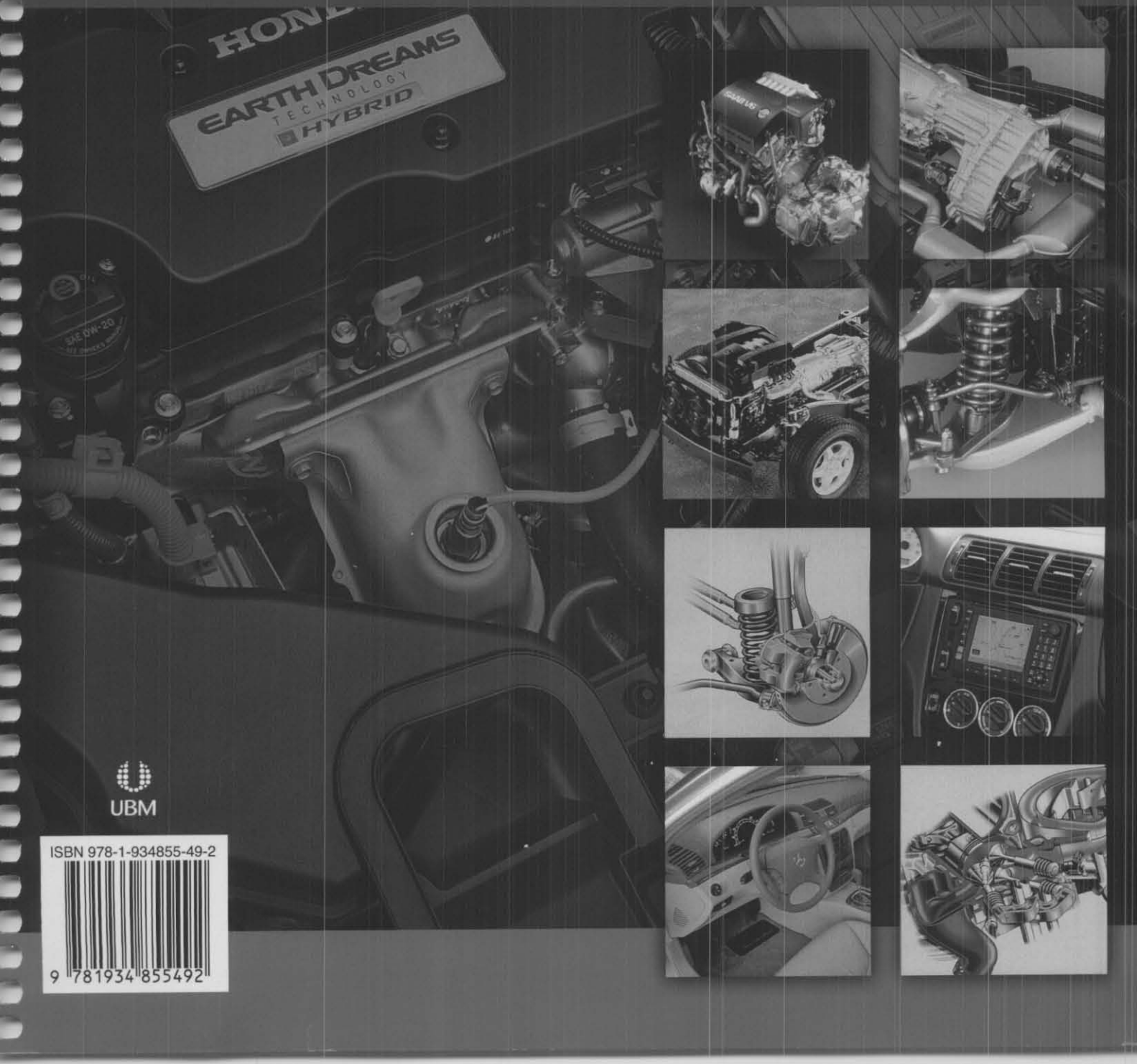
Motor Age TRAINING

Self-Study Guides for ASE Certification

SPECIALIST SERIES

L3 Light Duty Hybrid/ Electric Vehicle Specialist



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ISBN 978-1-934855-49-2

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Taking An ASE Certification Test

This study guide will help prepare you to take and pass the ASE test. It contains descriptions of the types of questions used on the test, the task list from which the test questions are derived, a review of the task list subject information, and a practice test containing ASE style questions.

