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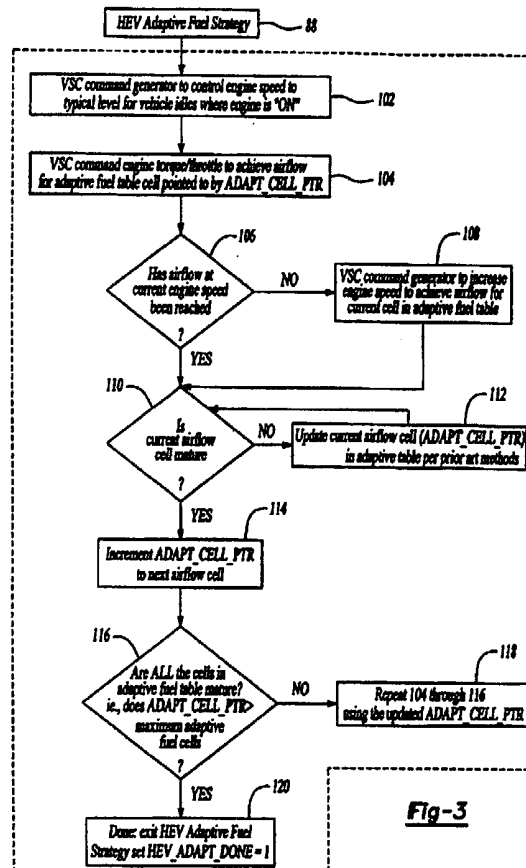
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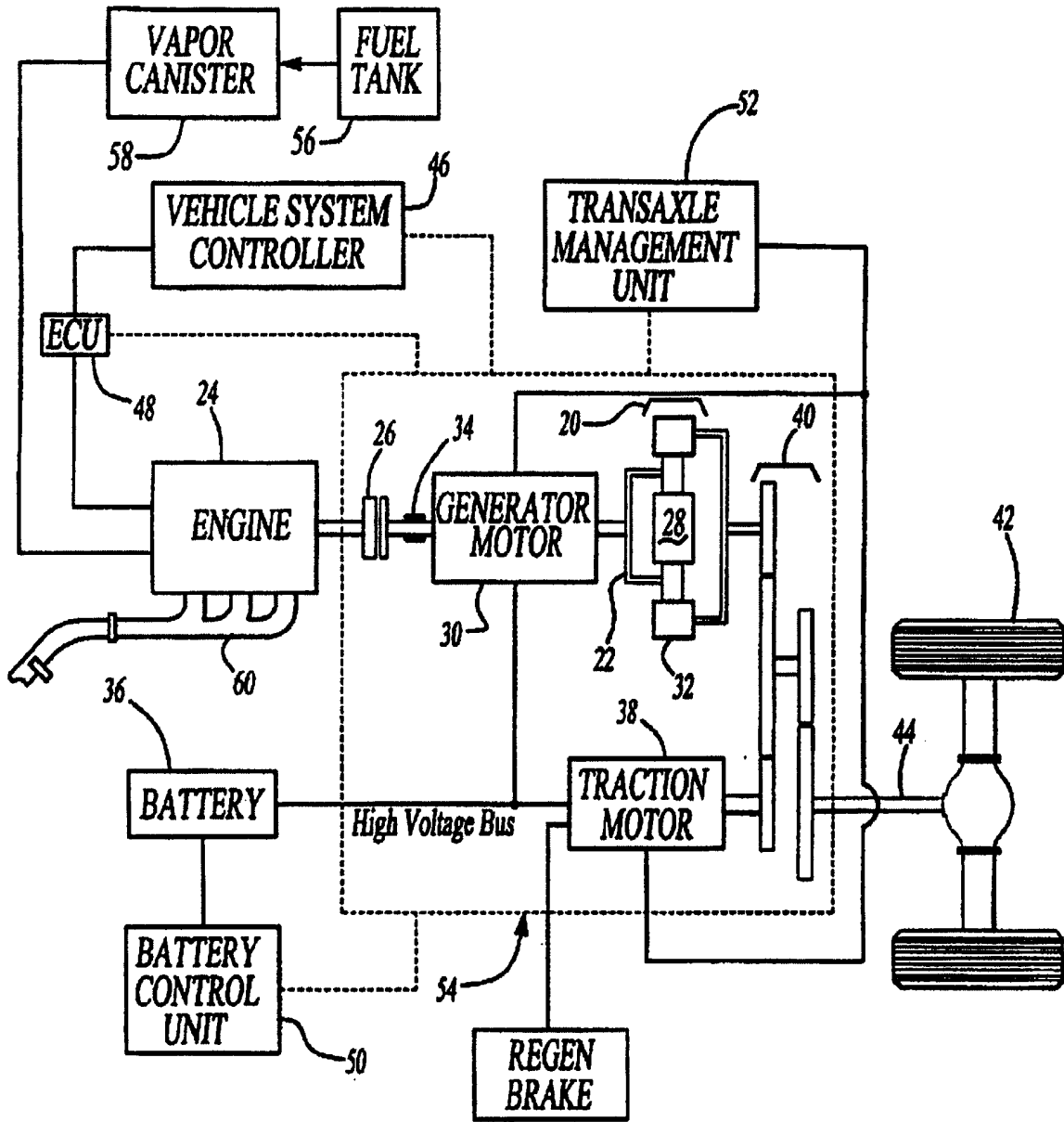
