature of the diesel supply to the engine. Consequently, efficiency is reduced and to an increasing degree with increasing journey lengths/times, since the engine body temperature initially increases with journey length/time.

The Applicant has identified a solution to this problem of running the  
15 heated excess diesel to be re-circulated back through the converter 4 en route to the diesel tank. This has the advantage of cooling the fuel before it returns to the tank and the additional benefit of contributing to the heating of the LPG en route to the metering valve 7. Furthermore, since diesel does not freeze at the low liquid LPG temperature, the converter is prevented from freezing up when  
20 the LPG passes through the converter. A yet further advantage is that the passing of diesel through the converter prevents corrosion of the converter.

In order for the converter to perform the above function the Applicant has identified the need to replace a conventional rubber diaphragm in the converter with a diaphragm of diesel-impervious material, such as Nitrile rubber, otherwise  
25 the diaphragm would fail. The diaphragm is placed between a main back plate and a secondary plate of the converter 4 and forms the seal for the coolant jacket. The main back plate and the secondary plate are common features of a

conventional converter that would be familiar to a person skilled in the relevant art. The diaphragm acts as an insulator in that it prevents the heat in the returning diesel from being transferred to the metal casing of the converter and thus wasted. It also ensures that the heat exchange process between the  
5 returning heated diesel and the cooler LPG flowing through the adjacent chamber in the converter is optimized. Using the modified converter in the aforementioned manner further improves the performance of the system of the present invention.

Another aspect of the present invention relates to the activation,  
10 calibration and optimization of the system in a vehicle.

Once the present invention has been installed in a vehicle, such as a truck, the system is then calibrated for that particular engine/vehicle and may then be optimized to achieve maximum efficiency. This will involve, for example, setting the PLC to the voltage levels for each parameter being measured, setting  
15 the percentage levels of LPG to be introduced to the air supply according to engine speed and calibrating the stepper motor accordingly.

This may be done using a processor, such as, for example, a conventional laptop computer with the appropriate software and physical connections to the PLC 8. The individual/user performing the activation,  
20 calibration and optimization may be present at the same location as the vehicle. Activation, calibration and optimization may be carried out with the vehicle stationary, on a rolling road or moving along a highway, depending on the operations being performed.

Alternatively, and preferably, activation, calibration and optimization may  
25 be carried out remotely. With reference to FIG 3, this may be achieved by coupling a wireless communication device 17, such as a conventional mobile telephone or wireless capable personal digital assistant (PDA) or the like, to the

power supply of the PLC 8 and to the PLC. The wireless communication device 17 may be connected to a transmitter/receiver 19 external to the vehicle for improved transmission/reception. The transmitter/receiver may additional to or be combined with a compact satellite dish to facilitate tracking of the vehicle.

- 5 The contact number of the wireless communication device 17 acts not only as a means of contacting the device, but also as a unique identifier for the system installed in the vehicle.

Once the system of the present invention has been installed, preferably by a previously approved technician, the technician may inform the individual performing the calibration and optimization that this has been done. The system may further comprise a disabling device that prevents the system being used until the individual performing the calibration is contacted and the individual deactivates the disabling device. The disabling device may comprise a security measure such as the requirement to enter one or more codes to activate the system. In particular, the PLC 8 may be disabled by the disabling device prior to activation.

Once the technician has contacted the individual, the individual may then perform the activation, calibration and optimization remotely and in real time by virtue of the communication device 17 and the PLC 8. Communication between the communication device and the PLC 8 may be via a short-range communication protocol such as Bluetooth™. This may again be carried out with the vehicle stationary, on a rolling road or moving along the highway, depending on the operations being performed. Hence, installation of the system may be performed anywhere in the world, without the necessity of the individual performing subsequent activation, calibration and optimization being in the same location as the installed system.

This feature of the present invention enables the base to download data

about the operation of the fuel control system from the vehicle and, for example, remotely modify the LPG percentages and or diesel percentages in the mixture for particular applications. For example, in an outward journey for a truck pulling a trailer, the trailer may comprise a particularly heavy load, which may require a higher proportion of LPG to be introduced to the air supply. The stepper motor and voltages and the like can be re-calibrated remotely, as described above, to provide a higher percentage of LPG at lower engine speeds to provide more power. Conversely, the return journey may comprise a much lighter load requiring a lower percentage of LPG to be introduced. Modification of the LPG percentages may be carried out by controlling injectors of the LPG, of which there will be at least two for V8 engines. Variation of the LPG injection may be in accordance with a control scheme comprising key adjustable parameters that may be varied remotely or via a locally connected processor as described above.