ABOUT ASE

The National Institute for Automotive Service Excellence (ASE) is a nonprofit organization founded in 1972 for the purpose of improving the quality of automotive service and repair through the voluntary testing and certification of automotive technicians. Currently, there are over 400,000 professional technicians certified by ASE in over 40 different specialist areas.

ASE certification recognizes your knowledge and experience, and since it is voluntary, taking and passing an ASE certification test also demonstrates to employers and customers your commitment to your profession. It can mean better compensation and increased employment opportunities as well.

ASE not only certifies technician competency, it also promotes the benefits of technician certification to the motoring public. Repair shops that employ at least one ASE technician can display the ASE sign. Establishments where 75 percent of technicians are certified, with at least one technician certified in each area of service offered by the business, are eligible for the ASE Blue Seal of Excellence program. ASE encourages consumers to patronize these shops through media campaigns and car care clinics.

To become ASE certified, you must pass at least one ASE exam and have at least two years of related work experience. Technicians that pass specified tests in a series earn Master Technician status. Your certification is valid for five years, after which time you must retest to retain certification, demonstrating that you have kept up with the changing technology in the field.

THE ASE TEST

An ASE test consists of forty to eighty multiple-choice questions. Test questions are written by a panel of technical experts from vehicle, parts and equipment manufacturers, as well as working technicians and technical education instructors. All questions have been pre-tested and quality checked on a national sample of technicians. The questions are derived from information presented in the task list, which details the knowledge that a technician must have to pass an ASE test and be recognized as competent in that category. The task list is periodically updated by ASE in response to changes in vehicle technology and repair techniques.

There are five types of questions on an ASE test:

- **Direct, or Completion**
- **MOST Likely**
- **Technician A and Technician B**
- **EXCEPT**
- **LEAST Likely**

Direct, or Completion

This type of question is the kind that is most familiar to anyone who has taken a multiple-choice test: you must answer a direct question or complete a statement with the correct answer. There are four choices given as potential answers, but only one is correct. Sometimes the correct answer to one of these questions is clear, however in other cases more than one answer may seem to be correct. In that case, read the question carefully and choose the answer that is most correct. Here is an example of this type of test question:

Customer Service 1-800-240-1968
FAX 218-740-6437
e-mail: PassTheASE@advanstar.com
URL: www.PassTheASE.com
L3 - ASE LIGHT DUTY HYBRID/ ELECTRIC VEHICLE SPECIALIST

A compression test shows that one cylinder is too low. A leakage test on that cylinder shows that there is excessive leakage. During the test, air could be heard coming from the tailpipe. Which of the following could be the cause?
A. broken piston rings
B. bad head gasket
C. bad exhaust gasket
D. an exhaust valve not seating

There is only one correct answer to this question, answer D. If an exhaust valve is not seated, air will leak from the combustion chamber by way of the valve out to the tailpipe and make an audible sound. Answer C is wrong because an exhaust gasket has nothing to do with combustion chamber sealing. Answers A and B are wrong because broken rings or a bad head gasket would have air leaking through the oil filler or coolant system.