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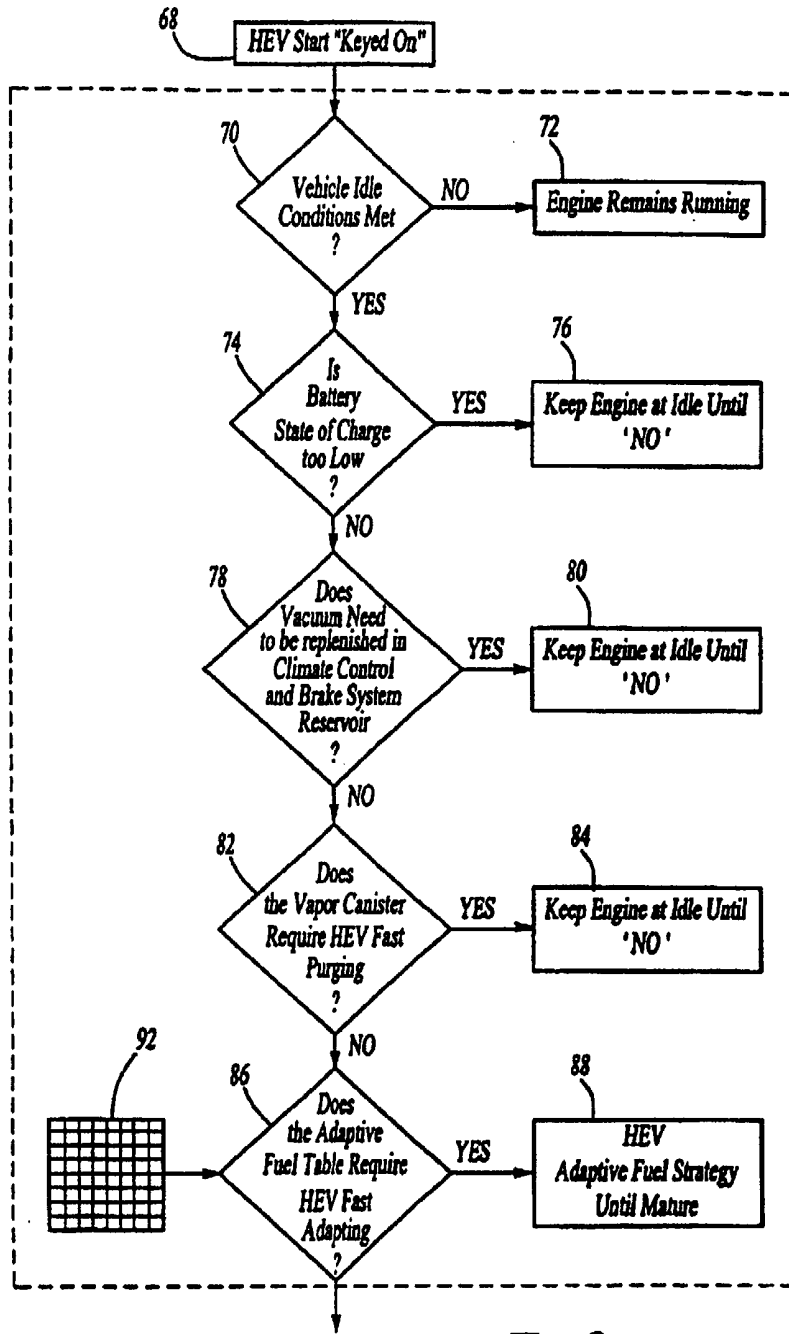
(54) Abstract Title  
**An adaptive fuel strategy for a hybrid vehicle**