The system may comprise more sensors to enable monitoring of various parameters of the vehicle, truck, trailer, or even driving characteristics of the driver. These parameters will also be available to the base remotely monitoring the vehicle. Sensors may be mounted at various locations to monitor parameters such as, but not limited to, axle weights, total load, road speed, engine revolution rates, gear changes and other temperatures and pressures.

One such sensor is a turbo boost sensor that detects boost from the turbocharger 10. The turbo boost sensor is coupled to the PLC 8 and turns on the LPG injectors only when a boost from the turbocharger is detected. Therefore, LPG is only injected when the engine is under load and requires it and not during periods such when the vehicle may be rolling downhill.

Another sensor that may be fitted is a pyrometer to monitor the temperature of the turbocharger 10. Since most turbochargers have a maximum operating temperature usually prescribed by the manufacturers, when this

prescribed temperature is detected, injection of LPG is suspended. This allows the turbocharger to cool down to a lower prescribed temperature before further LPG injection can commence and reduces the risk of overheating and blowing the turbocharger.

5           A yet further sensor is an oxygen sensor to detect oxygen levels in the exhaust emissions. The oxygen sensor will provide an indication of the burn efficiency of the diesel and the LPG and enable the consumption of both LPG and diesel to be varied to improve efficiency.

10           Another example of temperature monitoring is with the system of the present invention installed in a truck pulling a refrigerated trailer. A temperature sensor in the trailer or coupled to a refrigeration unit of the trailer could detect whether or not the refrigeration unit has been switched on. If not, an alarm/indicator could be raised at the base and the driver alerted to rectify the situation.

15           The system may further include a data logger that stores all data about engine and vehicle performance being monitored for a prescribed period, e.g. 30 days. In the event of an engine failure, the stored data will aid with diagnosing the cause. Access to the data is preferably restricted by a password protected interface and is preferably limited to direct rather than remote access to prevent  
20   tampering of the data.

          According to another embodiment, the LPG may be injected under higher pressure, e.g. at about 50 psi, into the high-pressure side of the diesel engine air inlet downstream of the turbocharger 10, thus bypassing the turbocharger. In this embodiment, a modified LPG phase converter 4 is clearly required.

25           The system of the present invention may be added to any conventional diesel engine to improve the efficiency of the engine and the LPG tank may be easily added to any vehicle. Where a vehicle has a plurality of diesel fuel tanks,

such as with trucks, the volume occupied by one of the diesel tanks may be reduced and replaced with the LPG tank or part thereof.

The Applicant has identified that the present invention is not limited to the introduction of LPG into the air supply of a diesel engine. Other gases that  
5 perform the same or an improved combustion function may be employed. For example, the Applicant has identified that methane could be used instead of LPG. Methane could be compressed and liquefied in accordance with conventional techniques and stored in the tank 2. However, due to the low temperature storage requirements of the liquefied methane, the tank 2 needs to  
10 comprise insulation means such as a vacuum to maintain the state of the liquefied and compressed methane. This may be achieved by inserting a cylinder of smaller diameter than that of tank 2 substantially concentrically within the tank and using the known Pearlite vacuum insulation method.

The Applicant envisages that the PLC 8 may be connected to an engine  
15 control manager (ECM) for the engine in order to, for example, modify and optimize injection of the diesel into the combustion chambers in accordance with introduction of the LPG into the air supply line 9.

Throughout the specification the aim has been to describe the invention without limiting the invention to any one embodiment or specific collection of  
20 features. Persons skilled in the relevant art may realize variations from the specific embodiments that will nonetheless fall within the scope of the invention.

