Multiple Fuel Vehicle

In multiple fuel vehicles it is generally the case that the petrol vehicle is modified to handle gas fuel by bolting on a large gas tank in the interior of the vehicle and duplicating controls with an additional gas inlet manifold to allow the vehicle to operate with these fuels.

This substantially increases costs as well as significantly reducing the available space within the vehicle.

The present invention is concerned with providing a fully integrated arrangement which does not reduce usable passenger or boot (trunk) space within the vehicle and is cost effective whilst meeting operational, performance and range requirements.

According to the invention there is provided a vehicle including engine means capable of operating on both gas fuel and liquid fuel, common inlet manifold means connected to the engine and including a plurality of gas fuel injectors mounted therein and a plurality of liquid fuel injectors mounted therein, a gas tank and a liquid fuel tank mounted beneath the vehicle floor external of

the passenger and boot compartments, and control means for controlling operation of the vehicle in both gas and liquid fuel modes such that the gas fuel is automatically selected dependent on engine speed and load when driving conditions replicate urban/city driving.

Further according to the invention there is provided a vehicle control device for controlling a gas and liquid fuelled vehicle including speed sensing means for sensing engine speed, air pressure sensing means for sensing engine load, means for automatically selecting gas fuel or petrol fuel dependent on sensed sped and pressure information, means for continually reassessing the selected fuel and means for means for automatically changing fuel utilisation where load and speed measurements require it.

Still further according to the invention there is provided a method of controlling a gas and liquid fuelled vehicle including the steps of sensing engine speed, sensing air pressure to determine engine load, automatically selecting gas fuel or petrol fuel dependent on sensed speed and pressure information, continually reassessing the selected fuel and automatically changing fuel utilisation where load and

speed measurements require it.

According to a further aspect of the invention there is provided a common inlet manifold for a multiple fuel vehicle engine including an air inlet duct for supplying air to cylinders within the engine, a port on the manifold for receiving each of a plurality of gas fuel injectors, a port on the manifold for receiving each of a plurality of liquid fuel injectors and a mounting flange on the manifold for mounting the manifold on the engine block.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows the integrated gas and liquid fuel systems in the bi-fuel vehicle;

Figure 2 shows a front sectional view from one end through the inlet manifold of Figure 1;

Figure 3 shows a part-sectional view of the inlet manifold, with associated passages, from the side;

Figure 4 shows the mechanism relating to speed and load utilised to automatically determine whether gas or liquid fuel is utilised; and

Figure 5 shows the arrangement for gas refuelling of the vehicle using the on-board compressor.

In a petrol vehicle an engine management arrangement including an electronic control unit (ECU) controls fuel injectors' which ECU thus controls the fuel intake for given speeds and loads, by utilising vehicle sensors and actuators at various points within the vehicle.

Where bi-fuel capability is required, as now described, compressed natural gas is utilised in addition to the petrol (gasoline) or diesel liquid fuel. In the arrangements to be described the gas is automatically selected under ECU control for urban/city driving. In these arrangement petrol will automatically be used for higher performance driving such as at high speeds, or when the stored gas is depleted. The ECU to be described has the capability to automatically control the gas or petrol utilisation which can be switched without noticeable affect to the driver.

The arrangement of Figure 1 shows such a bi-fuel vehicle 100 with the additional capability of gas refuelling with on-board compression and control. The vehicle includes an engine block 7 with both petrol injectors 2

and gas injectors 6 mounted on an inlet manifold 3. In addition to accommodating the injectors 2 and 6 the manifold will accommodate the suction intakes from the brake servo, petrol tank vapour canister discharge, engine crankcase ventilation and the like. The manifold is described in more detail below. A throttle 5 regulates the air intake to the engine under the control of the ECU 4.

Gas will pass from the cylindrical gas tank 27 through pipe 16 via regulator 20 to the injectors 6 and petrol will pass from petrol tank 8 through pipe 15 to injectors 2. The petrol tank 8 is refilled via filler point 14.

