

Section 4

Engine

Overview The 1NZ-FXE is one of two power sources for the Prius. The 1NZ-FXE is a 1.5 liter inline 4-cylinder engine with VVT-i (Variable Valve Timing with intelligence) and ETCS-i (Electric Throttle Control System with intelligence). The 1NZ-FXE includes a number of modifications that help balance performance, fuel economy and clean emissions in hybrid vehicles.

One unique aspect of the 1NZ-FXE is its Atkinson cycle valve timing, which allows the engine to decrease emissions by varying the relationship between the compression stroke and the expansion stroke. Another feature incorporated on '04 & later models is a special coolant heat storage system that recovers hot coolant from the engine and stores it in an insulated tank where it stays hot for up to three days. Later, an electric pump pre-circulates the hot coolant through the engine to reduce HC emissions normally associated with a cold start.

Engine

The 1NZ-FXE is a 1.5 liter inline 4-cylinder engine.



Figure 4.1

T071f401p

Engine Specifications

Model			'04 Prius	'03 Prius
Engine Type			1NZ-FXE	←
No. of Cyls. & Arrangement			4-Cylinder, In-line	←
Valve Mechanism			16-Valve DOHC, Chain Drive (with VVT-i)	←
Combustion Chamber			Pentroof Type	←
Manifolds			Cross-Flow	←
Fuel System			SFI	←
Displacement		cm ³ (cu. in.)	1497 (91.3)	←
Bore x Stroke		mm (in.)	75.0 x 84.7 (2.95 x 3.33)	←
Compression Ratio			13.0 : 1	←
Max Output		(SAE-NET)	57 kw @ 5000 rpm (76 HP @ 5000 rpm)	52 kw @ 4500 rpm (70 HP @ 4500 rpm)
Max Torque		(SAE-NET)	111 N·m @ 4200 rpm (82 ft·lbf @ 4200 rpm)	←
Valve Timing	Intake	Open	18° ~ -15° BTDC	18° ~ -25° BTDC
		Close	72° ~ 105° ABDC	72° ~ 115° ABDC
	Exhaust	Open	34° BBDC	←
		Close	2° ATDC	←
Firing Order			1-3-4-2	←
Research Octane Number			91 or higher	←
Octane Rating			87 or higher	←
Engine Service Mass * (Reference)		kg (lb)	86.1 (189.8)	86.6 (190.9)
Oil Grade			API SJ, SL, EC or ILSAC	API SH, SJ, EC or ILSAC
Tailpipe Emission Regulation			SULEV	←
Evaporative Emission Regulation			AT-PZEV, ORVR	LEV-II, ORVR

*: Weight shows the figure with the oil and engine coolant fully filled.

Figure 4.2

T071f402

VVT-i and Atkinson Cycle

VVT-i allows the engine control system to independently adjust intake valve timing. The 1NZ-FXE uses this ability to move between conventional valve timing and Atkinson cycle valve timing, varying the effective displacement of the engine.

In an Atkinson cycle engine, the intake valve is held open well into the compression stroke. While the valve is open, some of the cylinder volume is forced back into the intake manifold. This creates an effective reduction in engine displacement. By using the VVT-i system to continuously adjust intake valve timing between Atkinson cycle valve timing and conventional valve timing, the engine can maximize fuel efficiency whenever possible while still producing maximum power when required.

Valve Timing

The maximum retard closing timing of the intake valve by the VVT-i system has been decreased from 115 degrees ABDC (After Bottom-Dead-Center) in the '01-'03 Prius to 105 degrees ABDC in the '04 & later Prius.

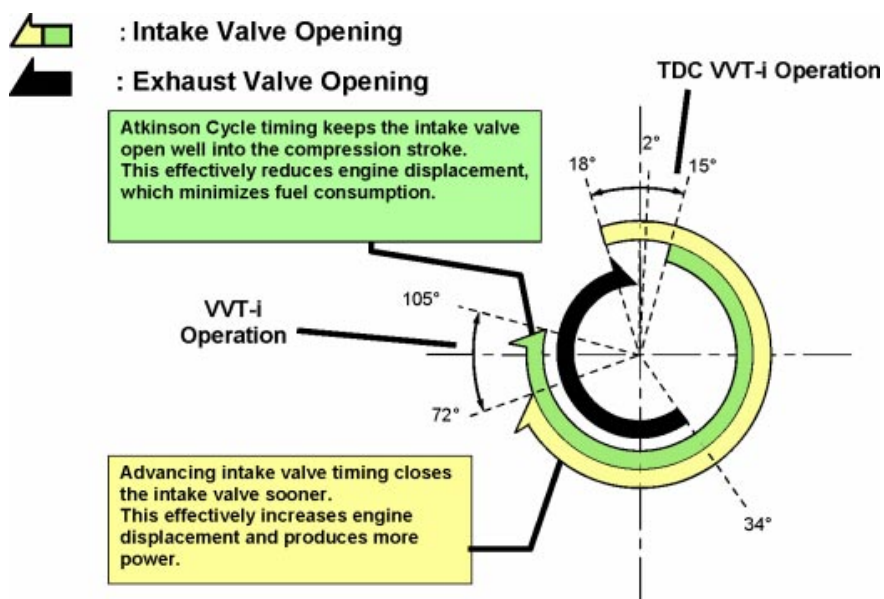


Figure 4.4

T071f404c

Intake Manifold

The intake manifold has a large surge tank that accommodates the air forced back into the manifold during the compression stroke of the Atkinson cycle engine.

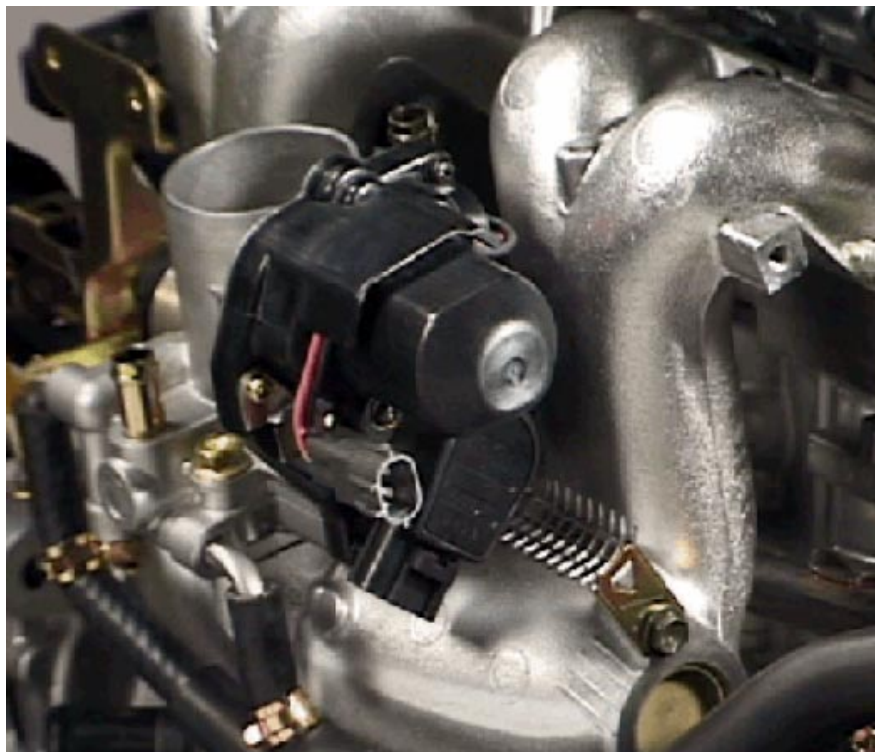


Figure 4.5

T071f405p

Intake Manifold Because some of the air is forced back into the intake manifold during the compression stroke of the Atkinson cycle, the 1NZ-FXE's intake manifold includes a large surge tank to accommodate the extra volume. Also, the length of the intake manifold's intake pipe has been shortened to improve air efficiency and the intake pipes have been integrated midstream to reduce weight. Finally, the throttle body has been positioned down flow in the center of the surge tank to achieve uniform intake air distribution.