## CLAIMS:

1. A fuel control system for controlling supply of a mixture to a combustion engine, said mixture comprising air, a first fuel and at least one other combustible material, said system comprising:
  - 5 a controller;
  - a first valve allowing egress of said other combustible material from a source thereof in response to a first activation signal;
  - a metering valve regulating supply of said combustible material into an air supply of said combustion engine;
  - 10 a phase converter located between, and being in fluid communication with, said first valve and said metering valve, said phase converter allowing passage of said other combustible material therethrough;
  - wherein, in response to an engine speed signal received by said controller, said controller regulates supply of said other combustible material into said air supply via said metering valve.
  - 15
2. The fuel control system of claim 1, further comprising a second valve located between said first valve and the phase converter and a third valve located between the phase converter and the metering valve, said  
20 second and third valves allowing passage of the combustible material therethrough respectively in response to detection by the controller of a second activation signal and the engine speed signal.
3. The fuel control system of claim 1, wherein the combustion engine is a  
25 diesel engine.
4. The fuel control system of claim 1, wherein the first activation signal is a

voltage signal detected when an ignition is switched on.

- 5 5. The fuel control system of claim 2, wherein, the second activation signal is a voltage signal detected from the alternator.
6. The fuel control system of claim 2, wherein the first, second and third valves are electrically operated solenoid valves.
- 10 7. The fuel control system of claim 1, wherein the phase converter is a negative (gas-on-demand) first stage regulator and heat exchanger.
8. The fuel control system of claim 1, wherein the first fuel for the combustion engine is passed through the phase converter.
- 15 9. The fuel control system of claim 1, wherein the metering valve is connected to the controller via an electrically operated stepper motor, said stepper motor operating the metering valve.
- 20 10. The fuel control system of claim 9, wherein the stepper motor is re-zeroed and recalibrated each time an engine ignition is switched on.
11. The fuel control system of claim 1, wherein the controller is a programmable logic controller (PLC).
- 25 12. The fuel control system of claim 1, further comprising a plurality of sensors to enable the controller to detect signals from one or more of: a foot brake, an engine brake, cruise control activation/deactivation, cruise



control resumption, an idle validation signal.

13. The fuel control system of claim 1, wherein the combustible material is liquefied petroleum gas (LPG).

5

14. The fuel control system of claim 1, wherein the combustible material is methane.

10

15. The fuel control system of claim 1, wherein the phase converter includes a diaphragm comprising fuel-impervious material.

16. The fuel control system of claim 15, wherein the fuel-impervious material is nitrile rubber.

15

17. The fuel control system of claim 1, further comprising a turbocharger and a sensor to monitor a temperature of the turbocharger.

18. The fuel control system of claim 1, further comprising an oxygen sensor to monitor levels of oxygen in emissions from said engine.

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19. The fuel control system of claim 1, further comprising a wireless communication device coupled to the controller to enable at least remote calibration of the fuel control system.

25

20. The fuel control system of claim 19, wherein the wireless communication device enables remote monitoring of parameters associated with the fuel control system.

21. A method of controlling a combustion engine comprising the fuel control system of claim 1, said method including the step of increasing the supply of the combustible material to the air supply in accordance with an increasing magnitude of the engine speed signal.
22. The method of claim 21, further including the step of limiting supply of the combustible material to the air supply upon detection by the controller of a prescribed engine speed.
23. The method of claim 21, further including the step of only supplying the combustible material to the air supply upon detection of boost from a turbocharger of the combustion engine.
24. The method of claim 21, further including the step of preventing supply of the combustible material to the air supply upon detection of a prescribed upper temperature of a turbocharger of the combustion engine.
25. The method of claim 24, further including the step of permitting supply of the combustible material to the air supply when the turbocharger has cooled to a prescribed lower temperature.
26. The method of claim 21, further including the step of measuring oxygen levels in emissions from the combustion engine and adjusting the supply of the combustible material to the air supply in response to said oxygen levels.

27. The method of claim 21, further including the step of remotely adjusting a level of the first fuel supplied to the combustion engine depending on the supply of combustible material to the air supply.

5

28. A method of calibrating the fuel control system of claim 1 installed in a vehicle, wherein said calibration is executed over a communication network via the controller and a wireless communication device coupled to said controller, said vehicle situated in a first location and a processor performing said calibration situated in a second location remote from said first location.

10

29. The method of claim 28, further comprising deactivating a disabling device of said fuel control system prior to performing said calibration.