(57) A method and system to mature/update adaptive fuel tables for a hybrid vehicle, comprising a controller operable: to determine whether an adaptive fuel table is not mature; to determine, using arbitration logic (fig 2), whether an adaptive fuel strategy is allowed to mature the adaptive fuel table; to cause the engine throttle to sweep through different airflow regions of the engine; to collect fuel shift data from engine sensors during the throttle sweep until the strategy orders data collection to stop; and to update the fuel shift data from the engine throttle sweep. Preferably a generator attached to the vehicle drive train, adds or subtracts torque to maintain constant engine speed during the throttle sweeps.

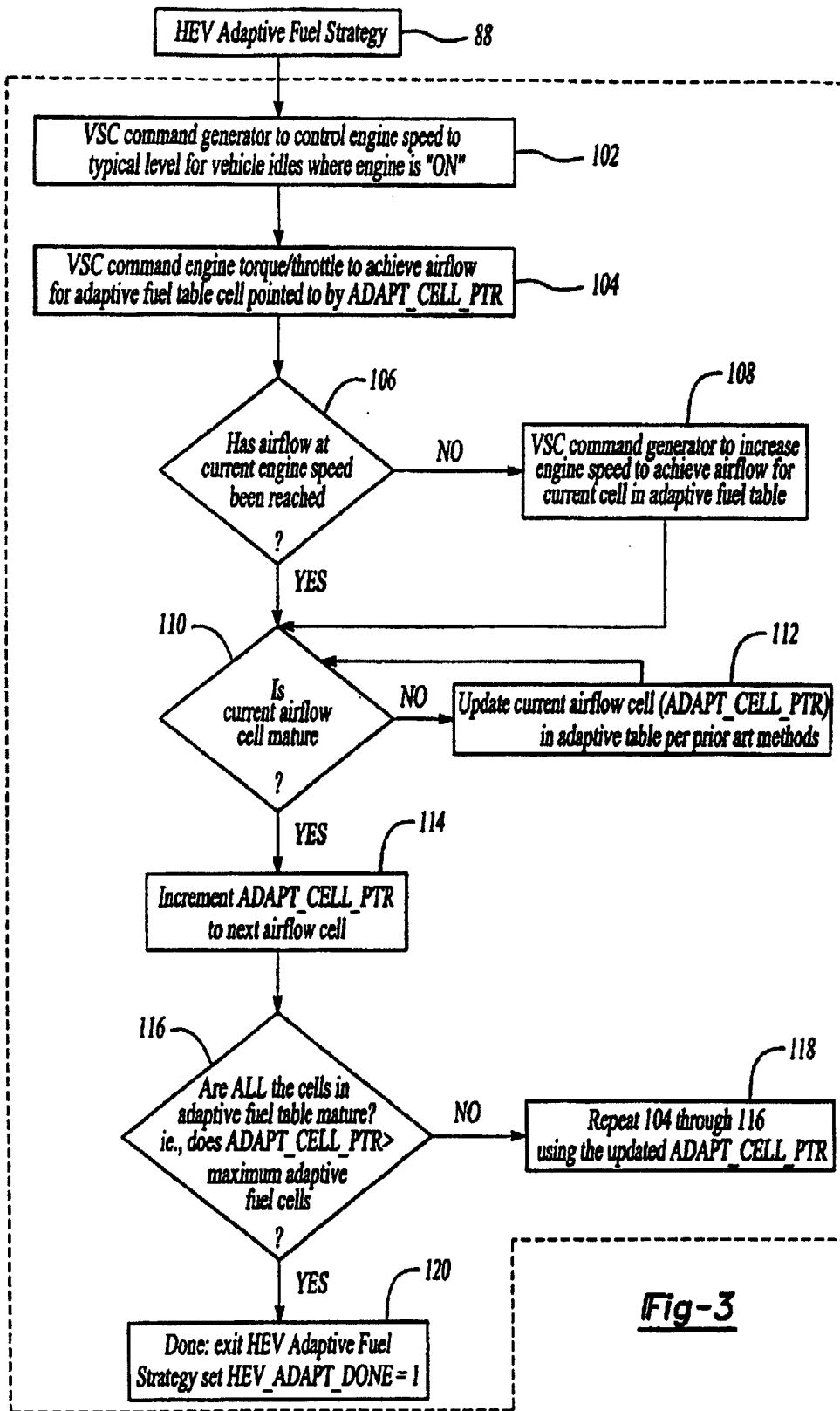




**Fig-1**



**Fig-2**



<b>Adaptive Fuel Table 92</b>		
<b>6</b>	<b>6.0 lbs/min</b>	<b>xxx</b>
<b>5</b>	<b>5.0 lbs/min</b>	<b>xxx</b>
<b>4</b>	<b>4.0 lbs/min</b>	<b>xxx</b>
<b>3</b>	<b>3.0 lbs/min</b>	<b>xxx</b>
<b>2</b>	<b>2.0 lbs/min</b>	<b>xxx</b>
<b>1</b>	<b>1.0 lbs/min</b>	<b>xxx</b>
<b>ADAPT_CELL_PTR</b>	<b>Corresponding Airflow</b>	<b>Fuel Shift Learned</b>

**Fig-4**

**AN ADAPTIVE FUEL STRATEGY FOR A HYBRID ELECTRIC VEHICLE**

The present invention relates generally to a Hybrid Electric Vehicle (HEV), and specifically to a method and system to optimize emissions using an adaptive fuel strategy for a hybrid electric vehicle (HEV).

The need to reduce fossil fuel consumption and emissions in automobiles and other vehicles predominately powered by Internal Combustion Engines (ICEs) is well known. Vehicles powered by electric motors attempt to address these needs. Another alternative solution is to combine a smaller ICE with electric motors into one vehicle. Such vehicles combine the advantages of an ICE vehicle and an electric vehicle and are typically called Hybrid Electric Vehicles (HEVs). See generally, U.S. Pat. No. 5,343,970 to Severinsky.

The HEV is described in a variety of configurations. Many HEV patents disclose systems where an operator is required to select between electric and internal combustion operation. In other configurations, the electric motor drives one set of wheels and the ICE drives a different set.

Other, more useful, configurations have developed. For example, a Series Hybrid Electric Vehicle (SHEV) configuration is a vehicle with an engine (most typically an ICE) connected to an electric motor called a generator. The generator, in turn, provides electricity to a battery and another motor, called a traction motor. In the SHEV, the traction motor is the sole source of wheel torque. There is no mechanical connection between the engine and the drive wheels. A Parallel Hybrid Electrical Vehicle (PHEV) configuration has an engine (most typically an ICE) and an electric motor that work together in varying degrees to provide the necessary wheel torque to drive the vehicle.

Additionally, in the PHEV configuration, the motor can be used as a generator to charge the battery from the power produced by the ICE.

5           A Parallel/Series Hybrid Electric Vehicle (PSHEV) has characteristics of both PHEV and SHEV configurations and is sometimes referred to as a "powersplit" configuration. In one of several types of PSHEV configurations, the ICE is mechanically coupled to two electric motors in a planetary  
10 gear-set transaxle. A first electric motor, the generator, is connected to a sun gear. The ICE is connected to a carrier. A second electric motor, a traction motor, is connected to a ring (output) gear via additional gearing in a transaxle. Engine torque can power the generator to  
15 charge the battery. The generator can also contribute to the necessary wheel (output shaft) torque if the system has a one-way clutch. The traction motor is used to contribute wheel torque and to recover braking energy to charge the battery. In this configuration, the generator can  
20 selectively provide a reaction torque that may be used to control engine speed. In fact, the engine, generator motor and traction motor can provide a continuous variable transmission (CVT) effect. Further, the HEV presents an opportunity to better control engine idle speed over  
25 conventional vehicles by using the generator to control engine speed.