The gas stored in tank 27 is at high pressure (typically 200 bar) and this is obtained from a low pressure source, typically a domestic natural gas source 17 at 1 bar and is made available to the vehicle via a low pressure quick release hose 12 coupled to the gas filling point 13 mounted on the vehicle. This low pressure gas passes through hose 36 and is converted into high pressure via the compressor 28 mounted in the region of the gas tank 27. The compressor is operated using vehicle power as described in more detail below.

The petrol tank 8 at least partially surrounds the gas tank 27 to act as impact buffer and to provide dual fuels storage from a compact source of storage. The gas tank could typically have a capacity of 17 litres and the petrol tank a capacity of 50 litres. Other combinations of capacity can be employed to replicate capacity for a given vehicle based on the overall size of the space available beneath the vehicle.

The hybrid tank 20 formed by tank portions 8 and 27 will fit within the space which would have been occupied by a standard petrol only tank, so no extra space is required internally or externally of the vehicle interior.

The petrol region 8 of the hybrid tank 20 includes a concave well or recess 26 for receiving the cylindrical gas tank 27. The resilient nature of the moulded tank 8 allows the wall portions 22 and 23 to grip the inserted gas tank 27 (in a jawlike action). The tank 8 serves as a buffer to any impacts in use.

Normal tank fixing points can be retained for the hybrid tank that would have been used for a petrol only tank.

The petrol capacity will be substantially retained and the volume displaced by the gas tank will only cause a

small reduction in the combined fuel range. This will provide the optimum fuel density, for the 'gas + petrol' operation, within the permissible space. The small cylindrical gas tank is of sufficiently robust construction to store the pressurised gas in a quantity useful for small day to day journeys. This capacity could provide 30-40 miles of travel, the tank being replenished every day.

Although the liquid fuel is described as petrol, it could be diesel or other liquid hydrocarbon fuel.

The gas tank 27 may be made from steel either in heavyweight section or alternatively of lightweight section for reduced cost and mass. The latter is assisted by relying on the underlying protection afforded by the petrol tank. Non metallic tanks could be employed using a non permeable polyethylene liner fully wrapped with carbon fibre. An important consideration with non metallic reinforced tanks is that they will expand and contract with changing internal gas pressure and are more vulnerable to impact damage if knocked. The configuration of the tanks assists in protecting the gas tank from impact damage whilst allowing some expansion of the gas tank to be accommodated.

Although more costly, non metallic tanks are more lightweight and less vulnerable to corrosion. The small capacity of tank 27 helps to keep this cost down.

The ECU 4 is configured to provide two main modes of operation. The first is to control the provision of vehicle power using petrol as the fuel. The second is to control the provision of vehicle power using gas as the fuel. In addition the ECU can be utilised to control the provision of vehicle power to drive a compressor refuelling sequence. This operation is described in more detail in our copending patent application with the title 'Vehicle Engine Management'.

In the ECU 4, when used for petrol vehicle control, the device receives information from vehicle sensors and uses this information to control the petrol injectors. The ECU determines the flowrate of air via the throttle and the correct amount of petrol for each cylinder intake stroke dependent on sensed information. The quantity of fuel is determined from stored information, known as mapping or calibration, of the engine speed and load, temperature, throttle position, ignition timing, air/fuel ratio, exhaust emissions and other powertrain sensors specific to the model of engine fitted.

Such an ECU arrangement 4 is shown in more detail in Figure 2 and includes a control/processor 72 and an associated storage area 73. The control 72 together with stored mapping controls the petrol injectors 2 via electric connections 19. The throttle has the electrical connection 43. The known engine sensors, including engine speed sensing, mentioned above are shown collectively as being received by input 78.

In the present vehicle, however, two other operations are envisaged and to keep down costs and size as well as to maximise control effectiveness, these have been incorporated into the same ECU 4, by the provision of additional storage areas 74 and 75 and an extended programming control. The same control 72 (e.g. a microprocessor) can be utilised for all three functions. For the sake of simplicity any interfacing for the sensors and power output stages for actuating the controls are omitted.

