While no one was looking very hard, Ford suddenly has become the first U.S.-based manufacturer of a gasoline-electric hybrid sedan – the 2010 Fusion, which is boasting best fuel economy in the class (41 mpg). However, Ford also is in its sixth year of making the compact car-like SUV, the Escape hybrid (and its twin sister the Mercury Mariner hybrid), and so it wouldn’t be surprising if you were starting to see one in your shop every now and then. This is a true high-voltage hybrid (330-volt nickel metal hydride battery pack) that can move on its electric motor alone, not one of those “mild hybrids” that have little more than engine stop-start and a 42-volt system.

Yes, it has a conventional 12-volt air conditioning system, so if the A/C is on, the engine will not stop when the vehicle does—or it will. The it-will-it-won’t depends on whether or not the motorist has:

- Selected Max A/C on models with manual air conditioning. If the system is in Max A/C, the engine will continue to run to keep the A/C going, even when the vehicle stops at a traffic light. If it’s in another A/C position, the engine will stop and so will the air conditioning (Figure 1). The manual A/C system with vacuum actuators and a cable to control the blend-air (temperature) door was used on 2005 through 2007 models.
- Pressed the ECON button on the control head of the hybrid with Ford’s Dual Automatic Temperature Control, which was installed on the Escape/Mariner hybrids starting in the 2008 model year (Figure 2). On most cars, the ECON button engages a mild shift strategy to improve fuel economy, but on the Escape/Mariner hybrid, it simply lets the A/C turn off during a braking stop, as at a traffic light. If the ECON button is not pressed, the engine will not shut down during a braking stop if the A/C is on.

The Escape/Mariner compressor is a conventional belt-driven design, with a non-replaceable shaft seal. Unlike the regular Escape/Mariner, the compressor in the hybrid has...
a thermal protection switch in the housing, next to the dis-
charge port. It’s wired in series with the A/C clutch coil. If
compressor discharge temperatures heat the switch to 239
degrees F., the switch opens to disconnect the clutch. The
switch resets at 221 degrees F. Typically, when the switch
fails, it’s open at normal ambient temperatures. You have to
know the switch is there and to look for it, as it doesn’t show
up in the wiring diagrams. However, the only “book” repair
is to replace the compressor.

Like many imports, the Escape hybrid uses a dual pres-
sure switch on the receiver-dryer. One pair of contacts opens
at high pressure to signal the powertrain control module to
disengage the A/C clutch (it’s in series with the ambient-
low pressure switch for low refrigerant charge). The second
set of contacts opens at moderate pressure to provide a
PCM trigger for high-speed fan. Unfortunately, Ford does
not provide pressure specifications for either of the sets of
switch contacts. The only diagnostic procedures available
are for switch failure: system-off, resistance across termi-
nals, which really doesn’t help much. The usual rules-of-
thumb for these switches are to trigger the high-speed fan
at about 230-270 psi and disengage the A/C clutch if high-
side pressures exceed 350 psi.

But what is most important is that the Escape/Mariner
hybrid also has an auxiliary air conditioning system – strict-
ly for the 330-volt battery pack (Figure 3). Unlike the simple
ductwork with fan for cooling the battery pack in other
hybrids, such as the Toyota Prius, this is true A/C – with
underbody refrigerant lines to an auxiliary expansion valve
and evaporator, a pair of fans in the battery box, even its
own air filter. Apparently, the location of the batteries and
the temperatures they encounter under some circumstanc-
es could require more than just fans in the Escape (Figures
4, 5).

That means that proper A/C operation is important not
only for occupant comfort, but for battery life too. The hy-
brid vehicle system also has a much larger oil fill (11 ounces
vs. 5 for the conventional Escape/Mariner, and requires 50%
more refrigerant (38 ounces vs. 25 for the conventional mod-
els).

We can’t say if this auxiliary A/C approach is something
you’ll possibly see in other hybrids. However, the rear A/C
housing also could cool a lithium-ion battery pack, as we’ve
heard will be in a Mercedes gas-electric hybrid sold in Eu-
rope. But the additional possibilities (or none) don’t change
the fact there’s a lot of Escape and Mariner hybrids on the
road, the vehicles remain in production and you have to be
prepared to work on them.
Most of the Escape/Mariner is covered by a conventional 3/36 warranty (long expired on many of the vehicles). However, the battery pack (not including the 12-volt accessories’ battery) and electronic/electrical system for hybrid operation are covered by a special warranty – eight years or 100,000 miles, whichever comes first. So even that may be expired on mileage. The auxiliary air conditioning, to the extent that it ties into the regular A/C for the passenger cabin, would be limited to 3/36. If there is a hybrid system shutdown caused by anything outside the hybrid-specific components, of course, that’s a customer-pay, even if the 8/100 warranty is still in force.

continued on page 5

HYBRID BASICS OVERVIEW

In case you really don’t understand the basics of a gas-electric hybrid, here’s an overview. The Escape/Mariner is a “series/parallel” hybrid, with a special version of the 2.5-liter four cylinder (prior to 2009, the previous version—2.3 liters—was used).