ETCS-i With ETCS-i on the Prius, there is no accelerator cable connected to the throttle valve. Instead, the ECM looks at the output of the Accelerator Pedal Position Sensor to determine driver demand, and then calculates the optimal throttle valve opening for the current driving condition. It then uses the throttle control motor to control the throttle valve angle.

Engine Control System Sensors

Mass Airflow Meter The Mass Airflow Meter determines the amount of air flowing into the intake manifold. To measure airflow, a heated platinum wire is positioned in the intake air stream just above the throttle body. The temperature of the hot wire is maintained at a constant value by controlling the current flow through the hot wire. Incoming air tends to cool the hot wire. As airflow increases, current flow through the wire must be increased to maintain the hot wire's set temperature. This current flow is then measured and reported to the ECM as the output voltage of the airflow meter.

Intake Air Temperature Sensor The Intake Air Temperature Sensor is built into the Mass Airflow Meter and uses an NTC (Negative Temperature Coefficient) thermistor to monitor intake air temperature. As intake air temperature increases, the thermistor's resistance and the signal voltage to the ECM decrease.

Engine Coolant Temperature Sensor The Engine Coolant Temperature Sensor is located in the engine block and uses an NTC thermistor monitor engine coolant temperature. As coolant temperature increases, the thermistor's resistance and the signal voltage to the ECM decrease.

Accelerator Pedal Position Sensor The Accelerator Pedal Position Sensor is mounted on the accelerator pedal assembly. Two Hall ICs are used to detect accelerator pedal position. Due to the characteristics of the Hall ICs, different signals are output depending on whether the pedal is being pressed or released. The HV ECU receives the signals and compares them to ensure that there is no malfunction.

Throttle Position Sensor The Throttle Position Sensor is mounted on the throttle body and converts throttle valve angle into two voltage signals (VTA and VTA2). The ECM compares the two voltages to ensure there is not malfunction.

The ECM uses this information to calculate throttle valve opening, then actuates the throttle control motor to adjust throttle valve position accordingly.

Idle Speed Control ETCS-i adjusts the throttle valve angle to control idle speed. No separate idle speed control system is required. The system includes idle-up control during cold engine operation, intake air volume control to improve engine startability, and load compensation for changes such as when the A/C is turned ON or OFF.

Knock Sensor The Knock Sensor is mounted on the cylinder block and detects detonation or knocking in the engine. The sensor contains a piezoelectric element that generates a voltage when cylinder block vibrations due to knocking deform the sensor. If engine knocking occurs, ignition timing is retarded until the knock is suppressed.

Crankshaft Position Sensor The Crankshaft Position Sensor (NE signal) consists of a toothed signal plate mounted on the crankshaft and an inductive pick up coil. The signal plate has 34 teeth, with one gap created by missing teeth, so the sensor generates a 34-pulse waveform for every crankshaft revolution. Since this is an inductive sensor, both the frequency and amplitude of the generated signal increase with increasing engine rpm. The ECM uses the NE signal to determine engine rpm and detect misfires.

Camshaft Position Sensor The Camshaft Position Sensor (G2 signal) consists of a signal plate with a single tooth that is mounted on the exhaust camshaft and a pick up coil. The sensor generates one-pulse waveform for every revolution of the exhaust camshaft. Since this is an inductive sensor, both the frequency and amplitude of the generated signal increase as engine rpm increases. The ECM uses the G2 signal to determine the position of the number one piston for the ignition firing order.

Heated O2 Sensors On the '01-'03 Prius, the sensors include:

- Bank 1, Sensor 1*
- Bank 1, Sensor 2*

*Sensor 1 - refers to the sensor ahead of the catalytic converter. This sensor measures the oxygen content of the engine exhaust gases. The ECM uses this input to adjust fuel trim.

*Sensor 2 - refers to the sensor after the catalytic converter. This sensor is used to measure catalyst efficiency.

The O2 Heater Control maintains the temperature of the O2 Sensors to increase accuracy of detection of the oxygen concentration in the exhaust gas.

Air/Fuel Ratio Sensor On the '04 and later Prius, the Bank 1 Sensor 1 O2 sensor is replaced by an A/F sensor. The A/F sensor detects the air/fuel ratio over a wider range, allowing the ECM to further reduce emissions.

The Prius uses a planar (flat) A/F sensor. The sensor and heater on a planar sensor are narrower than those on a conventional cup sensor. This allows the heater to heat the alumina and zirconia more quickly, accelerating sensor activation.

Exhaust System

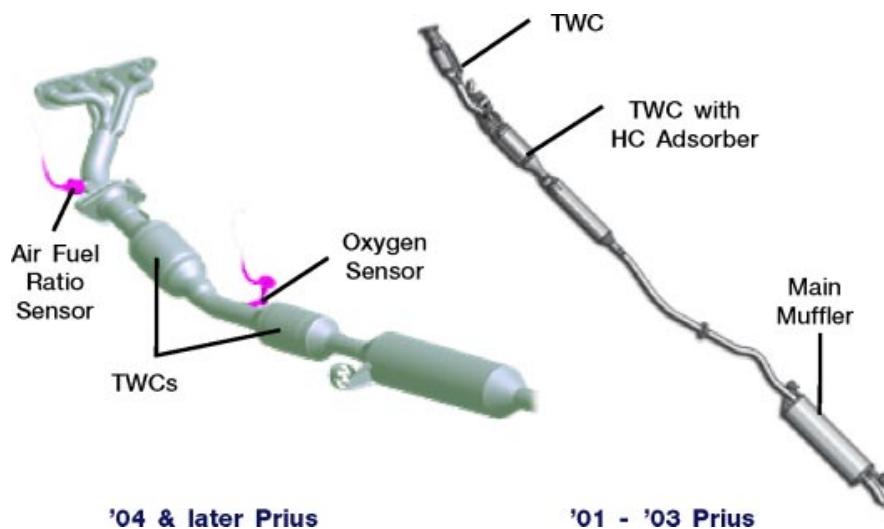


Figure 4.6

T071f406c

HC Adsorber and Catalyst System (HCAC)

('01-'03 Prius)

The HCAC system adsorbs and retains unburned hydrocarbons (HC) produced by the engine during and following a cold start. Once the engine has warmed up, the hydrocarbons are released and purged through the warm three-way catalyst. This improves exhaust emissions at low temperatures.

HCAC - Cold Engine

When the engine is started, the ECM signals the HCAC VSV to apply vacuum to the HCAC actuator, closing the bypass valve. Exhaust gases pass through the HC adsorber where HC is stored until the temperature of the HC adsorber rises. This prevents HC from being emitted when catalyst temperatures are low.