For gas operation, the petrol injectors 2 are no longer used in this mode and the gas injectors 6 come into play. The gas supplied to the injectors will typically be at a pressure of 7 bar, having been reduced from the tank pressure via the regulator 20 (of Figure 1).

The gas injectors operate in a similar manner to the petrol injectors, but the amount of gas fuel mixing with the air will be different for the same set of circumstances. To accommodate this change, a separate mapping store 74 is provided. The existing engine sensors can be employed to provide intelligence on conditions to allow the gas mapping to be effective. Hence the throttle position will be different but the throttle position sensor 26 will provide an output via electrical cable 83 to the control 72. The injectors 6 will be pulsed to open a needle valve therein against spring pressure using an internal electromagnetic coil within the injector housing via control cable 19.

The control 72 can be programmed to make the decision as to which fuel is the most appropriate and this can be determined from sensed parameters such as load, speed and fuel capacity remaining. As an alternative to throttle speed sensor 26, a manifold pressure sensor 76 is shown connected to ECU 4 via lead 77 which will provide a reading of the pressure (partial vacuum) indicative of the load relating to the density of air in the manifold. Sensor 27a is provided to supply information to the ECU on gas pressure indicative of volume in the tank 27 via cable 82.

The ECU will make use of the absolute manifold pressure indicative of load (dependent on throttle opening) together with engine speed information to determine whether gas or petrol is the most appropriate fuel at that moment. This is achieved using the mechanism shown in Figure 4.

The vertical coordinate P indicates the absolute level of manifold pressure of the vehicle and the horizontal coordinate S indicates the engine speed. The area within which the engine will operate is shown within the boundary A. Thus point D indicates the manifold pressure for that vehicle which is measured to occur at wide open throttle. Point E indicates the maximum engine speed designated for the vehicle.

In a petrol only vehicle, the whole area bounded by A would have settings for all operations. However, in the gas and petrol vehicle of the present invention, a unique area C is incorporated for gas only operation, the area B being reserved for petrol operation.

Thus the volumetric throughput of the engine defined by the speed/pressure relationship will indicate the

appropriate operational area for the vehicle.

Urban driving is the most appropriate for gas utilisation, both in terms of expected loads and speeds and in terms of the cleaner fuel.

The device selects the gas operation within the urban driving profile equivalent to that within area C. Hence the maximum speed point F for gas operation could be in the region of 2500 rpm. The manifold pressure maximum point G for gas could in practice correspond to that given by a 60% throttle opening, for example. An engine idle speed for the vehicle could be 800 rpm.

In the ECU 4, any particular combination of low speed and low pressure will cause a particular location within the gas map memory store 74 to be accessed and the appropriate engine management settings therein will be output to control the operational settings of the gas injectors 6, for example, via the controller 72 of the ECU (see Figure 2).

At higher speeds or loads, the store 73 is accessed at a particular location to look up stored information so that engine management settings therein will be output to control petrol injectors 2.

Hence the configuration provides seamless operation including changeover from gas to petrol without any intervention by the driver.

Although the operational areas of figure 4 are shown as rectangular, in practice the boundaries used could be of other shapes to reflect the particular handling capabilities of a given engine/vehicle. Thus some parts of the gas area shown could in practice be within the petrol boundary.

It is also possible for the ECU 4 to include a lapsed time loop using the processor 72 control to ensure that rapid excursions from the gas region to the petrol region do not immediately trigger petrol utilisation until the need is sustained.

The ECU could also be programmed to switch from gas to petrol over several engine revolutions, so that at changeover, some cylinders will be operating on gas whilst others are operating on petrol during the changeover phase.

Where the ECU determines that gas fuel is depleted, areas within the store 73 will be accessed instead at

low speeds/loads to allow petrol operation to take over rather than utilising store 74.

There may be circumstances which replicate urban driving even though it is in fact out of town driving. For example, slow moving motorway traffic caused by congestion would trigger gas utilisation. However the clean nature of the gas fuel will be a bonus under such circumstances.