MOST Likely

This type of question is similar to a direct question but it can be more challenging because all or some of the answers may be nearly correct. However, only one answer is the most correct. For example:

When a cylinder head with an overhead camshaft is discovered to be warped, which of the following is the most correct repair option?
A. replace the head
B. check for cracks, straighten the head, surface the head
C. surface the head, then straighten it
D. straighten the head, surface the head, check for cracks

The most correct answer is B. It makes no sense to perform repairs on a cylinder head that might not be usable. The head should first be checked for warpage and cracks. Therefore, answer B is more correct than answer D. The head could certainly be replaced, but the cost factor may be prohibitive and availability may be limited, so answer B is more correct than answer A. If the top of the head is warped enough to interfere with cam bore alignment and/or restrict free movement of the camshaft, the head must be straightened before it is resurfaced, so answer C is wrong.

Technician A and Technician B

These questions are the kind most commonly associated with the ASE test. With these questions you are asked to choose which technician statement is correct, or whether they both are correct or incorrect. This type of question can be difficult because very often you may find one technician's statement to be clearly correct or incorrect while the other may not be so obvious. Do you choose one technician or both? The key to answering these questions is to carefully examine each technician's statement independently and judge it on its own merit. Here is an example of this type of question:

A vehicle equipped with rack-and-pinion steering is having the front end inspected. Technician A says that the inner tie rod ends should be inspected while in their normal running position. Technician B says that if movement is felt between the tie rod stud and the socket while the tire is moved in and out, the inner tie rod should be replaced. Who is correct?
A. Technician A
B. Technician B
C. Both A and B
D. Neither A or B

The correct answer is C; both technicians' statements are correct. Technician B is clearly correct because any play felt between the tie-rod stud and the socket while the tire is moved in and out indicates that the assembly is worn and requires replacement. However, Technician A is also correct because inner tie- rods should be inspected while in their normal running position, to prevent binding that may occur when the suspension is allowed to hang free.

EXCEPT

This kind of question is sometimes called a negative question because you are asked to give the incorrect answer. All of the possible answers given are correct EXCEPT one. In effect, the correct answer to the question is the one that is wrong. The word EXCEPT is always capitalized in these questions. For example:

All of the following are true of torsion bars **EXCEPT**:
A. They can be mounted longitudinally or transversely.
B. They serve the same function as coil springs.
C. They are interchangeable from side-to-side
D. They can be used to adjust vehicle ride height.

The correct answer is C. Torsion bars are not normally interchangeable from side-to-side. This is because the direction of the twisting or torsion is not the same on the left and right sides. All of the other answers contain true statements regarding torsion bars.

LEAST Likely

This type of question is similar to EXCEPT in that once again you are asked to give the answer that is wrong. For example:

Blue-gray smoke comes from the exhaust of a vehicle during deceleration. Of the following, which cause is **LEAST** likely?
A. worn valve guides
B. broken valve seals
C. worn piston rings
D. clogged oil return passages

The correct answer is C. Worn piston rings will usually make an engine smoke worse under acceleration. All of the other causes can allow oil to be drawn through the valve guides under the high intake vacuum that occurs during deceleration.

PREPARING FOR THE ASE TEST

Begin preparing for the test by reading the task list. The task list describes the actual work performed by a technician in a particular specialty area. Each question on an ASE test is derived from a task or set of tasks in the list. Familiarizing yourself with the task list will help you to concentrate on the

areas where you need to study.

The text section of this study guide contains information pertaining to each of the tasks in the task list. Reviewing this information will prepare you to take the practice test.

Take the practice test and compare your answers with the correct answer explanations. If you get an answer wrong and don't understand why, go back and read the information pertaining to that question in the text.

After reviewing the tasks and the subject information and taking the practice test, you should be prepared to take the ASE test or be aware of areas where further study is needed. When studying with this study guide or any other source of information, use the following guidelines to make sure the time spent is as productive as possible:

- Concentrate on the subject areas where you are weakest.
- Arrange your schedule to allow specific times for studying.
- Study in an area where you will not be distracted.
- Don't try to study after a full meal or when you are tired.
- Don't wait until the last minute and try to 'cram' for the test.