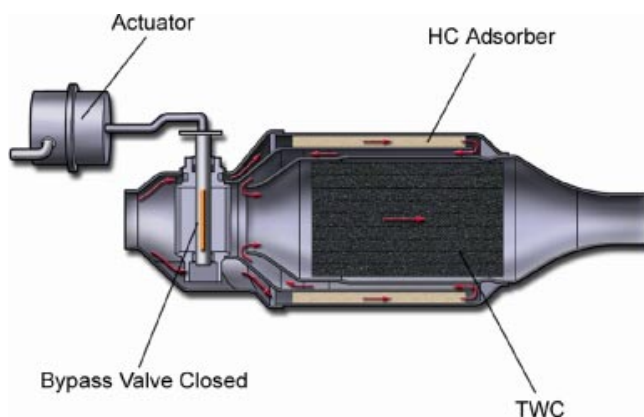


Figure 4.7

T072f207c

HCAC - Purge

When the TWC reaches operating temperature the VSV closes and the bypass valve opens. Stored HC is now purged and flows through the TWC where it is oxidized.

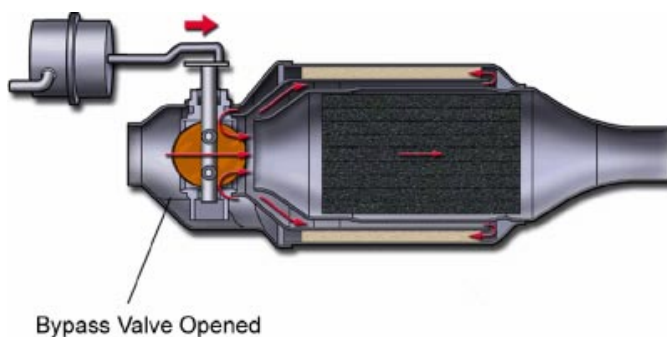


Figure 4.8

T072f208c

HCAC - Scavenge During Deceleration

During deceleration, the VSV is turned on, closing the bypass valve. This scavenges any HC that remains in the HC adsorber.

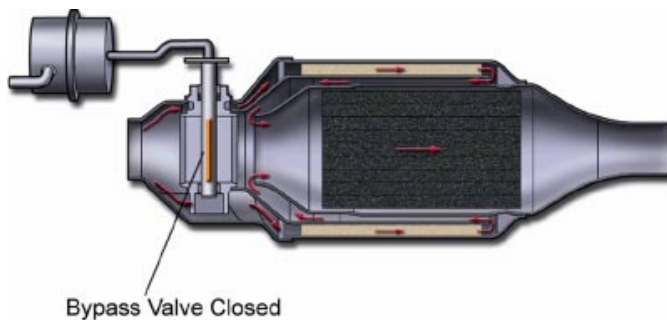


Figure 4.9

T072f209c

Cooling System The 1NZ-FXE uses a pressurized, forced-circulation cooling system. A thermostat with a bypass valve located on the water inlet housing controls coolant flow to maintain suitable temperature distribution in the cooling system.

The radiator for the engine and the A/C condenser are integrated to minimize space requirements. On the '04 & later Prius, the radiator for the inverter cooling system has also been integrated into the same unit.

Cooling System

The coolant heat storage tank on the '04 & later Prius can store hot coolant up to three days. This allows for quick engine warm up and reduces emissions.

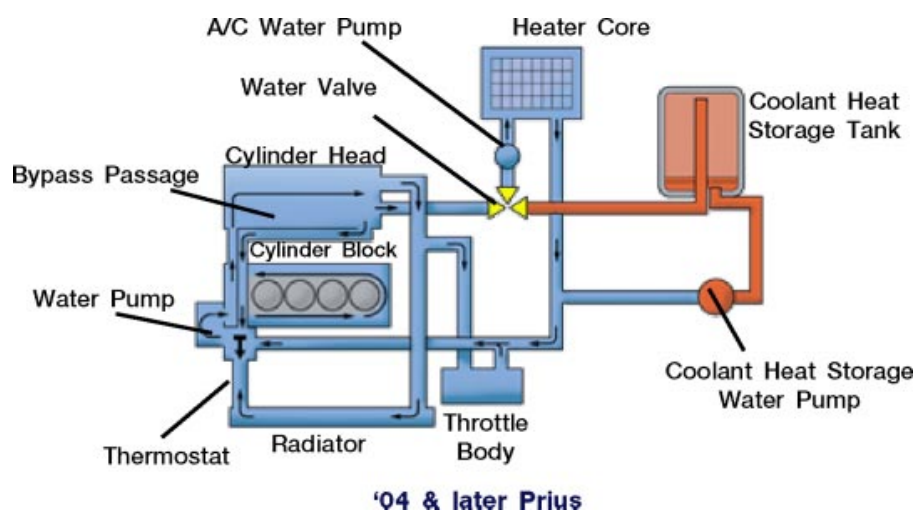


Figure 4.10

T071f410c

Radiator & Condenser

On the '04 & later Prius the engine and inverter radiators are integrated with the A/C condenser.

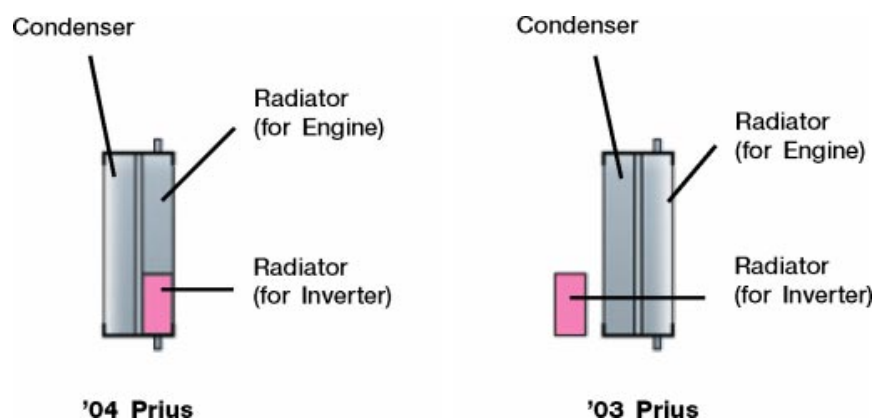


Figure 4.11

T071f411c

Coolant Heat Storage

Starting with the '04 Prius, the cooling system includes a Coolant Heat Storage Tank that can store hot coolant at 176 degrees Fahrenheit for up to three days. When starting a cold engine, the system uses an auxiliary water pump to force the hot coolant into the engine. This 'preheating' of the engine reduces HC exhaust emissions.

Coolant Heat Storage Tank

The storage tank is a large vacuum insulated container located near the left front bumper.