15

20

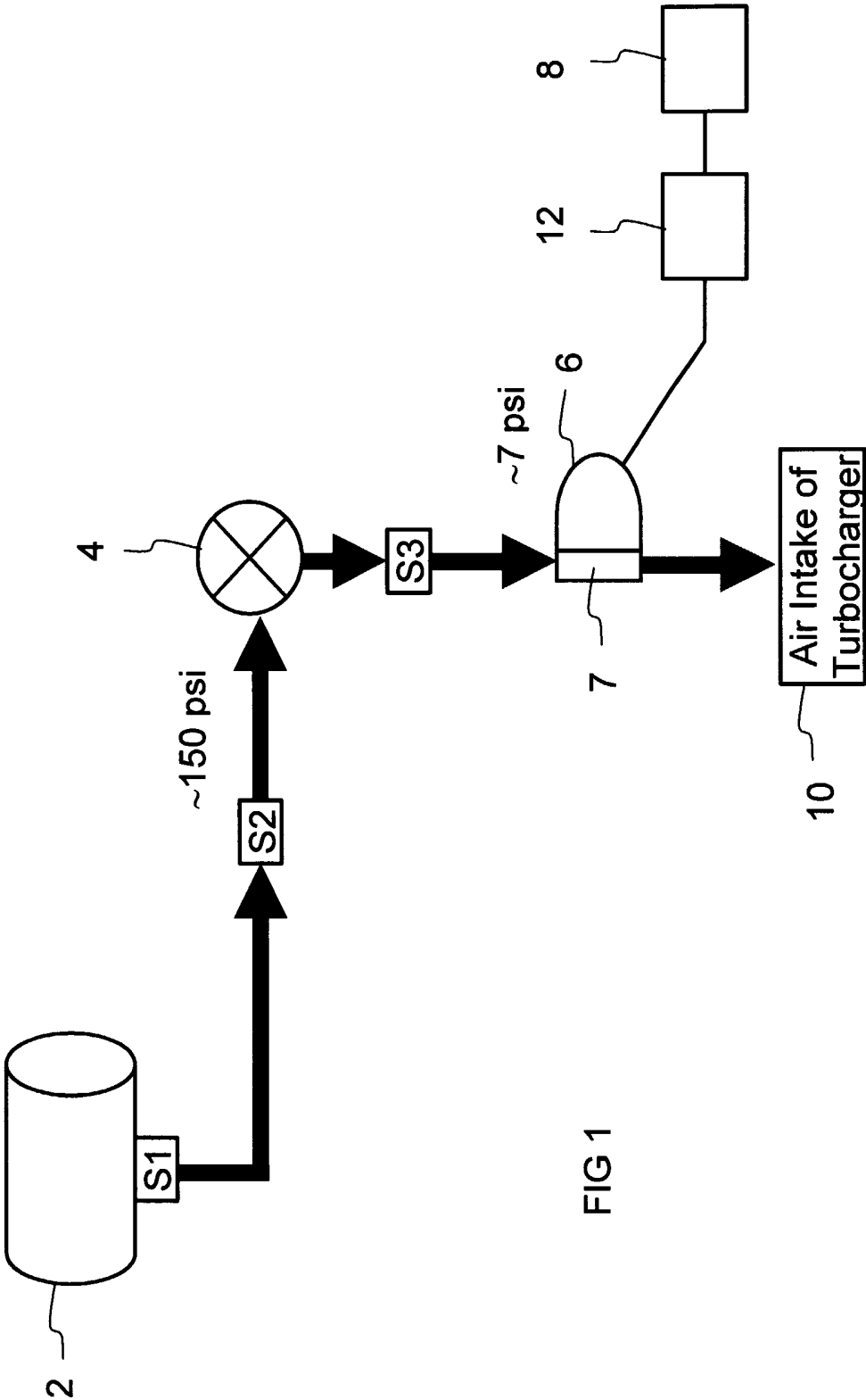


FIG 1

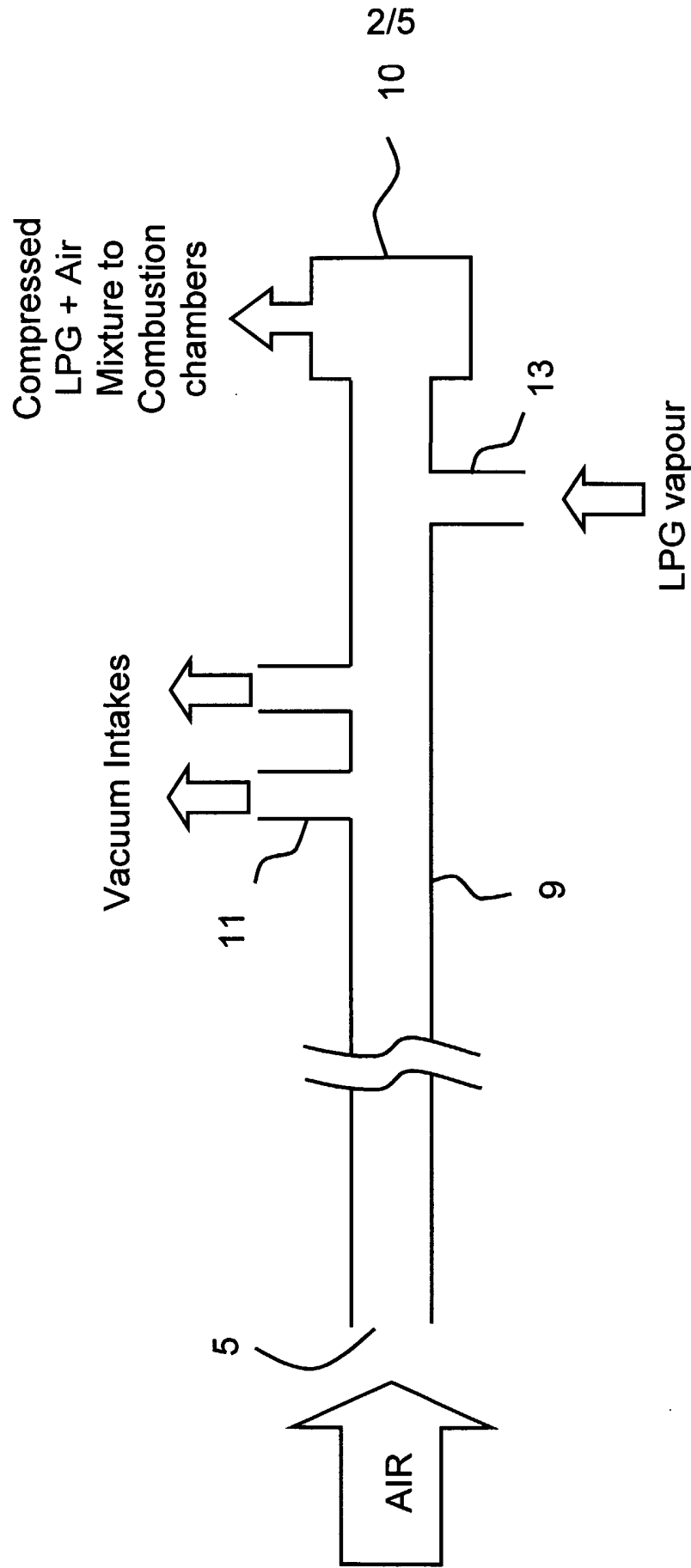


FIG 2

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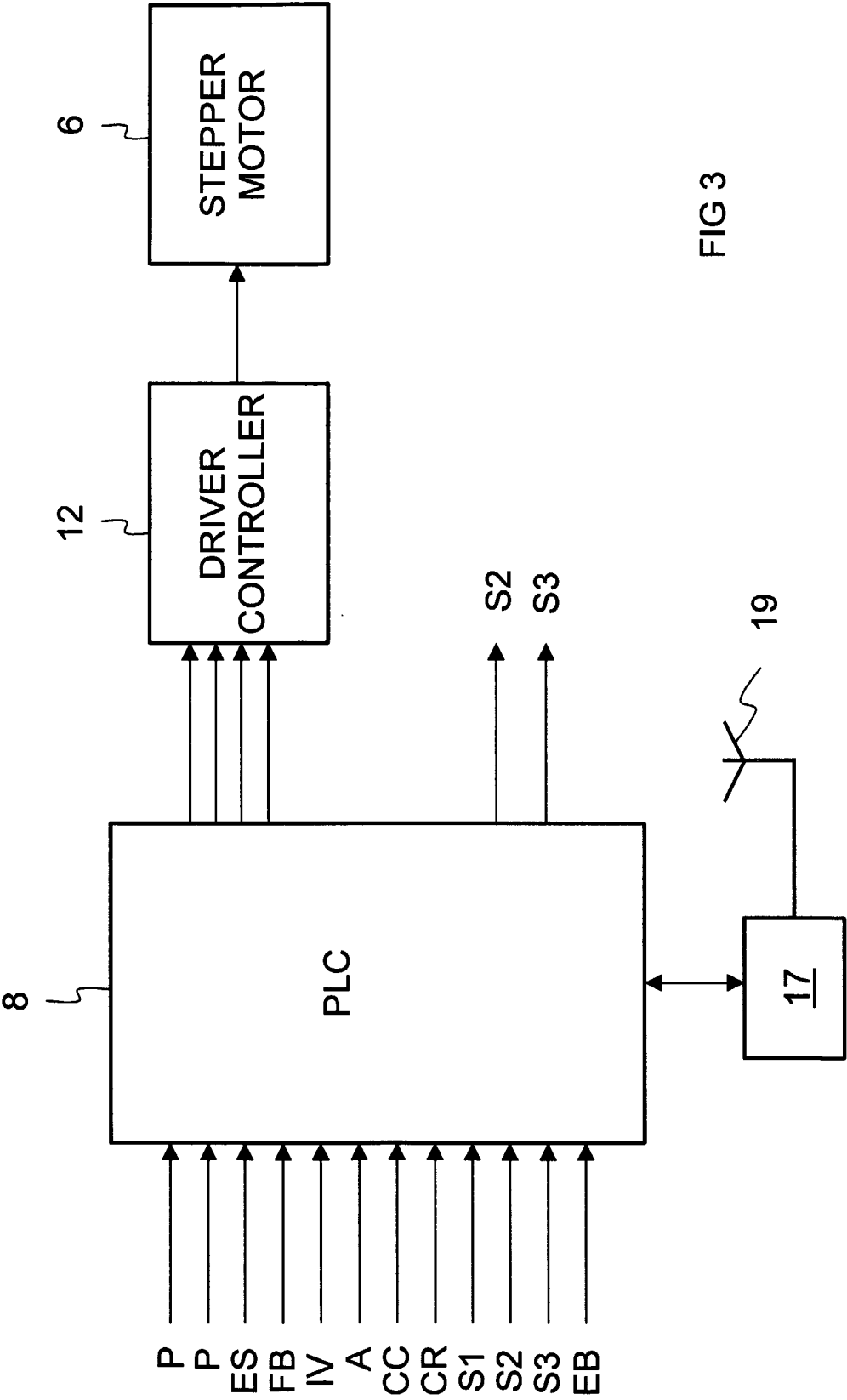


FIG 3

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	Gov. speed	1st Log	2nd Log	3rd Log	4th Log
Engine speed (RPM)	2100	1801	1595	1401	1166
Vehicle speed (MPH)	55	45	42	37	31
Fuel rate (GPH)	26.0	27.5	26.8	23.4	19.6