- With a simple series hybrid, the electric motor is the only way power goes to the wheels – none available yet, but wait for the Chevy Volt. The motor in the Volt either will be powered by the high-voltage battery pack, or if depleted, by a generator on a small engine.
- With a parallel hybrid (all Honda hybrids), both the engine and the electric motor work together all the time to

---

**Figure 6.** Wiring schematic for auxiliary A/C system (2008 model shown, with Dual ATC system). Notice that “refrigerant distribution valve” (for cabin A/C) is controlled by the PCM, and that the “battery zone valve” for auxiliary air system is controlled by Traction Battery Control Module. Although not shown, the high-voltage battery box fans also are controlled by the TBCM.
turn the wheels, with the motor basically adding power to what the engine supplies.

- The Escape/Mariner, the new Fusion hybrid, and all Toyota and General Motors hybrids (except the 42-volt “mild hybrids”) are series/parallel types, which means they can run entirely on electricity from the battery pack powering what is called a “traction motor,” or entirely on gasoline engine power, or by a combination of the two. The traction motor is built into a transmission assembly, along with a second motor, called the “generator motor,” which both starts the engine (no conventional starter on the engine) and also charges the batteries (no conventional generator either).

The power distribution to move the Escape/Mariner hybrid is regulated by the Powertrain Control Module (PCM) in conjunction with the Transmission Control Module (TCM). When the vehicle is being braked, the wheels feed back energy, to turn the traction motor in the opposite direction, in which it then operates as a generator to charge the batteries. This also further helps slow down the vehicle, and the electricity it generates in the process is called “regenerative braking.”

As on all hybrids with high-voltage battery packs, the box that holds the Escape/Mariner nickel metal hydride batteries (250 D-cell size) is in back, above the rear axle. The battery box also holds the TBCM (another acronym you’ve got to know)—Traction Battery Control Module. Those batteries power the “traction motor,” the one that moves the Escape/Mariner on electricity, or contributes to vehicle acceleration. The TBCM both monitors the batteries and conditions in the box, and controls the auxiliary HVAC system that keeps them cool (Figure 6). The battery pack is called the High Voltage Traction Battery (HVTB) and it’s rated at 330 volts. The peak voltage in the hybrid system, however, can go up to about 400 volts. The high-voltage system is NOT grounded to the vehicle chassis. The circuit is isolated from the chassis, in what is called a “floating ground.”

The battery pack is under the luggage area floor. Lift the carpet and there’s the box cover plate (Figure 7). The safety switch, to ensure that high voltage isn’t floating though the vehicle where it could pose a danger, is at the right side of the cover plate. For maximum safety when working on the car, always turn the switch to the off position, labeled “Service Shipping, No Voltage,” although the high-voltage pack also is disconnected whenever the ignition is off. The pack also contains a fuse that opens in case of a short circuit, another level of protection. And all high-voltage connectors disable the high voltage whenever they’re unplugged.
Focus On The Refrigeration System

As noted earlier, there are two variations of the system, one for the 2005-07 manual A/C, one for the electronic ATC since 2008.

2005-07 Models with Manual Passenger Cabin A/C: The TBCM is able to communicate with the PCM, which controls A/C compressor operation. If the TBCM decides it needs A/C to cool the high-voltage battery pack, it will transmit the A/C request on a data bus. The engine will start and the compressor will run, even if the dashboard control head is in the OFF position, and even if the engine had been off because the vehicle has been braked to a stop. The TBCM simultaneously will open a refrigerant zone valve at the auxiliary system to allow refrigerant flow into the rear evaporator (Figure 8). And when it does this, refrigerant flows through the entire system – front and auxiliary (although with the HVAC blower off, there wouldn’t be much, if any, passenger compartment cooling). This system does include an evaporator temperature sensor, which along with other sensors, allows the PCM to cycle the compressor.

2008-on Models with Automatic Temperature Control: The TBCM also can ask for A/C, and the compressor and auxiliary system will operate similarly to the manual A/C with one exception: there is a second refrigerant zone valve, at the right front strut tower, controlled by the Powertrain Control Module, which also gets signals from the Dual ATC module, itself taking reports from the evaporator temperature sensor. If the motorist is not asking for A/C, the front refrigerant valve will close and the refrigerant flow will bypass the under-dash evaporator, saving pumping energy (Figure 9). This setup also reduces the possibility of front evaporator ice-up under some possible conditions.