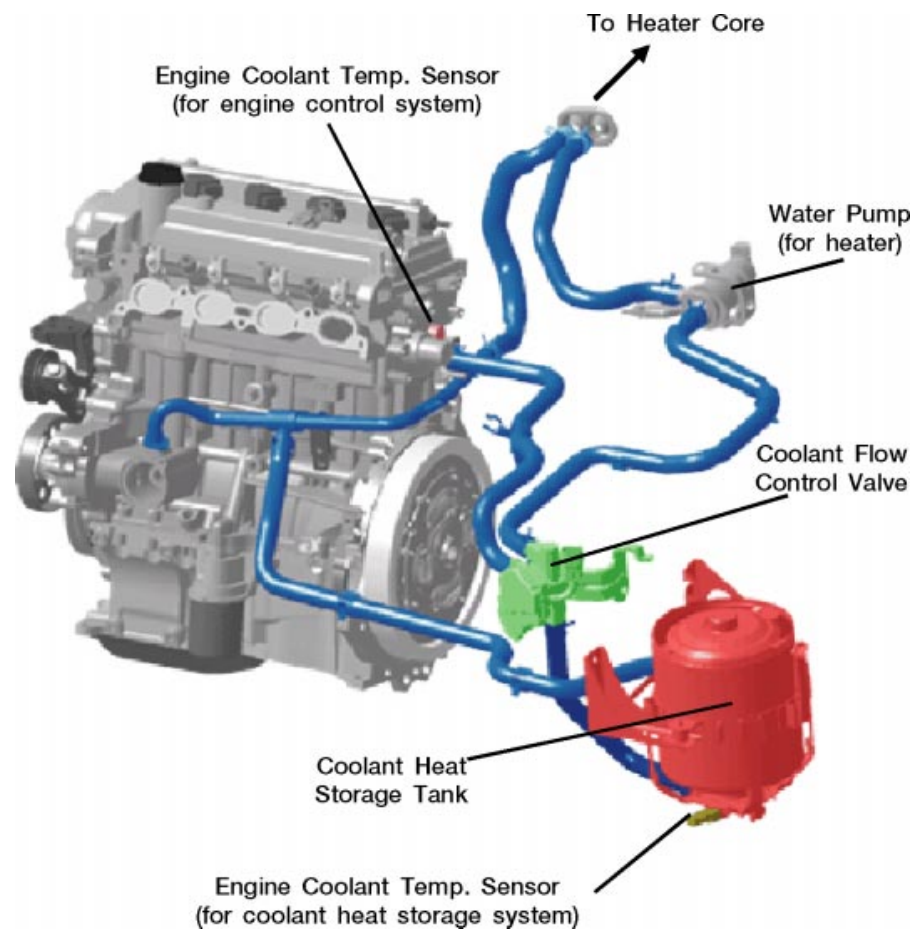


Figure 4.12

T072f203c

**Coolant Heat
Storage Tank**

Coolant Drain Plug

Outlet Temp Sensor



Figure 4.13

T072f204p

**Coolant Heat
Storage Tank**

Water Pump



Figure 4.14

T072f205p

SERVICE TIP

When servicing the coolant system on the '04 & later Prius:

- Disconnect the coolant heat storage water pump connector to prevent circulation of the coolant and prevent possible injury.
- Drain the engine coolant.
- When refilling, operate the coolant heat storage water pump to help the inflow of coolant into the tank.

Rotary Water Valve

Switches between three positions to control flow of coolant in and out of coolant heat storage system.

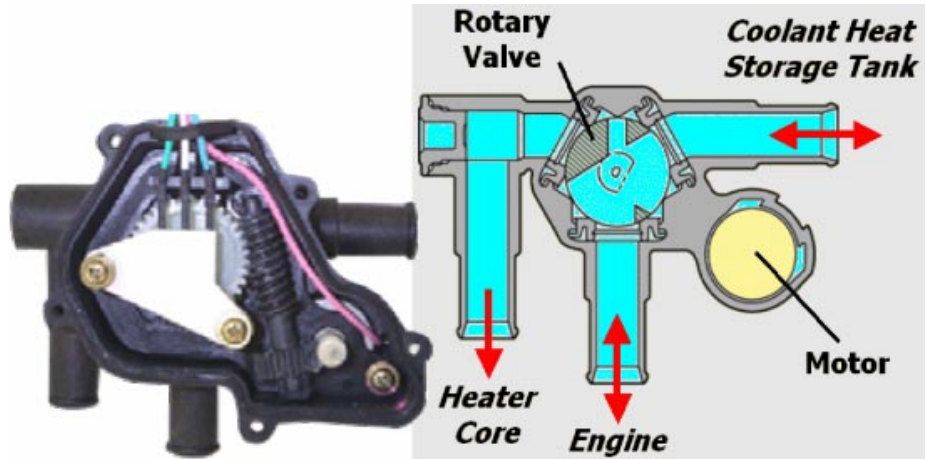


Figure 4.15

T072f206c

Coolant Heat Storage Tank Operation

Preheat Operation.

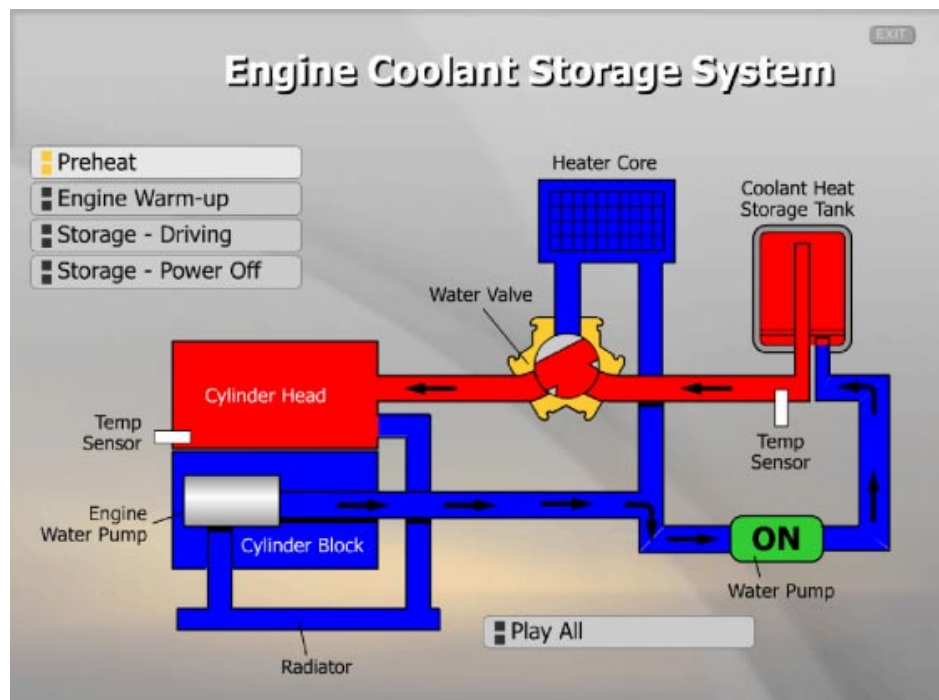


Figure 4.16

T071f416c

Coolant Heat Storage Tank Operation

Engine Warm-up
Operation.