Manifold Pressure ("Hg)	47.5	54.2	55.1	49.1	41.5
Fuel Pressure (PSI)	92.8	90.6	89.1	87.6	83.8
Fuel Temperature (°F)	76	75	73	70	68
Air Temperature (°F)	134	138	129	117	103
Engine HP	540	575	581	518	441
Corrected HP	535	588	573	509	433
Wheel HP - measured	433	489	494	448	383
Wheel HP - corrected	438	493	495	444	376
Inlet Air Restriction	-12.7	-11.2	-9.4	-7.0	-4.5

FIG 4

	Gov. speed	1st Log	2nd Log	3rd Log	4th Log
Engine speed (RPM)	2098	1802	1601	1395	1186
Vehicle speed (MPH)	55	48	42	37	31
Fuel rate (GPH)	25.5	28.5	26.2	22.3	19.4
Manifold Pressure ("Hg)	48.5	55.2	57.1	51.0	42.0
Fuel Pressure (PSI)	92.0	89.7	89.3	87.8	81.3
Fuel Temperature (°F)	111	108	99	92	87
Air Temperature (°F)	112	108	92	92	75
Engine HP	522	584	583	487	432
Corrected HP	535	588	570	490	433
Wheel HP - measured	488	524	528	478	400
Wheel HP - corrected	490	535	539	474	392
Inlet Air Restriction	-12.4	-12.0	-10.1	-8.9	-4.3