The desirability of combining an ICE with electric motors is clear. There is great potential for reducing  
30 vehicle fuel consumption and emissions with no appreciable loss of vehicle performance or drivability. The HEV allows the use of smaller engines, regenerative braking, electric boost, and even operating the vehicle with the engine shut down. Nevertheless, new ways must be developed to optimize  
35 the HEV's potential benefits.

One such area of HEV development is HEV engine operations. In an HEV, the engine has many functions. Its primary function is to provide drive torque. Other functions can include the following: charging the battery, purging a vapour canister, learning the shifts in the fuel delivery system to an adaptive fuel table, powering an air conditioning ("A/C") compressor if the compressor is mechanically driven by a front end accessory drive (FEAD) belt, replenishing vacuum to a vacuum reservoir, maintaining catalyst temperature (for optimal emissions), and maintaining engine temperature (for climate control system to provide heat to the passenger compartment). While performing these functions, the HEV engine must optimize emissions and fuel consumption without negatively impacting drivability and performance.

One of the techniques available in an HEV to reduce emissions and fuel consumption is to turn the engine off when it is not needed. If the engine is not running, the electric motor provides the required driving torque.

When running, the engine is used in both drive and vehicle idle conditions. Idle conditions exist when the vehicle is not moving. In an HEV, the engine is generally and ideally off during idle conditions. However, some HEV functions require the engine to remain on even in vehicle idle conditions. One such function can be the maturing of an HEV engine's adaptive fuel table. Adaptive fuel tables are known in the prior art to optimize emissions from internal combustion engines. See generally, Fuel Controller with an Adaptive Adder, U.S. Pat. No. 5,464,000 to Pursifull, et al. (Ford Motor Company).

As discussed in this referenced patent and known in the prior art, electronic fuel control systems are used predominantly today in most vehicles. The fuel controller



systems vary the amount of fuel delivered to the engine cylinders based on the engine speed, mass airflow rate, and the oxygen content of the exhaust. These fuel controllers typically try to maintain the ratio of air and fuel at or near stoichiometric (considered to be approximately 14.6:1 A/F ratio for most types of gasoline engine) by implementing a closed loop fuel controller. Maintaining A/F at or near stoichiometric allows the catalytic converter to convert the exhaust gas into clean by-products at an optimal level.

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A typical prior art closed loop fuel controller determines the proper amount of fuel to deliver to the engine cylinders as follows. First, the airflow entering the engine is measured and then converted to an estimate of the amount of air charge entering each cylinder. This estimate is then modified by the concentration of oxygen in the exhaust gas as measured by an exhaust gas oxygen sensor (EGO).

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The oxygen content of the exhaust gas directly reflects the A/F ratio of the previous combustion event so that, if the A/F ratio was not near stoichiometric, a correction factor can be applied to the fuel amount delivered for the next combustion event. For example, if the EGO indicates a rich A/F mixture (less than stoichiometric), then the fuel amount will be reduced for the next combustion event. If the EGO indicates a lean A/F mixture, then the fuel amount will be increased for the next combustion event.

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The adaptive fuel control feature, as discussed in the referenced patent and known in the prior art, enhances the closed loop fuel controller by learning the long-term "shifts" in the fuel delivery system. The amount of fuel required during closed loop fuel operation varies from engine to engine within a given engine configuration. The variation is due to differences in fuel system components

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such as fuel injectors and mass airflow sensors, the different degrees to which these components age, and the conditions under which the vehicle is driven. The adaptive fuel controller "learns" these long-term fuel adjustments  
5 for the many combinations of engine speed and engine air charge (or airflow) that can occur in the operation of an engine. The adaptive fuel controller learns a fuel shift if the actual A/F ratio is outside of a calibrated range relative to stoichiometric. The amount of the adjustment  
10 learned is proportional to how far from stoichiometric the actual A/F was and how quickly the gains used for adaptive corrections are calibrated. These learned or "adapted" adjustments in A/F are then stored in an adaptive fuel table for future use by the closed loop fuel controller when those  
15 same engine speed and air charge conditions are encountered again. Once the actual A/F returns to stoichiometric, the adaptive fuel cell is considered to be "mature".

The adaptive fuel table is a KAM (keep alive memory)  
20 type table. There are many different types of adaptive fuel tables. One type uses a matrix and a number of columns for engine speed on the x-axis and a number of rows for airflow on the y-axis.

25 Another method uses engine "load" instead of airflow. Load is a normalized engine air charge defined as the current amount of air charge inducted into the cylinder divided by the maximum amount of air charge possible at that given engine speed. Yet another method uses the airflow  
30 dimension only and disregards the effect of engine speed. Regardless of the adaptive fuel table used, the result is the same. When the system is "adapting" to a particular airflow cell, the cell is updated with the air/fuel shift amount. That amount is used the next time the system is at  
35 that airflow point.

Adaptive fuel table strategies in the prior art operate while the engine is running because they need to spend a period of time at a given airflow condition in order to adapt the fuel shift to the appropriate fuel cell in the table until that cell is "mature". Adaptive fuel strategies typically do not run while the vapour canister is being purged or while some on-board diagnostic monitors are running.

Therefore, adaptive fuel, purge, and monitoring strategies tend to compete for engine running time to accomplish their tasks. This situation is exacerbated in an HEV because the vehicle's ICE is not always on. Therefore, the HEV's ability to quickly mature its adaptive fuel table is diminished.

It is an object of the invention to provide a new method and system for an HEV to quickly update an adaptive fuel table.