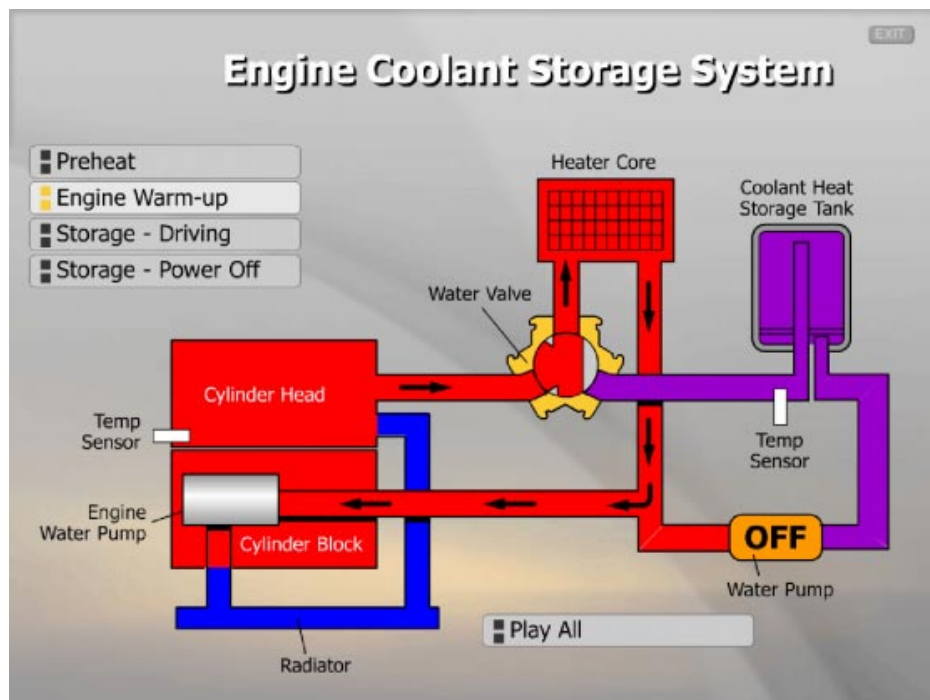


Figure 4.17

T071f417c

Coolant Heat Storage Tank Operation

Storage Operation
(during driving)

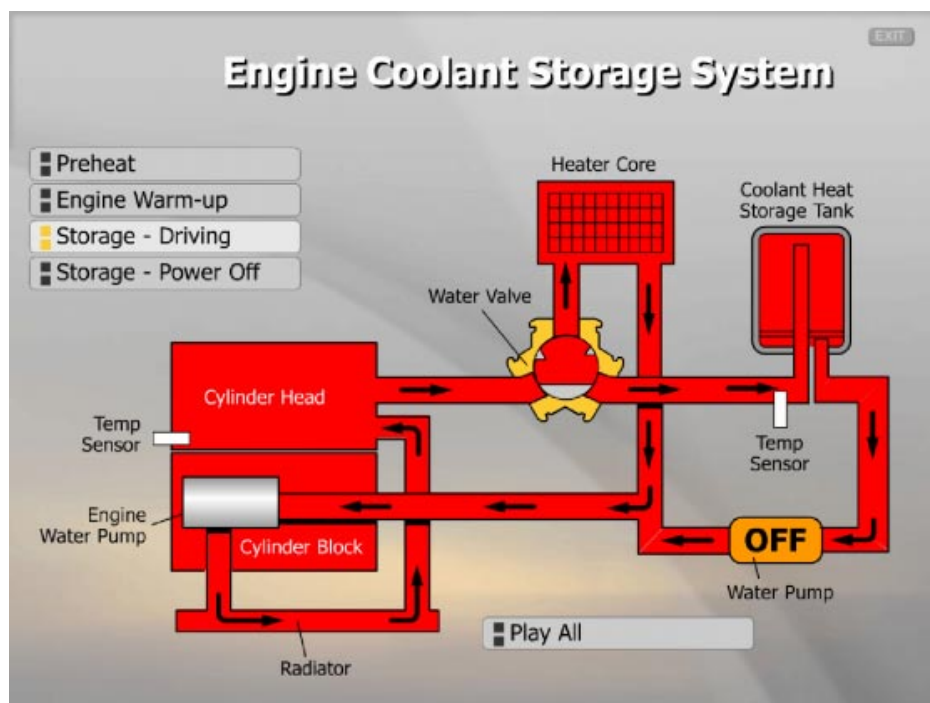


Figure 4.18

T071f418c

Coolant Heat Storage Tank Operation

Storage Operation
(IG-OFF)

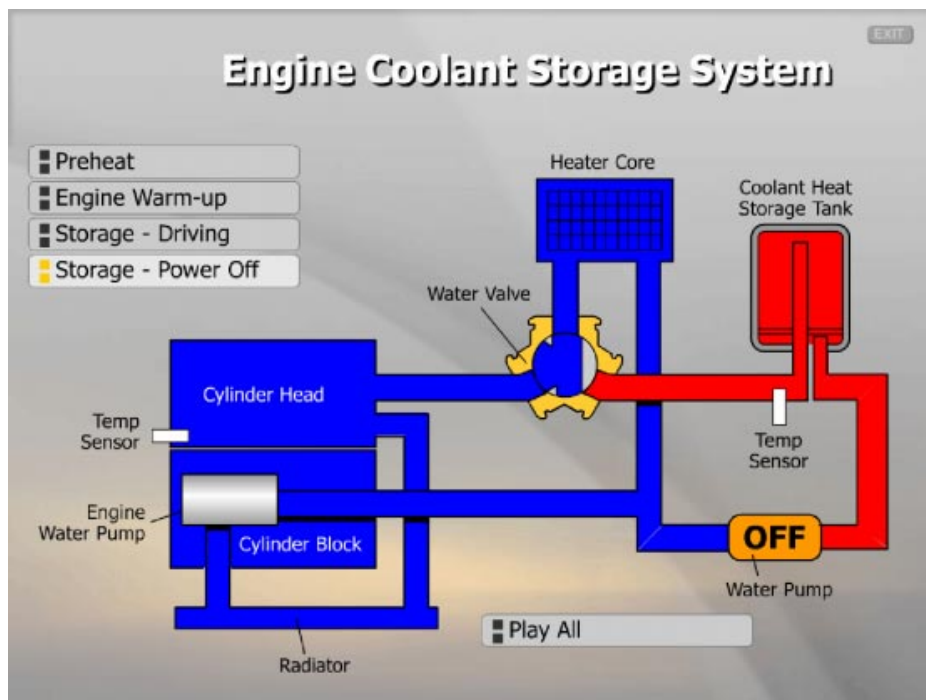


Figure 4.19

T071f419c

Bladder Fuel Tank The bladder fuel tank reduces the amount of fuel lost to evaporation. To prevent evaporation the fuel is stored inside a flexible resin storage tank sealed within a metal outer tank. The resin tank expands and contracts with the volume of the fuel, so the space into which fuel can evaporate is minimized. This approach dramatically reduces evaporative emissions.

Fuel Bladder

The resin bladder in the Prius fuel tank expands and contracts with the changing quantity of fuel.

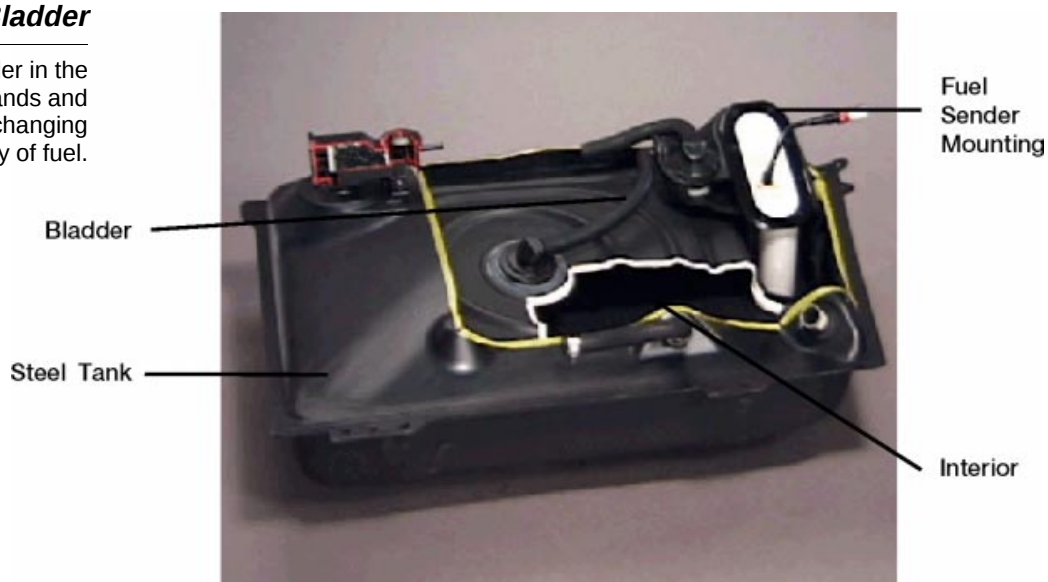


Figure 4.20

T071f420p

Fuel Gauge The direct acting fuel gauge is located in the sealed inner tank. This gauge consists of a pipe surrounded by a coil. A magnet attached to a float in the pipe moves up and down with changes in fuel level causing a change in the coil's magnetic field. This results in a slight difference in potential at either end of the coil that is read by the Meter ECU.