FIG 5

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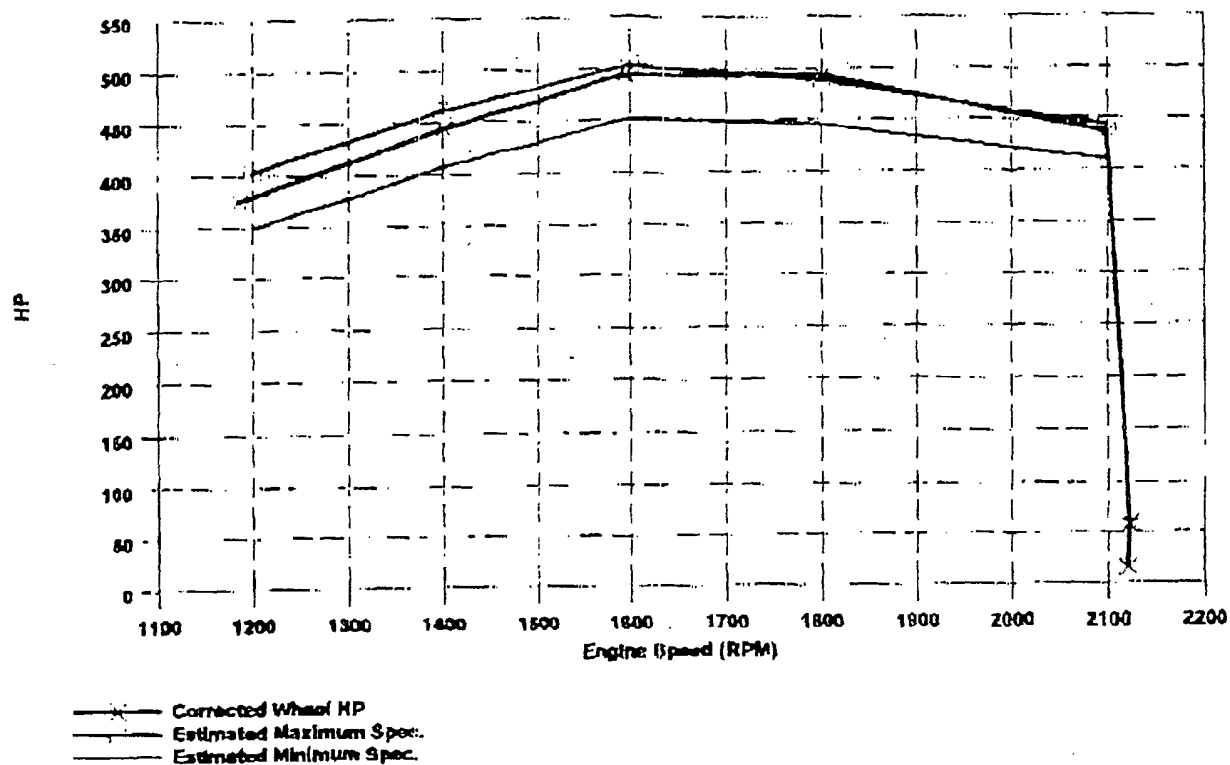