According to a first aspect of the invention there is provided a system to mature adaptive fuel tables for an engine of a hybrid electric vehicle the system comprising a controller operably connected to an engine throttle and one or more engine sensors wherein the controller is operable to determine whether an adaptive fuel table is not mature, to determine whether an adaptive fuel strategy is allowed under a system idle arbitration logic to mature the adaptive fuel table, to cause the engine throttle to sweep through different airflow regions of an engine, to collect fuel shift data from the engine sensors during the throttle sweep until the adaptive fuel strategy orders data collection to stop and to update the fuel shift data from the engine throttle sweep data in the adaptive fuel cell table.

The determination of whether the adaptive fuel strategy is allowed under the system idle arbitration logic may comprise a determination that engine idle conditions are met, a determination that engine operation is necessary, a  
5 determination that a battery state of charge is not too low, a determination that vacuum does not need to be replenished in a climate control and brake system reservoir and a determination that a system vapour canister does not require HEV-fast purging.

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The order to the engine throttle to sweep may comprise the controller moving the throttle to a next higher throttle position/airflow cell in the adaptive fuel table.

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The order to stop data collection may comprise a signalling from the controller that all fuel shifts for all airflow cells have finished adapting, whereby the adaptive fuel cell is considered mature.

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Preferably, maturing of the adaptive fuel tables may occur independent of other conventional adaptive fuel strategies that may occur simultaneously.

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The order to sweep the engine throttle may further comprise an order to increase the torque so as to hold the engine at a constant speed during the engine throttle sweeps whereby overall desired torque remains constant.

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The increasing of torque may comprise an order to a generator to connect to the engine to hold the engine at a constant speed whereby overall desired torque remains constant.

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Alternatively, the order to sweep the engine throttle may further comprise an order to reduce torque so as to hold

the engine at a constant speed during the engine throttle sweeps whereby overall desired torque remains constant.

The reducing of torque may comprise an order to a generator to connect to the engine to hold the engine at a constant speed whereby overall desired torque remains constant.

According to a second aspect of the invention there is provided a method to mature adaptive fuel tables for a hybrid electric vehicle comprising the steps of determining through a controller whether the adaptive fuel table is not mature, determining that an adaptive fuel strategy is allowed under a system idle arbitration logic to mature the adaptive fuel table, ordering an engine throttle to sweep through different airflow regions of an engine, collecting fuel shift data from engine sensors during the throttle sweep until the adaptive fuel strategy orders data collection to stop and adapting fuel shift data from the engine throttle sweep data in the adaptive fuel cell table.

The determination of whether the adaptive fuel strategy is allowed under the system idle arbitration logic may comprise determining engine idle conditions are met, determining engine operation is necessary, determining a battery state of charge is not too low, determining vacuum does not need to be replenished in a climate control and brake system reservoir and determining that a system vapour canister does not require HEV-fast purging.

The ordering the engine throttle to sweep may comprise the step of moving the throttle to the next higher throttle position/airflow cell in the adaptive fuel table.

The ordering to stop data collection may comprise a signalling from the controller that all fuel shifts for all

airflow cells have finished adapting, whereby the adaptive fuel cell table is considered mature.

5 Preferably, maturing of the adaptive fuel tables may occur independent of other conventional adaptive fuel strategies that may occur simultaneously.

10 The ordering of the engine throttle to sweep may further comprise the step of ordering the addition of torque to the engine to hold the engine at a constant speed during the engine throttle sweeping whereby overall desired torque remains constant.

15 The addition of torque may comprise ordering a generator to connect to the engine and holding the engine at a constant speed whereby overall desired torque remains constant.

20 Alternatively, the ordering of the engine throttle to sweep may further comprise the step of ordering the subtracting of torque to the engine to hold the engine at a constant speed during the engine throttle sweeps whereby overall desired torque remains constant.

25 The subtraction of torque may comprise ordering a generator to connect to the engine to holding the engine at a constant speed whereby overall desired torque remains constant.

30 According to a third aspect of the invention there is provided hybrid electric vehicle having a system in accordance with said first aspect of the invention.

35 The invention will now be described by way of example with reference to the accompanying drawing of which:-

Fig. 1 illustrates a general hybrid electric vehicle (HEV) configuration;

5 Fig. 2 illustrates a partial and simplified schematic diagram of an HEV idle mode flow chart for an HEV;

Fig. 3 illustrates a schematic diagram of the HEV adaptive fuel strategy for an HEV; and

10

Fig. 4 illustrates an example of an adaptive fuel table.

The present invention relates to Hybrid Electric  
15 Vehicles (HEVs) and Figure 1 demonstrates just one possible configuration, specifically a Parallel/Series Hybrid Electric Vehicle (powersplit) configuration.

In a basic powersplit HEV, a Planetary Gear Set 20  
20 mechanically couples a Carrier Gear 22 to an Engine 24 via a One Way Clutch 26. The Planetary Gear Set 20 also mechanically couples a Sun Gear 28 to a Generator Motor 30 and a Ring (output) Gear 32. The Generator Motor 30 also mechanically links to a Generator Brake 34 and is  
25 electrically linked to a Battery 36. A Traction Motor 38 is mechanically coupled to the Ring Gear 32 of the Planetary Gear Set 20 via a Second Gear Set 40 and is electrically linked to the Battery 36. The Ring Gear 32 of the Planetary Gear Set 20 and the Traction Motor 38 are mechanically  
30 coupled to Drive Wheels 42 via an Output Shaft 44.

The Planetary Gear Set 20 splits the Engine 24 output energy into a series path from the Engine 24 to the Generator Motor 30 and a parallel path from the Engine 24 to  
35 the Drive Wheels 42.