The electronic Dual ATC already was in use on other models, so Ford just adapted it for the 2008-on Escape/Mariner hybrid. The box-like refrigerant zone valves may look alike, but they are not interchangeable.

With either system, the TBCM operates the battery zone valve, the pair of 12-volt fans that are built into the High Voltage Traction Battery box, and a pair of air flaps on the auxiliary A/C housing – one for outside air, one for recirc. When outside air by itself is sufficient for cooling, it comes in through a slot in the rear quarter window, and airflow exits through a slot behind the rear bumper (Figure 10). To avoid an ambient air debris buildup on the batteries, there’s an air filter in the housing, and it’s accessible by removing a panel cover in the left rear of the vehicle. When the auxiliary A/C is operating, the system is in recirc.

Most parts of the auxiliary A/C are individually replaceable, including the evaporator, TXV, refrigerant lines, air temperature sensor, temperature door actuator and battery box zone valve. However, the battery box is an assembly in itself – including not only the cells that comprise the High Voltage Battery Module, but the TBCM and the two cooling fans it controls.
Battery Cooling Is Always A Priority

If the passenger cabin is being cooled, and the HV battery pack temperature gets too high, the TBCM opens the battery zone valve, and also tells the PCM what it’s done, so the PCM can watch both temperature sensors for possible evaporator icing.

As we’ve said, under any circumstances, the need for HV battery pack cooling overrides an engine shutdown, as during a traffic stop. The engine will run, even with no A/C request for the cabin.

Diagnosis

Basically, system diagnosis is pretty much the same as any conventional 12-volt A/C with an auxiliary system in the rear. The significant exceptions are that:

- The operating strategies are determined in part by the battery box cooling requirements.
- The rear fans and rear A/C module (that TBCM) are all part of the box that holds the high-voltage battery pack, but as we’ve pointed out, they’re on a 12-volt circuit.
- The zoning of the front and rear systems, with the computer control of a solenoid-type refrigerant flow valve by the Dual ATC module (cabin valve), and auxiliary A/C refrigerant flow valve by the TBCM (high-voltage battery box).

The two systems are covered by many trouble codes, with the passenger cabin system codes primarily HVAC. All HVAC module codes are “B” codes (HVAC is a body module), except for four “U” codes (communications between modules—see MACS Service Reports, May, 2009 issue).

The auxiliary system codes are in the TBCM. Seven are “P” (powertrain) codes, and two are “B” (body) codes. See chart (Figure 11).

The code diagnostics all refer the technician to a pinpoint test. We know that technicians would prefer to look to the diagnostic routine, to see what part is involved, and replace it. There’s a widespread attitude that all the pinpoint tests will do is make you go through a slew of tests for every strip of wiring in the circuit, just to prove that the problem is really in a module. Honest, that isn’t so, and the first time you find a damaged wire or a bad connection, you’ll become a believer.

All the TBCM tests are of low-voltage circuits. Only one is for an ignition-on voltage test at the evaporator temperature sensor terminal (4.7 to 5.3 volts), a test made for diagnosis of Code B2950. The others are made with the ignition off, for resistance readings. Because the high-voltage battery pack fans are built into the box, if there’s a battery pack fan code, you can listen for fan operation (or probably not) with a stethoscope at the pack box.

Cooling Systems

Like other series-parallel hybrids, the Escape has a pair of cooling systems and three water pumps – one engine-driven and two electric. One of the two electrics is to provide some circulation of engine coolant for heating when the engine is turned off during a braking stop (Figure 12).

<table>
<thead>
<tr>
<th>DTC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1239</td>
<td>Airflow Blend Door (also called mode door)</td>
</tr>
<tr>
<td></td>
<td>Driver Circuit Failure</td>
</tr>
<tr>
<td>B2950</td>
<td>Air Conditioning System Circuit</td>
</tr>
<tr>
<td>P0535</td>
<td>A/C Evaporator Temperature Sensor Circuit Failure</td>
</tr>
<tr>
<td>P0A7E</td>
<td>Hybrid Battery Pack Over Temperature (if any related DTCs are present, DIAGNOSE those DTCs first. If no other DTCs are present, TEST the base A/C system)</td>
</tr>
<tr>
<td>P0A81</td>
<td>Hybrid Battery Pack Cooling Fan 1 Control Circuit Failure</td>
</tr>
<tr>
<td>P0A96</td>
<td>Hybrid Battery Pack Cooling Fan 2 Control Circuit Failure</td>
</tr>
<tr>
<td>P0A9B</td>
<td>Hybrid Battery Pack Temperature Sensor Circuit Failure</td>
</tr>
<tr>
<td>P2612</td>
<td>A/C Refrigerant Distribution Valve (Battery Zone) Control Circuit Low</td>
</tr>
<tr>
<td>P2613</td>
<td>A/C Refrigerant Distribution Valve (Battery Zone) Control Circuit High</td>
</tr>
</tbody>
</table>