In the above arrangements, the switchover of fuel will be effected without any noticeable change of handling of the vehicle by the driver. It may be preferable, however, to include an indicator device 45 (see Figure 1) to display to the driver what fuel source is currently employed.

In order to accommodate the gas injectors 6 and petrol injectors 2 a special manifold 3 has been devised which can replace a normal single fuel manifold to make fitting easy and keep costs down. The manifold shown (see also Figure 3) is moulded from lightweight, somewhat resilient plastic material and includes two sets of four metallic inserts 2a and 6a for receiving the petrol injectors and gas injectors respectively. Each engine cylinder 19 in this 4 cylinder example has

an air intake duct 40 which is connected to the engine block 7 by means of a flange 43. Each duct is supplied from a common manifold 44 by a series of curved ducts 45 (typically of 30mm internal bore).

The length of the curved ducts 45 and internal shape of the manifold 44 are designed to provide resonant frequencies in tune with the engine combustion so as to produce a near constant engine output torque over a wide range of engine operating speeds.

Each air duct 40 is fitted with a smaller, typically 10mm bore, intake to accommodate the petrol fuel injector. A fuel manifold 50 typically made from zinc or aluminium alloy and commonly known as a fuel rail provides the petrol fuel supply. The main flow of air 42 into the manifold 44 is through a butterfly valve or throttle 56, typically of 50mm bore.

A smaller flow of air 53 passes through a port of typically 12mm bore via a valve (not shown) to regulate the engine idle speed. The manifold 44 operates under suction and several ports 54 of typically 4mm bore allow for the suction intake from the brake servo, petrol tank fuel vapour canister discharge, engine crankcase ventilation and the like.

In operation, as each engine piston 57 performs its air/fuel intake stroke, each engine cylinder intake valve 18 opens allowing air 55 and petrol 56 to enter the cylinder 19 as the cylinder volume expands. The mass flowrate of air 55 is determined by sensors linked to the ECU 4 and pulses of electrical power are sent via the cable 19 to an electromagnetic coil in the petrol injector 2. This partially opens a needle valve against spring pressure to allow the correct amount of fuel 56 to pass through the injector so that the fuel mixes with the air 55 as it enters the engine through the cylinder valve 18.

Each port 60 accommodates a gas fuel injector 6. Each injector is connected to the engine control unit (ECU) 9 by means of the electrical cable 24 and to a gas fuel supply 63, typically at 7 bar gas pressure, by means of a gas fuel manifold 62 typically made from steel tube and commonly known as a gas rail. Sensors for gas pressure and temperature (not shown) are connected to the ECU 4.

In operation, the ECU 4 determines the flowrate of air 55 and provides the correct amount of either gas or petrol for each cylinder intake stroke according to

whichever fuel the engine is required to operate on at that moment in time. The quantity of fuel is determined from stored information, known as mapping or calibration, as mentioned above, of the engine speed and load, temperature, throttle position, ignition timing, air/fuel ratio, exhaust emissions and other powertrain sensors specific to the model of engine fitted. Since the throttle position, using gas for a particular load, will be different from that when using petrol, the throttle position sensor signal will be used to enable a smooth transfer between fuels without a noticeable momentary loss of power. Under certain conditions, there is a delay in the changeover fuel reaching the injectors and this has to be anticipated by the ECU. Instead of changing all injectors at once, in an alternative embodiment the ECU program is modified to change the fuel for each engine cylinder over a longer sequence whilst manipulating the ignition timing to minimise any noticeable effects on power output.

As discussed above, in addition to the bi-fuel operation, the vehicle has the capability to allow refuelling at a convenient gas supply source at the driver's house, for example. The supply will typically be available at a pressure of 1 bar and needs compression to typically 200 bar to allow a significant

volume to be stored. The driver can initiate the gas refill cycle once the vehicle is parked and the low pressure hose is connected to the gas filling point as detected by sensor 13a via lead 41. The ECU 4 controls operation of the compressor 28 via lead 46. The compressed gas begins to fill the tank 27 and pressure information is available to the ECU from sensor 27a via lead 42. The cycle can be arranged to be automatic so that replenishment is effected without further intervention from the driver once manual initiation is instigated using the stored sequence information stored in store 25 within the ECU 4.