NOTE

The fuel pump is integrated with the fuel tank and cannot be serviced separately.

Fuel Gauge Sender

Direct-acting fuel gauge, consisting of a magnetic float, is located in the sub tank.

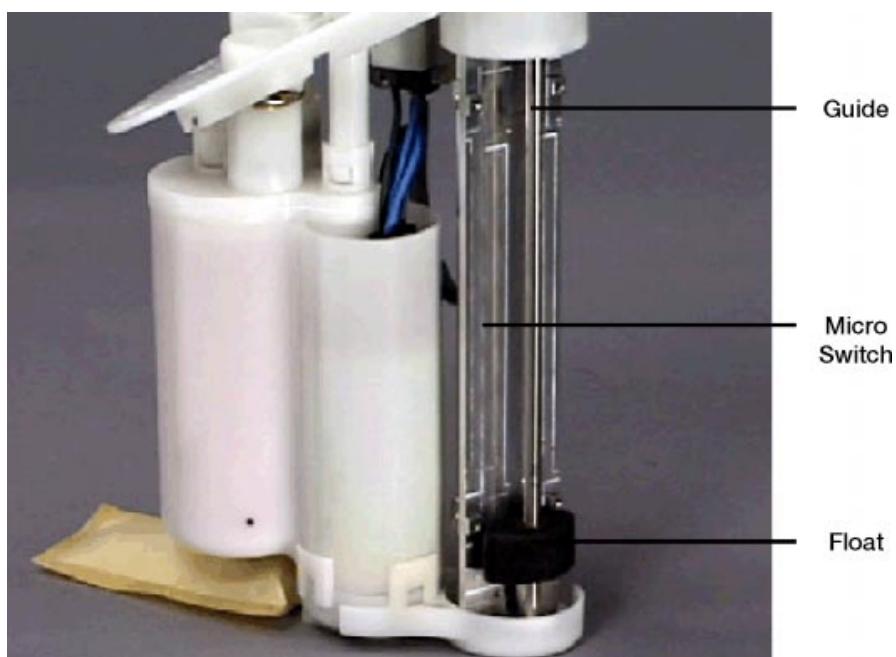
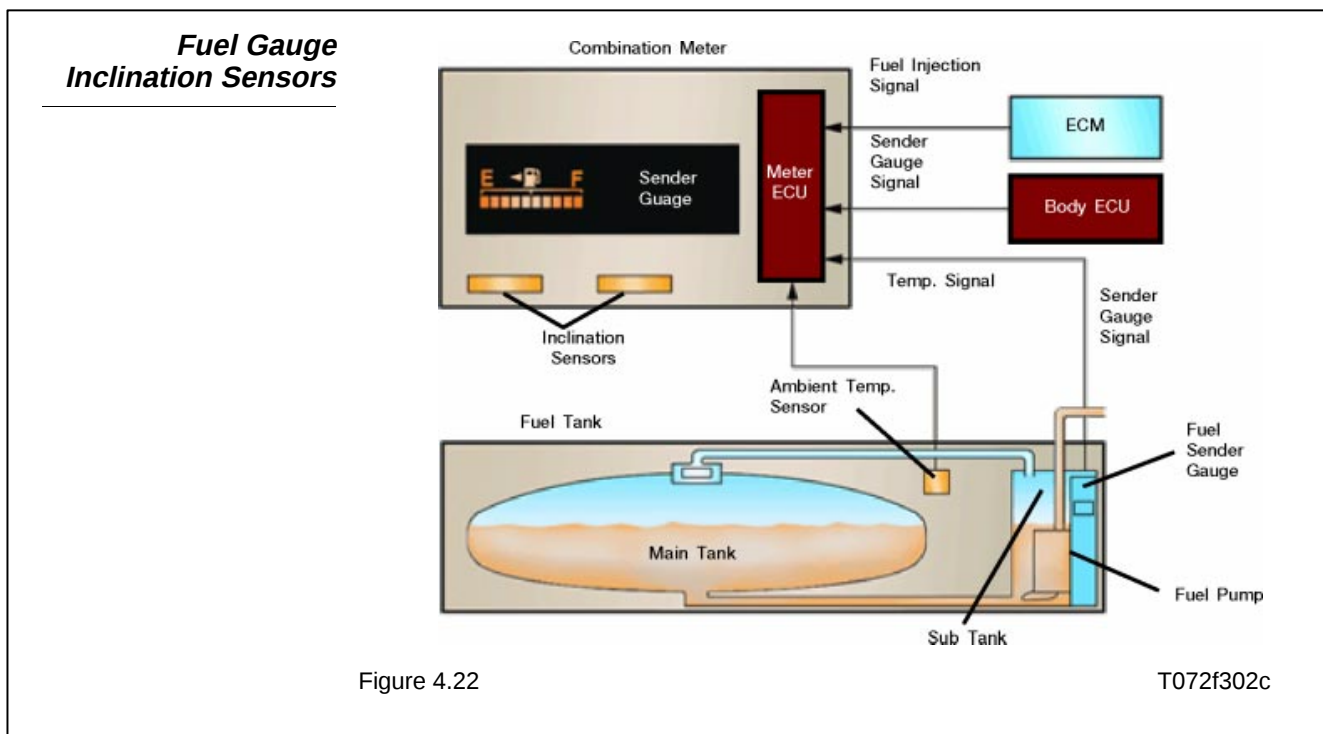


Figure 4.21

T071f421p

Inclination Sensors There are two inclination sensors located in the meter ECU that detect vehicle longitudinal and latitudinal inclination to correct the fuel level calculation. Corrections are made based on the signals from the inclination sensors and the ambient temperature sensor located in the fuel tank.

The inclinometer must be reset if the driver can only pump a few gallons of gas into his/her tank, or the vehicle runs out of gas with three or four bars left on the fuel meter. The inclinometer must also be reset if the Prius is refilled on an excessive slope or if the fuel gauge becomes inaccurate. Please refer to the Prius Repair Manual for the inclinometer calibration procedure.



NOTE

Unlike conventional vehicles, on a hybrid vehicle the engine may start many times in a single drive cycle. This increases potential “hot soak” issues.

Fuel Capacity Fuel capacity can vary for several reasons:

- Temperature - At low ambient temperatures, the resin material used for the flexible inner tank may lose some of its ability to expand during refueling. If the outside temperature is 14°F, the size of the tank is reduced by approximately 5 liters.
- Fuel Nozzle Fit - The bladder fuel tank uses gas pump pressure to help inflate the bladder during refueling, so the Prius fuel filler neck is equipped with a rubber seal to ensure a tight seal between the pump nozzle and the filler neck. If the gas pump nozzle is dented, scratched, or gouged the poor fit between the pump nozzle and the filler neck can reduce fuel tank capacity.