Figure 11. Traction Battery Control Module system has its own set of diagnostic trouble codes, separate from those for the main HVAC system. Ford service information (such as www.motorcraftservice.com) has pin-out tests for sensors and actuators.

Figure 12. Operation of motor electronics liquid cooling system is as critical for hybrid operation, as is the high-voltage battery box. The underhood system has a dedicated electric water pump (4), a specific (smaller) radiator (7) located in front of the engine cooling radiator, and a specific pressurized coolant reservoir. Hoses (5) and (6) go to the transaxle. Other parts: (1) “degas” reservoir; (2) motor electronics cooling hose to specific radiator; (3) hose from “degas” reservoir to electric pump;
The other electric pump is part of the motor electronics cooling system. It is a specific circuit with its own reservoir (adjacent to the engine coolant reservoir), and its own radiator, a heat exchanger not quite as tall as the one for the engine cooling system. It uses the same coolant (Zerex G-05, also used by Mercedes-Benz, Chrysler – although with orange dye—and all other Ford products except the old Mercury Cougar, for which a DexCool-type coolant is supplied). Both coolant reservoirs (unlike some other hybrids) have the same pressure cap (17 psi) (Figures 13).

The flow circuit is from both the pressurized reservoir and the motor electronics to the electric pump, and through the electric CVT (continuously variable transmission) into the driver’s side of the electronics radiator, through that, and back to both the pressurized reservoir (which Ford calls a de-gas bottle) and motor electronics. Note the T-fitting that brings the flow from both the reservoir and motor electronics to the pump. Also note the radiator hose (at upper right) back into the reservoir and motor electronics.

The pump runs whenever the ignition is on, which tells you that the electronics generate a lot of heat. There is no temperature sensor to trigger it. It’s not exactly noisy (or it shouldn’t be), but you can check the pump from underneath with the car on a lift – you either should be able to hear it run with a stethoscope, or if you feel it, note the slight vibration.

If there’s a motor electronics/transaxle cooling problem, an instrument cluster warning light in the shape of a red triangle should go on (Figure 14). And if you check for trouble codes, you could get any or all of the following: P1AOE, P1AOF, POA3C, POA7A, POA7C and P1AOD. That red triangle could be for other faults in the motor electronics, but if you see those codes, a cooling system check would be worth doing.

We’re not going to take you through the diagnostic routines or pin-out tests for these codes, and the others that also could be logged. But we’ll describe the codes to show you what happens when there’s a motor electronics cooling system failure.

- **P1AOF**: Hybrid PCM, vehicle disabled
- **POA3C**: Drive motor “A” inverter is over temperature (yes, running too hot)
- **POA7A**: Generator inverter performance (could be almost anything in the circuit, but with all these other codes relating to temperature, the motor electronics cooling system is certainly suspect)
- **POA7C**: Motor electronics coolant temperature sensor indicates over-temperature condition (well here you’re getting the word from the sensor itself)
- **POA3D**: Hybrid PCM code, generator disabled
- **POA3E**: Hybrid PCM code, generator inverter is over temperature (you get the idea)
- **POA3F**: Hybrid PCM code, vehicle disabled (well, are you surprised if everything’s running too hot?)
- **P1AOC**: This is an informational code, confirming that the vehicle is in a limited operating strategy, which means that it’s running, but obviously not normally, particularly the hybrid section.

The PO codes are generic, and they should be enough to point you to the cooling system. The P1 codes are maker-specific, and if you have Ford enhanced data, they may come up, depending on how extensive the enhanced data provided by your scan tool is.

Checking out this cooling system is not dramatically different from any cooling system. The cap has to hold pressure, and there has to be a full system.

The first check is to see if there’s coolant flow through the system, and a simple way is to look for coolant movement in the pressurized reservoir (it may be helpful to see flow if you hold a shop light on the back side of the reservoir). If there doesn’t seem to be flow, check the motor electronics pump itself.