After the manual initiation by means of a designated switch the program employed within the ECU (and described in more detail in the aforementioned copending patent application) follows a sequence of steps and checks to ensure safe operation automatically. The detection of an error will trigger an audible/visual alarm. The visual alarm could comprise a display unit with indicia relating to the particular detected event. This could be incorporated in an expanded display 45. Hence in operation, for example if the hose is determined not to be connected this will result in an indication or prompt on the display.

The on-board compressor arrangement utilised during the automatic cycle is described in more detail in Figure 5.

The compressor 28 is a two stage compressor of the type disclosed in our copending patent application with the title 'Compressor Arrangement'. It includes a body portion 90 which includes a first cylindrical chamber 91 and a second smaller cylindrical chamber 92. Rams A and B are connected by rod 94 and hydraulic fluid under pressure simultaneously pushes piston A and pulls piston B during part of the operational cycle. This allows gas received externally via coupling 13 and duct 36 to be drawn into chamber 91. On completion of the stroke, the hydraulic pressure rises rapidly and a spool valve 34 switches and causes hydraulic fluid to force the rod 94 in the reverse direction so compressing the gas in chamber 91.

The compressed gas passes via conduit 95 and valve 96 into the now open chamber 92 to provide a second stage of compression, once the hydraulic fluid reverses flow on actuation of the spool valve into its second bi-stable position. After the second stage of compression the compressed gas is allowed to exit to the storage tank 27. The hydraulic fluid spool valve 34 ensures that correct passage of the hydraulic fluid is

maintained. The power to drive the hydraulic fluid is provided by an electric motor 30 via a belt 31 to hydraulic pump 29 under the control of the ECU 4. Fluid passes to the compressor 28 under the switching action of the spool valve 34 to allow second stage compression of the gas whilst the first stage intake is occurring and vice versa.

The compressor may be cooled internally by liquid in a reservoir 35 passing through a radiator 32 and filter 33 in the vehicle engine cooling system. This may be simplified by using a hydraulic pump 29 designed to operate with a glycol based fluid so that the coolant in the engine cooling system can be used directly to power and cool the compressor without the need for an intermediate fluid or secondary cooling circuit.

The electrical power is provided by the engine running to generate electricity via an alternator (not shown). This avoids draining the battery.

The on-board arrangement utilising the common ECU avoids long recharging times when a low pressure source of natural gas is available. A recharge cycle of 30 minutes or less is possible.

It would also be possible for a compressor of this type to be mounted at the home gas supply and be powered to provide pressurised gas to the vehicle. Couplings to the vehicle and associated hoses will need to be sufficiently robust to handle such pressures. It is convenient, however, to have the compressor on board to allow the possibility of the vehicle recharging at more than one location yet not incurring the cost of a compressor station at each location.

Although the arrangements described have generally related to a 4 cylinder engine which is naturally aspirated, other engine configurations as regards cylinder numbers and aspiration could be employed.

This arrangement could therefore also be applied to turbocharged or blown systems, where air is forced through the manifold by an external fan or blower than being drawn into the engine by suction from the engine cylinders as each piston performs an intake stroke, or to more recent engine technologies which employ air ram and direct fuel injection.

CLAIMS

1. A vehicle including

engine means capable of operating on both gas fuel and liquid fuel,

common inlet manifold means connected to the engine and including a plurality of gas fuel injectors mounted therein and a plurality of liquid fuel injectors mounted therein,

a gas tank and a liquid fuel tank mounted beneath the vehicle floor external of the passenger and boot compartments and

control means for controlling operation of the vehicle in both gas and liquid fuel modes such that gas fuel is automatically selected dependent on engine speed and load where driving conditions replicate urban/city driving.