FIG 6

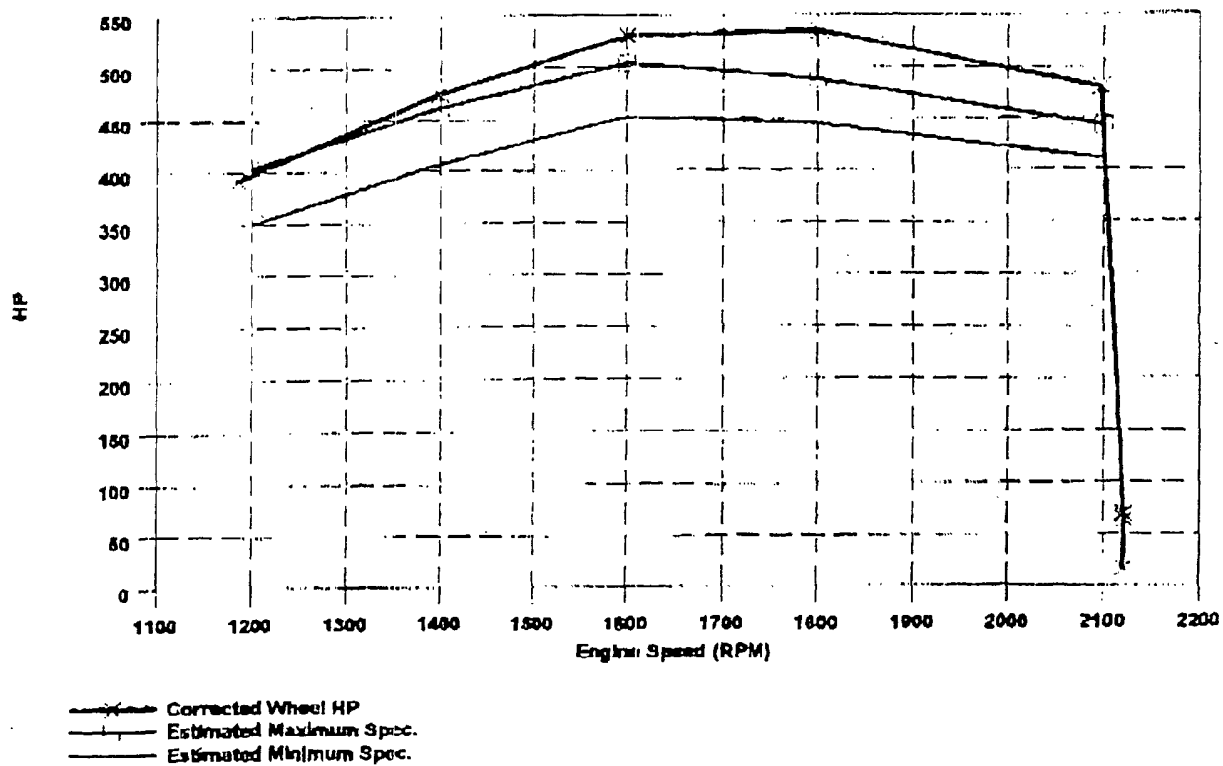


FIG 7



# INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU02/01637

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. <sup>7</sup>: F02M 21/02, F02D 19/08

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)

Refer electronic database consulted below

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 21/-, F02D 19/-, F02B 43/00, 69/04 and keywords speed and engine

## 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 5937800 A (BROWN et al) 17 August 1999 Whole document	1-18, 21-27 19-20, 28-29
X	GB 2166267 A (GASPOWER INTERNATIONAL LIMITED) 30 April 1986 Whole document	1-18, 21-27
X	CA 1203132 A (LAING et al) 15 April 1986 Whole document	1-18, 21-27

☒ 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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

11 February 2003

Date of mailing of the international search report

20 FEB 2003

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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU02/01637

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5370097 A (DAVIS) 6 December 1994 Whole document	1-18, 21-27
X	US 4641625 A (SMITH) 10 February 1987 Whole document	1-18, 21-27
X	US 4505249 A (YOUNG) 19 March 1985 Whole document	1-18, 21-27
Y	US 6151549 A (ANDREWS et al) 21 November 2000 Whole document	19-20, 28-29
Y	WO 92/09957 A1 (WEBER USA INC) 11 June 1992 Whole document	19-20, 28-29
<p><b>NOTE:</b> For the "Y" category documents, US 5937800 can be combined with either one of the other two "Y" category documents.</p>		

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/AU02/01637**

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	5937800	EP	980468	WO	9945253		
GB	2166267	AU	49556/85	BR	8507021	CA	1270162
		CN	85107926	DK	2702/86	EG	17400
		EP	197080	ES	547768	ES	8609597
		FI	862383	GR	852435	IN	166277
		MX	158582	NO	862301	NZ	213778
		US	4641625	WO	8602407	ZA	8507544
US	5370097	AU	65228/94	EP	690957	WO	9421911
US	4505249	CA	1227976	EP	165354	JP	60230528
		US	4597364				
US	6151549	US	5983156				
WO	9209957	AU	90811/91				
END OF ANNEX							