If you do happen to find that the motor electronics electric pump isn’t humming, you can try tapping it, and if it suddenly starts to run, replace it. The pump is part of a complete kit with all the necessary hardware (Ford No. 5M6Z-8C419-A).

If even tapping doesn’t help, check for battery (12-volt) voltage to the pump. If there’s none, you have a circuit problem. If the pump feed terminal has voltage and ground and the terminal connections are good, the pump apparently is dead. It happens. Get the kit.

The electronics cooling system has a capacity of 3.7 quarts, compared with 8.5 quarts for the engine cooling system. To drain the electronics system, put the vehicle on a lift, remove the left side splash shield and disconnect the coolant hoses from the transaxle (Figure 15).

**Boost Starting**

The Escape/Mariner hybrid doesn’t have a generator or a conventional 12-volt starter on the engine, but it does have a 12-volt battery for lights and other accessories (Figure 16). That battery is charged by the high-voltage system through the DC-to-DC converter, which is controlled by the PCM. The 12-volt battery can be boost-started with jumper cables from another vehicle’s 12-volt battery. However, if there is no donor car, and if the engine cranks but doesn’t start, jump-start the high-voltage battery this way: turn the ignition off, remove the panel at the driver’s
side of the dashboard and press the jump start button (Figure 17) then wait eight minutes to allow the 12-volt battery to charge the high-voltage pack, before you try to start the vehicle. Pressing the button will cause a light on the button to go on, and when it flashes rapidly for two minutes, turn the ignition to RUN and try to start the engine. If the button flashes slowly, the 12-volt battery was weak and will need a boost.

Worth remembering: the TBCM is on a maxi fuse – a 50-ampere in the under-hood fuse box.

What You May Want To Buy

For safety, you should wear insulated gloves when working on high-voltage hybrids, but you don’t need (or want) lineman’s gloves, which typically are rated for 7000 volts and above, but would be impractical for working on cars. There are rubber-insulated gloves that offer sufficient protection and let you use fingers and hands normally. Escape/Mariner peak voltage is 400; Prius is 650.

Most ordinary voltmeters probably don’t have the capability of making the insulation resistance tests that are important on hybrids. If you intend to go into hybrid service, you may find it useful to know that Toyota’s recommended meter is a Fluke 1587. It’s Category III 1000-volts, Category IV 600 volts, a specification which many other meters also match. But the ability to perform ultra-high-resistance tests on hybrid high-voltage harnesses is the difference, with a rating of 2 gigohm. If a Fluke 1587 is outside your budget, however, you still should look for an insulation multimeter in another reputable brand that also meets the Cat III-1000/Cat IV-600 spec. The less-expensive Fluke 1577 is rated to 600 megohms, which is adequate, and there are other insulation multimeters with even higher readings, from which you can choose.
1. Technician A says to provide cabin cooling when the engine shuts off, all hybrid vehicles use electrically driven compressors. Technician B says to increase fuel efficiency, all hybrid vehicles use variable displacement compressors. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

2. Most compressor clutch relays on late model cars:
   a. Are grounded/controlled by the BCM
   b. Are solid state devices
   c. Contain diodes
   d. Are universal and interchangeable

3. Technician A says the compressor clutch coil circuit on a 2008 Ford Edge contains a 1.0 amp fuse. Technician B says when testing a diode with a digital multimeter, the diode is bad if the meter reading is not 0.5 volt or higher. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

4. Technician A says the current draw of a typical mechanical-type compressor clutch relay will be 0.50 amp or less. Technician B says the current draw of a typical compressor clutch coil will usually be 3.0 to 5.0 amps. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

5. Technician A says computers can only “understand” digital signals. Technician B says some control module output signals can be on/off, or cycled, and that the effect of this is a variable voltage to the component being controlled. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

6. Technician A says Hall Effect sensors are the most common digital input devices used by control modules. Technician B says varying voltage type sensors can be DC or AC. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

7. Technician A says when diagnosing computer controlled circuits and components, the best tool to start with is a digital multimeter. Technician B says when diagnosing computer controlled circuits and components, the best tool to start with is a scope. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

8. Concerning positive coefficient thermistors, Technician A says when temperature decreases, resistance increases. Concerning negative coefficient thermistors, Technician B says when temperature increases, resistance decreases. Technician A says when temperature increases, resistance decreases. Technician B says when temperature decreases, resistance increases. Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

9. In Figure 11 on page 7, the meter reading is:
   a. 10.37 KΩ
   b. 10.37 Ω
   c. 10,370 ohms
   d. Both a and c are correct

10. Mode door actuators:
    a. May include no provision to prove feedback
    b. May contain a feedback sensor
    c. May contain a logic module
    d. All of the above

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