2. A vehicle as claimed in claim 1 wherein the common inlet manifold means includes a common air inlet duct for supply of air to each engine cylinder.

3. A vehicle as claimed in claim 2 wherein the common

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air duct includes a plurality of air passages corresponding to the number of engine cylinders.

4. A vehicle as claimed in claim 3 wherein the plurality of air passages are of curved configuration arranged to provide resonant frequency in time with engine combustion to produce substantially constant engine output torque at different engine speeds.

5. A vehicle as claimed in any preceding claim wherein a liquid fuel manifold and a gas fuel manifold provides fuel to each of the plurality of injectors.

6. A vehicle as claimed in any preceding claim wherein the liquid fuel tank is configured to at least partially surround the gas tank to allow the gas tank to be protected from impact, the gas tank being configured to store pressurised gas.

7. A vehicle as claimed in claim 6 wherein the liquid tank is formed of plastic moulded material of flexible characteristic to act as a buffer to absorb impacts.

8. A vehicle as claimed in any preceding claim including means for controlling an automatic refill cycle to fill the gas tank at high pressure from a low

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pressure gas supply in response to sensed information from sensors within the vehicle.

9. A vehicle as claimed in claim 8 wherein the control means provides common control of the refill cycle and the operation of the vehicle in gas or liquid fuel utilisation modes.

10. A vehicle as claimed in claim 8 or 9 including compressor means for compressing gas from an external source using vehicle power.

11. A vehicle as claimed in claim 10 wherein the compressor means includes two chambers interconnected via a rod like device cooperating with a ram device and valve means to allow gas to enter one chamber during a delivery stroke as the gas in other chamber is compressed by fluid pressure.

12. A vehicle as claimed in any one of claims 8 to 11 wherein the control means is configured to control the automatic startup of the vehicle, means are provided to monitor gas pressure and the control means is configured to automatically shut down the vehicle when refuelling requirements are detected as having been met.

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13. A vehicle as claimed in any one of claims 1 to 7 including a fluid compressor operable by hydraulic fluid to recharge the gas tank.

14. A vehicle as claimed in claim 13 wherein the fluid compressor includes to interconnected chambers configured to cause the compressed gas passing from the first chamber during its delivery stroke to enter the second chamber during its intake stroke to provide two stages of gas compression.

15. An common inlet manifold for a multiple fuel vehicle engine including an air inlet duct for supplying air to cylinders within the engine, a port on the manifold for receiving each of a plurality of gas fuel injectors, a port on the manifold for receiving each of a plurality of liquid fuel injectors and a mounting flange on the manifold for mounting the manifold on the engine block.

16. A vehicle control device for controlling a gas and liquid fuelled vehicle including speed sensing means for sensing engine speed, air pressure sensing means for sensing engine load, means for automatically selecting gas fuel or petrol fuel dependent on sensed speed and pressure information, means for continually reassessing

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the selected fuel and means for automatically changing fuel utilisation where load and speed measurements require it.

17. A device as claimed in claim 16 including timing means for selecting fuel changeover only after an elapsed period has occurred to avoid unnecessary fuel changes.

18. A device as claimed in claim 16 or 17 wherein the speed and load information utilised to select gas fuel operation is selected within a range which replicates urban/city driving to ensure the cleaner fuel is utilised under such circumstances.

19. A method of controlling a gas and liquid fuelled vehicle including the steps of sensing engine speed, sensing air pressure to determine engine load, automatically selecting gas fuel or petrol fuel dependent on sensed speed and pressure information, continually reassessing the selected fuel and automatically changing fuel utilisation where load and speed measurements require it.

20. A vehicle capable of operating on both liquid and gas fuel substantially as described herein with

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reference to the accompanying drawings.

21. A common inlet manifold substantially as described with reference to the accompanying drawings.

22. A vehicle control device substantially as described with reference to the accompanying drawings.

23. A method of controlling a gas and liquid fuelled vehicle substantially as described.



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