NOTE

Overfilling (trying to force additional fuel into the tank) pushes excess fuel into the EVAP system. This may cause EVAP DTCs and may even require the replacement of some EVAP system components.

Energy Monitor The Energy Monitor, which includes a historical bar graph and total trip fuel economy (MPG), is very accurate. Multiple, comparative calculations are performed by several computers.

Fuel usage and fuel economy are calculated by monitoring fuel injector duration and operating frequency. The ECU compares these values with miles traveled to calculate miles per gallon.

The battery ECU closely monitors energy consumption in Watts. By calculating the amount of energy spent, recovered, and stored, the computer can calculate the required fuel burn. Fuel required to create this amount of energy is compared against the engine ECU fuel injection calculation to insure accuracy.

Driving pattern, speed, and load characteristics are stored in the HV ECU as “Historical Data.” Historical Data is used to further refine the MPG calculation. This data takes about three to six weeks to accumulate if the battery is disconnected or the HV ECU is replaced.

Fuel Type & Octane Rating Use only 87 Octane unleaded gasoline in the Prius. The Prius has a smaller fuel tank opening to help prevent nozzle mix-ups. At a minimum, the gasoline used should meet the specifications of ASTM D4814 in the United States. Do not use premium gasoline. It may causes starting problems with the Prius. There is no gas mileage benefit when using premium gas!

EVAP System Checks

To check for leaks in the EVAP system the Prius introduces purge vacuum into the entire system, then looks for changes in pressure. Any loss of vacuum indicates a leak in the system.

To detect EVAP leaks from the vapor reducing fuel tank, the Prius uses the density method. This method uses an O₂ sensor to measure HC density in the exhaust gases. Added HC from a leak will cause a reduction in exhaust oxygen content.

EVAP Parts Location

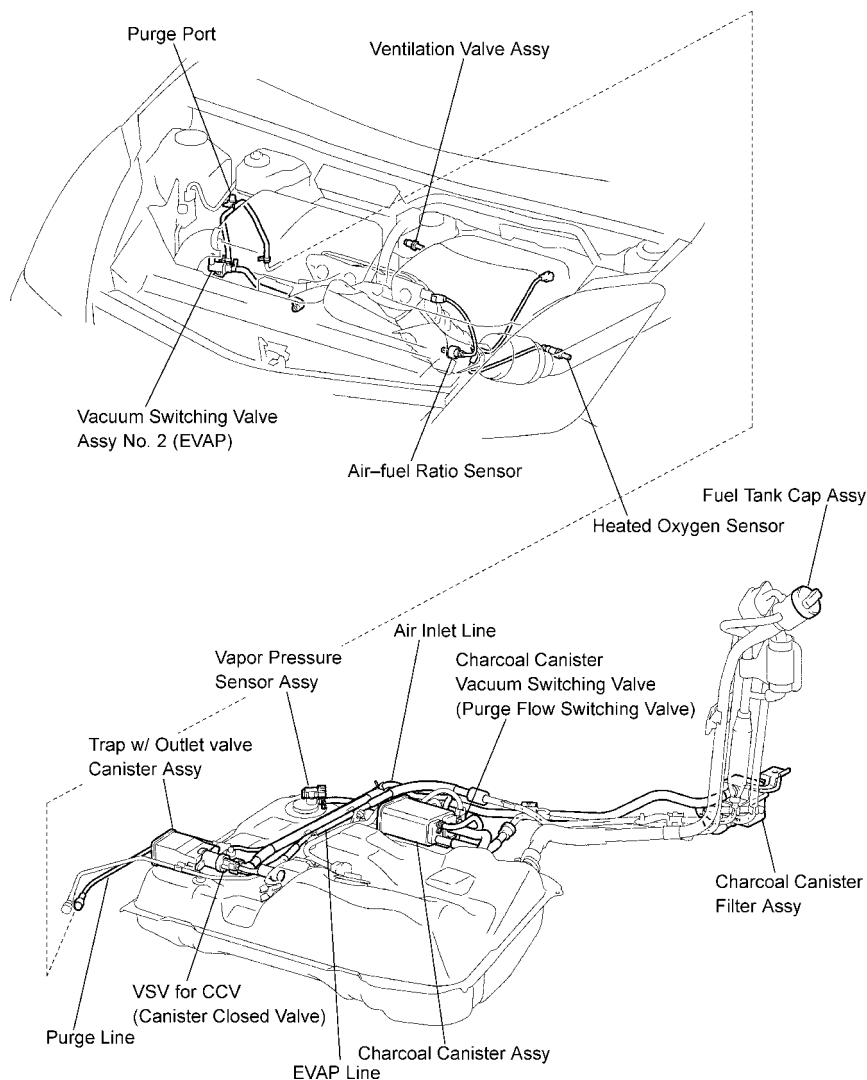


Figure 4.23

T072f020c

EVAP Components The EVAP system includes the following main components:

- Canister Closed Valve VSV – This **normally open** valve is located between the fresh air line and the fuel tank. This Vacuum Switching Valve (VSV) stops airflow into the EVAP system to seal the system and enable leak detection. It is also known as the CAN CTRL VSV or the CCV VSV.
- Purge Flow Switching Valve VSV – Allows vacuum from the EVAP VSV (or Purge VSV) to flow through the canister. When activated by the ECM during internal fuel bladder leak detection, it switches airflow from the canister to the outer tank bladder only. This VSV is also called the Tank Bypass VSV on the Diagnostic Tester.
- EVAP (Alone) VSV – Is used to control engine vacuum to the EVAP system in order to remove stored hydrocarbons from the charcoal canister. It is also used for system leak detection and may be referred to as the Purge VSV.
- Vapor Pressure Sensor (VPS) - The ECU provides a 5V signal and ground to the Vapor Pressure Sensor. The VPS sends a voltage signal back to the ECU, which varies between 0.1 – 4.9V in response to tank pressure.
- Fuel Cutoff Valve - Causes the filler nozzle to shut off when the fuel tank is full to prevent overfilling.
- Refuel Check Valve - Anti-siphon valve that prevents fuel from entering EVAP system lines. Also called Tank Over Fill Check Valve.

NOTE

The following VSVs are referred to by several different names in some Toyota repair information:

- CAN CTRL VSV - Canister Closed Valve or CCV VSV
- Tank Bypass VSV - Purge Flow Switching Valve
- EVAP VSV (Alone) - Purge VSV
- Refuel Check Valve - Tank Over Fill Check Valve

EVAP Control Components

On the '04 & later Prius, the fresh air inlet has been relocated from the air cleaner to the vicinity of the fuel inlet.