Engine 24 speed can be controlled by varying a split to the series path while maintaining a mechanical connection through the parallel path. The Traction Motor 38 augments the Engine 24 power to the Drive Wheels 42 on the parallel path through the Second Gear Set 40. The Traction Motor 38 also provides the opportunity to use energy directly from the series path, essentially running off power created by the Generator Motor 30. This reduces losses associated with converting energy into and out of chemical energy in the Battery 36 and allowing all Engine 24 energy, minus conversion losses, to reach the Drive Wheels 42.

A Vehicle System Controller (VSC) 46 controls many components in this HEV configuration by connecting to each component's controller. An Engine Control Unit (ECU) 48 connects to the Engine 24 via a hardware interface.

The ECU 48 and VSC 46 can be based in the same unit, but are actually separate controllers. The VSC 46 communicates with the ECU 48, as well as a Battery Control Unit (BCU) 50 and a Transaxle Management Unit (TMU) 52 through a communication network such as a Controller Area Network (CAN) 54.

The BCU 50 connects to the Battery 36 via a hardware interface. The TMU 52 controls the Generator Motor 30 and Traction Motor 38 via a hardware interface.

The main function of the ECU 48 in this HEV system is to operate the Engine 24 in a manner that delivers requested Engine 24 torque by the VSC 46 in a manner that minimizes exhaust emissions and fuel consumption. This is accomplished partly through the ECU 48 control of the air/fuel ratio, including the use of an adaptive fuel control strategy.



Because conventional adaptive fuel strategies compete with vapour canister, purge control and diagnostic monitoring strategies for engine running time to accomplish their tasks, and because the Engine 24 is not "on" all the time during a given HEV drive cycle not as many  
5 opportunities exist to mature an adaptive fuel table as in a conventional vehicle. Therefore, one of the key enablers for maintaining good A/F control in the HEV is the implementation of an HEV Adaptive Fuel Strategy 88 (Figure  
10 2).

The present invention provides a method and system to mature an HEV's Adaptive Fuel Table 92 as quickly into a new drive cycle as possible where the new drive cycle is  
15 initiated with a "key on" start following a vehicle inactive, or "key off", period.

Figure 2 is a partial and simplified flow chart of a possible Engine 24 "on" idle arbitration method, located  
20 inside the VSC 46. The purpose of such a method is to determine if the Engine 24 needs to be running at a vehicle idle condition, and if so, for what purpose. The method then can initiate different actions from the Engine 24 (and/or other HEV components) based on the reason for Engine  
25 24 to be running.

One such reason to keep an engine 24 running is the need to mature the Adaptive Fuel Table 92.

30 Figure 2 demonstrates just one possible sequence of steps and, for illustrative purposes only, it only shows steps prior to the determination of whether the Adaptive Fuel Table 92 (Figure 4) needs to be updated.

35 During the course of a drive cycle (key "on" 68 to key "off"), the vehicle will go into an idle condition once

vehicle idle entry conditions are met at Step 70. For instance, the vehicle checks for low vehicle speed and accelerator position at Step 70. If vehicle idle conditions are not met, the vehicle remains in the current drive mode at Step 72.

If vehicle idle conditions are met, the VSC 46 determines if any vehicle operations require the Engine 24 to remain running during vehicle idle mode. If not, the Engine 24 may be shut down. At Step 74, the VSC 46 determines whether Battery 36 state of charge ("SOC") is too low.

If the SOC is lower than a calibrated threshold level, the VSC 46 commands the Engine 24 to remain on during idle mode at Step 76 and initiates other actions to handle this task.

If the Battery 36 SOC is not too low, the VSC 46 proceeds to Step 78 and determines whether the vacuum needs to be replenished in a vehicle's climate control and brake system reservoir. If the vacuum needs to be replenished, the VSC 46 commands the Engine 24 to remain on during idle at Step 80 and initiates other actions to handle this task.

If the reservoir vacuum does not need to be replenished, the VSC 46 moves to step 82 and determines if a Vapour Canister 58 (Figure 1) requires purging.

If the Vapour Canister 58 requires purging the VSC 46 commands the Engine 24 to remain on during idle at Step 84 and initiates other actions to handle this task. If the Vapour Canister 58 does not need to be purged the VSC 46 moves to step 86 to determine if the Adaptive Fuel Table 92 has reached a mature state for this drive cycle.

The Adaptive Fuel Table 92 provides this maturity determination at Step 86. At each key "on" 68 (new drive cycle), a flag called HEV\_ADAPT\_DONE is initialized to 0 (indicating the HEV adaptive fuel routine has not been completed for this drive cycle) and a pointer called ADAPT\_CELL\_PTR is initialized to 1 (referencing the first airflow cell of the Adaptive Fuel Table 92). Step 86 determines whether the HEV\_ADAPT\_DONE flag = 0 (table is not mature) and whether other standard conditions for adapting the fuel tables, as are known in the prior art, have been met (such as the engine having reached its stabilized operating temperature).

Generally, if HEV\_ADAPT\_DONE=0 in Step 86, and the other standard Adaptive Fuel Strategy 88 conditions have been met, the VSC 46 commands the Engine 24 to remain "on" at idle and initiates the HEV Adaptive Fuel Strategy 88 (inside the ECU 48 or VSC 46) at Step 88. This strategy is the subject matter for the present invention and the preferred embodiment is illustrated in Figure 3.

The HEV Adaptive Fuel Strategy 88 illustrated more completely in Figure 3, uses vehicle idle modes early in the drive cycle to force the Engine 24 to operate at airflow conditions used as reference cells in the Adaptive Fuel Table 92, thereby maturing the Adaptive Fuel Table 92 more quickly.