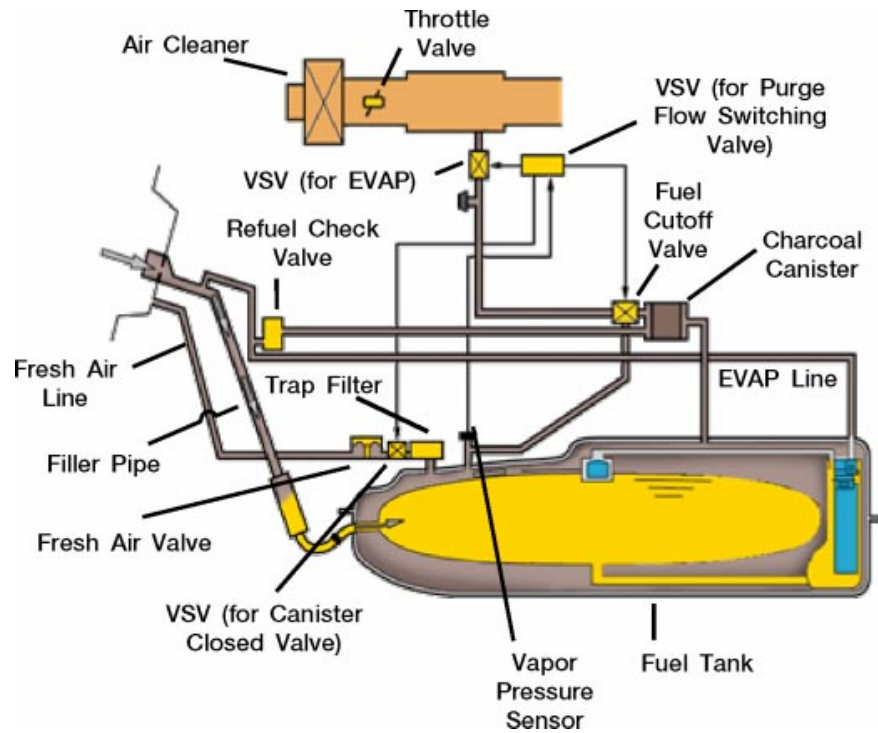


Figure 4.24

T071f424c

Operation - ORVR Refueling

When refueling, the engine is OFF and EVAP VSV is CLOSED (OFF). The resin bladder expands as fuel enters, so there is virtually no vapor space above the fuel. Hydrocarbon (HC) vapor flows from the secondary tank and fuel pump through the EVAP line to the charcoal canister where the HC is absorbed and stored.

Airflows from the charcoal canister to the airspace between the metal outer tank and bladder and to the Canister Closed Valve. The Canister Closed Valve (CCV) is OPEN, allowing air to exit from the Fresh Air Valve. The Refuel Check Valve and Fuel Cutoff Valve work together to prevent overfilling and liquid fuel from entering the charcoal canister.

ORVR Refueling

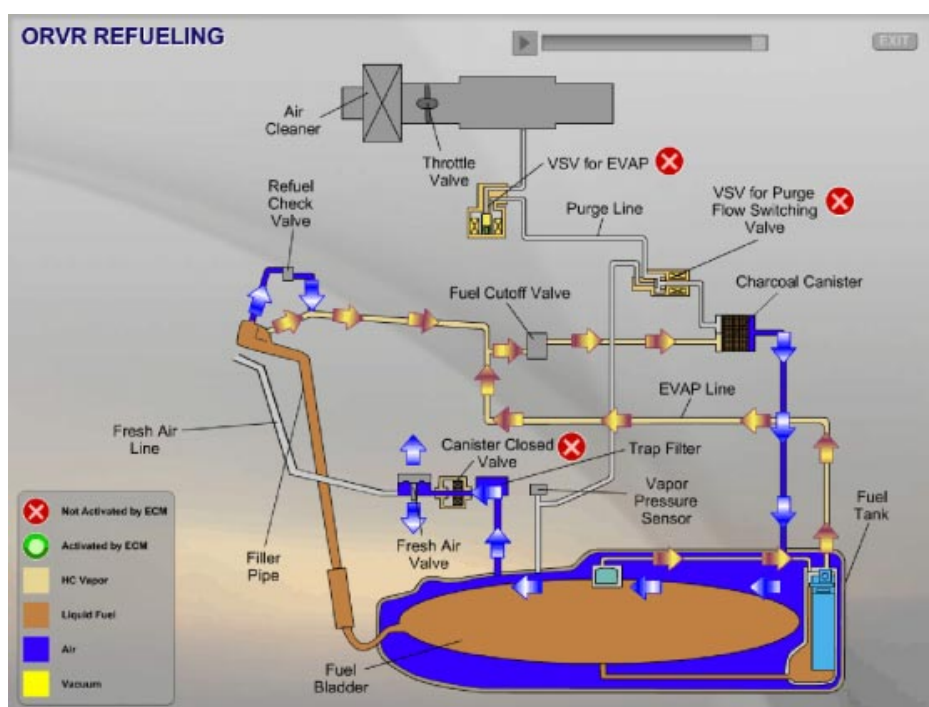


Figure 4.25

T072f028c

Purging During normal purge operation the engine is running and the ECM duty cycles the EVAP VSV ON and OFF allowing vacuum from the intake manifold to pull air through the EVAP system. The Purge Flow Switching Valve is OFF, opening the connection between the charcoal canister and the EVAP VSV. HC vapor flows from the charcoal canister to the EVAP VSV and into the intake manifold.

The Canister Closed Valve (CCV) is OPEN, allowing fresh air to enter from the air cleaner and flow through the airspace between the metal outer tank and bladder and up to the charcoal canister. As this air passes through the canister, it purges the HC.

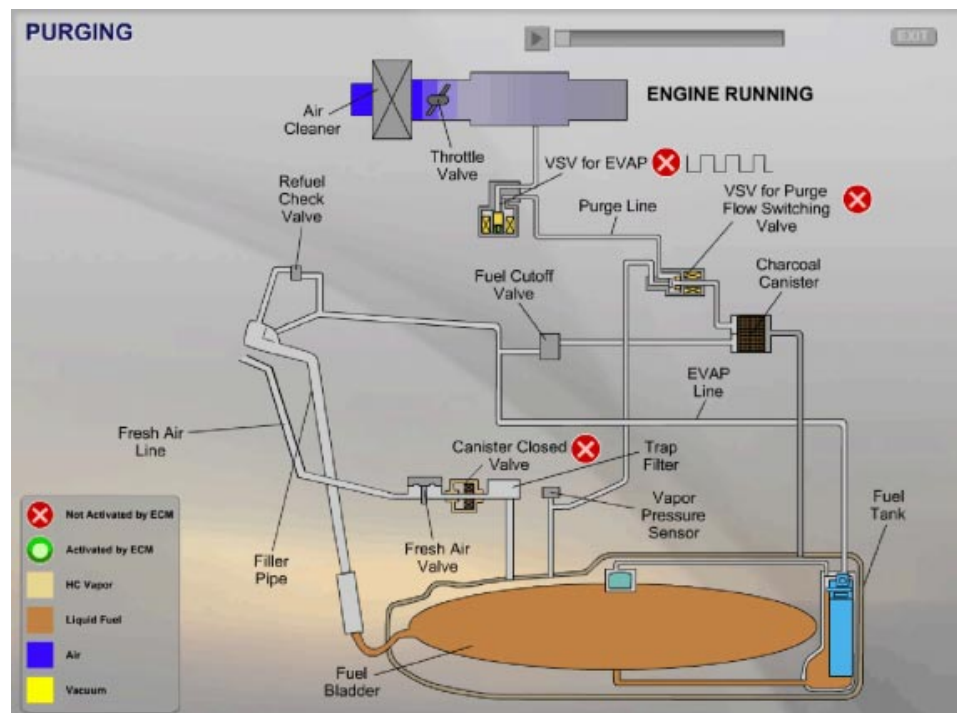


Figure 4.26

T071f426c