As indicated in Figure 2, a key "on" 68 initiates a new drive cycle, the VSC 46 strategy checks every vehicle idle mode at Step 86 to see if HEV\_ADAPT\_DONE=0 and whether other HEV Adaptive Fuel Strategy 88 conditions are met. For instance, the VCS 46 strategy monitors whether the Engine 24 has reached a stabilized operating temperature.

If these HEV Adaptive Fuel Strategy 88 conditions are met, the VSC 46 invokes the HEV Adaptive Fuel Strategy 88 shown in Figure 3.

5           At Step 102 of the HEV Adaptive Fuel Strategy 88, the VSC 46 commands the Generator Motor 30 to control the Engine 24 speed at a typical speed used when the engine is "on" during vehicle idle modes (i.e., an idle speed). This allows use of the typical idle speed to sweep through the  
10          airflow cells in the Adaptive Fuel Table 92 (shown more specifically in Figure 4) so that a driver's perception of engine speed when the vehicle is at idle will not be disrupted.

15           Next, at Step 104, the VSC 46 commands the Engine 24 to run at a brake torque level that represents a certain throttle position to achieve the Engine 24 airflow specified by ADAPT\_CELL\_PTR. For example, in Figure 4, if  
20          ADAPT\_CELL\_PTR=1, the Adaptive Fuel Strategy 88 points to the first adaptive fuel table row 130, and corresponds to an airflow of 1.0 lbs/min. Thus, the VSC 46 would control the Engine 24 torque in order to achieve 1.0 lbs/min of airflow and update that particular airflow cell of the Adaptive Fuel Table 92.

25           The Adaptive Fuel Strategy 88 requires an electronic throttle controller (not shown in Figure 1) to perform a torque-based Engine 24 control strategy. This type of control strategy converts a desired Engine 24 torque into an  
30          equivalent throttle position.

          Next, Step 106 checks whether Engine 24 throttle has enough range of authority to deliver the desired airflow for the current Engine 24 speed. Most engines are able to  
35          achieve higher airflows for the same throttle position if the engine speed is raised. Thus, if the Engine 24 throttle

has reached its maximum position, and the desired airflow for the given adaptive fuel cell has not been achieved, the strategy moves to Step 108 where the VSC 46 commands the Generator Motor 30 to increase the Engine 24 speed until the  
5 desired airflow is reached.

Whether the desired airflow is achieved by increasing the Engine 24 torque/throttle at Step 104 or Engine 24 speed at Step 108, the next Step 110 determines whether that  
10 particular airflow cell is mature (as determined by prior art methods). If not mature, then prior art adaptive fuel strategies can be used to update that cell until it is mature at Step 112.

15 Once the current airflow cell is mature or updated, the ADAPT\_CELL\_PTR parameter is incremented by one in Step 114, thus pointing to the next airflow cell in the Adaptive Fuel Table 92 (For example, as shown in Figure 4, the next cell would be in table row 132). Next, in Step 116, the strategy  
20 determines whether all of the airflow cells in the Adaptive Fuel Table 92 have been matured. In this example, this is accomplished by using a check such as "is the ADAPT\_CELL\_PTR value greater than the maximum number of airflow cells defined in the Adaptive Fuel Table 92"? If yes, then the  
25 logic moves to Step 120, and indicates the end of the HEV Adaptive Fuel Strategy 88 by setting the flag HEV\_ADAPT\_DONE = 1. If no, the Adaptive Fuel Strategy 88 repeats steps 104 through 116 using the new airflow cell represented by ADAPT\_CELL\_PTR until all the cells in the Adaptive Fuel  
30 Table 92 are reached.

Once HEV\_ADAPT\_DONE = 1, the HEV Adaptive Fuel Strategy 88 will never be invoked by the VSC 46 for future vehicle idle modes in the current drive cycle (Figure 2). Also, if  
35 the HEV Adaptive Fuel Strategy 88 is in the middle of updating the airflow cells and a condition occurs that

requires the strategy to stop (such as the vehicle is no longer in an idle mode, or the Vapour Canister 58 requires purging), the HEV Adaptive Fuel Strategy 88 will remember the airflow cell it was last updating via ADAPT\_CELL\_PTR.

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For example, if at one vehicle idle mode the HEV Adaptive Fuel Strategy 88 got through 2 of the 6 cells in the Adaptive Fuel Table 92, and then the driver pressed the accelerator to leave the idle mode, then the HEV Adaptive Fuel Strategy 88 would exit with HEV\_ADAPT\_DONE still=0 but would have ADAPT\_CELL\_TMR=3. Thus, the next time a vehicle idle condition occurred, the HEV Adaptive Fuel Strategy 88 would begin updating cell 3 of 6 and continue on in this manner until all the cells were mature and HEV\_ADAPT\_DONE = 1.

15

This HEV Adaptive Fuel Strategy 88 is not intended to replace a conventional prior art adaptive fuel strategy, but rather to work with an existing one. Outside of the HEV Adaptive Fuel Strategy 88, the conventional prior art adaptive fuel strategy can work in its normal manner to check the different airflow cells of the table as they are encountered when the engine is running in various drive modes. The purpose of the HEV Adaptive Fuel Strategy 88 is to provide a quick way to achieve a mature Adaptive Fuel Table and thereby ensuring robust tailpipe emissions at all times.

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The above-described embodiment of the invention is provided purely for purposes of example. Many other variations, modifications, and applications of the invention may be made without departing from the scope of the invention.

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### CLAIMS

1. A system to mature adaptive fuel tables for an engine of a hybrid electric vehicle the system comprising a controller operably connected to an engine throttle and one or more engine sensors wherein the controller is operable to determine whether an adaptive fuel table is not mature, to determine whether an adaptive fuel strategy is allowed under a system idle arbitration logic to mature the adaptive fuel table, to cause the engine throttle to sweep through different airflow regions of an engine, to collect fuel shift data from the engine sensors during the throttle sweep until the adaptive fuel strategy orders data collection to stop and to update the fuel shift data from the engine throttle sweep data in the adaptive fuel cell table.

2. A system as claimed in Claim 1 wherein the determination of whether the adaptive fuel strategy is allowed under the system idle arbitration logic comprises a determination that engine idle conditions are met, a determination that engine operation is necessary, a determination that a battery state of charge is not too low, a determination that vacuum does not need to be replenished in a climate control and brake system reservoir and a determination that a system vapour canister does not require HEV-fast purging.

3. A system as claimed in claim 1 or in claim 2 wherein the order to the engine throttle to sweep comprises the controller moving the throttle to a next higher throttle position/airflow cell in the adaptive fuel table.

4. A system as claimed in any of claims 1 to 3 wherein the order to stop data collection comprises a signalling from the controller that all fuel shifts for all

airflow cells have finished adapting, whereby the adaptive fuel cell is considered mature.

5           5.    A system as claimed in any of claims 1 to 4  
wherein maturing of the adaptive fuel tables can occur  
independent of other conventional adaptive fuel strategies  
that may occur simultaneously.

10           6.    A system as claimed in any of claims 1 to 5  
wherein the order to sweep the engine throttle further  
comprises an order to increase the torque so as to hold the  
engine at a constant speed during the engine throttle sweeps;  
whereby overall desired torque remains constant.

15           7.    A system as claimed in claim 6 wherein adding  
torque comprises an order to a generator to connect to the  
engine to hold the engine at a constant speed whereby  
overall desired torque remains constant.

20           8.    A system as claimed in any of claims 1 to 5  
wherein the order to sweep the engine throttle further  
comprises an order to reduce torque so as to hold the engine  
at a constant speed during the engine throttle sweeps  
whereby overall desired torque remains constant.

25           9.    A system as claimed in claim 7 wherein reducing  
torque comprises an order to a generator to connect to the  
engine to hold the engine at a constant speed whereby  
overall desired torque remains constant.

30           10.   A method to mature adaptive fuel tables for a  
hybrid electric vehicle comprising the steps of determining  
through a controller whether the adaptive fuel table is not  
mature, determining that an adaptive fuel strategy is  
35   allowed under a system idle arbitration logic to mature the  
adaptive fuel table, ordering an engine throttle to sweep



through different airflow regions of an engine, collecting fuel shift data from engine sensors during the throttle sweep until the adaptive fuel strategy orders data collection to stop and adapting fuel shift data from the engine throttle sweep data in the adaptive fuel cell table.

11. A method as claimed in Claim 10 wherein determining whether the adaptive fuel strategy is allowed under the system idle arbitration logic comprises determining engine idle conditions are met, determining engine operation is necessary, determining a battery state of charge is not too low, determining vacuum does not need to be replenished in a climate control and brake system reservoir and determining that a system vapour canister does not require HEV-fast purging.

12. A method as claimed in claim 10 or in claim 11 wherein ordering the engine throttle to sweep comprises the step of moving the throttle to the next higher throttle position/airflow cell in the adaptive fuel table.

13. A method as claimed in any of claims 10 to 12 wherein ordering to stop data collection comprises a signalling from the controller that all fuel shifts for all airflow cells have finished adapting, whereby the adaptive fuel cell table is considered mature.

14. A method as claimed in any of claims 10 to 13 wherein maturing of the adaptive fuel tables can occur independent of other conventional adaptive fuel strategies that may occur simultaneously.

15. A method as claimed in claim 10 to 14 wherein ordering the engine throttle to sweep further comprises the step of ordering the addition of torque to the engine to hold the engine at a constant speed during the engine

throttle sweeping whereby overall desired torque remains constant.

5           16. A method as claimed in claim 15 wherein adding torque comprises ordering a generator to connect to the engine and holding the engine at a constant speed whereby overall desired torque remains constant.

10           17. A method as claimed in any of claims 10 to 14 wherein ordering the engine throttle to sweep further comprises the step of ordering the subtracting of torque to the engine to hold the engine at a constant speed during the engine throttle sweeps whereby overall desired torque remains constant.

15

          18. A method as claimed in claim 17 wherein subtracting torque comprises ordering a generator to connect to the engine to holding the engine at a constant speed whereby overall desired torque remains constant.

20

          19. A hybrid electric vehicle having a system as claimed in any of claims 1 to 9.

25           20. A system substantially as described herein with reference to the accompanying drawing.

          21. A method substantially as described herein with reference to the accompanying drawing.

30           22. A hybrid electric vehicle substantially as described herein with reference to the accompanying drawing.



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Application No: GB 0129335.6  
Claims searched: 1 to 22

22

Examiner: Jason Clee  
Date of search: 26 June 2002

**Patents Act 1977  
Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): None

Int Cl (Ed.7): B60K: 6/02 & 6/04  
F02D: 41/14, 41/18 & 41/24

Other: Online: WPI, EPODOC & JAPIO

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	US 6321714 (Ford Global Technologies Inc.)	-
A	US 5996337 (Engelhard Corp. & Motorola Inc.)	-
A	JP 2000291471 A (Toyota Jidosha KK) especially see the abstract	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.