REGISTERING FOR ASE COMPUTER-BASED TESTING

Registration for the ASE CBT tests can be done online in myASE or over the phone. While not mandatory, it is recommended that you establish a myASE account on the ASE website (www.ase.com). This can be a big help in managing the ASE certification process, as your test scores and certification expiry dates are all listed there.

Test times are available during two-month windows with a one-month break in between. This means that there is a total of eight months over the period of the calendar year that ASE testing is available.

Testing can be scheduled during the daytime, night, and weekends for maximum flexibility. Also, results are available immediately after test completion. Printed certificates are mailed at the end of the two-month test window. If you fail a test, you will not be allowed to register for the same test until the next two-month test window.

TAKING THE ASE TEST – COMPUTER-BASED TESTING (CBT)

On test day, bring some form of photo identification with you and be sure to arrive at the test center 30 minutes early to give sufficient time to check in. Once you have checked in, the test supervisor will issue you some scratch paper and pencils, as well as a composite vehicle test booklet if you are taking advanced tests. You will then be seated at a computer station and given a short online tutorial on how to complete the ASE CBT tests. You may skip the tutorial if you are already familiar with the CBT process.

The test question format is similar to those found in written ASE tests. Regular certification tests have a time limit of 1 to 2 hours, depending on the test. Recertification tests are 30 to 45 minutes, and the L1 and L2 advanced level tests are capped at 2 hours. The time remaining for your test is displayed on the top left of the test window. You are given a warning when you have 5 minutes left to complete the test.

Read through each question carefully. If you don't know the answer to a question and need to think about it, click on the "Flag" button and move on to the next question. You may also go back to previous questions by pressing the "Previous Question" button. Don't spend too much time on any one question. After you have worked through to the end of the test, check your remaining time and go back and answer the questions you flagged. Very often, information found in questions later in the test can help answer some of the ones with which you had difficulty.

Some questions may have more content than what can fit on one screen. If this is the case, there will be a "More" button displayed where the "Next Question" button would ordinarily appear. A scrolling bar will also appear, showing what part of the question you are currently viewing. Once you have viewed all of the related content for the question, the "Next Question" button will reappear.

You can change answers on any of the questions before submitting the test for scoring. At the end of the examination, you will be shown a table with all of the question numbers. This table will show which questions are answered, which are unanswered, and which have been flagged for review. You will be given the option to review all the questions, review the flagged questions, or review the unanswered questions from this page. This table can be reviewed at any time during the exam by clicking the "Review" button.

If you are running out of time and still have unanswered test questions, guess the answers if necessary to make sure every question is answered. Do not leave any answers blank. It is to your advantage to answer every question, because your test score is based on the number of correct answers. A guessed answer could be correct, but a blank answer can never be.

Once you are satisfied that all of the questions are complete and ready for scoring, click the "Submit for Scoring" button. If you are scheduled for more than one test, the next test will begin immediately. If you are done with testing, you will be asked to complete a short survey regarding the CBT test experience. As you are leaving the test center, your supervisor will give you a copy of your test results. Your scores will also be available on myASE within two business days.

To learn exactly where and when the ASE Certification Tests are available in your area, as well as the costs involved in becoming ASE certified, please contact ASE directly for registration information.

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1-800-390-6789
http://www.ase.com

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Notes

Light Duty Hybrid/Electric Vehicle Specialist

TEST SPECIFICATIONS
(TEST L3)

CONTENT AREA	NUMBER OF QUESTIONS IN ASE TEST	PERCENTAGE OF COVERAGE IN ASE TEST
A. Battery System	11	25%
B. Internal Combustion Engine	6	13%
C. Drive Systems	9	20%
D. Power Electronics	13	29%
E. Hybrid Supporting Systems	6	13%
Total	**45**	**100%**

There could be additional questions that are included for statistical research purposes only. Your answers to these questions will not affect your test score, but since you do not know which ones they are, you should answer all questions in the test.

It should be noted that the number of questions in each content area may not equal the number of tasks listed. Some of the tasks are complex and broad in scope, and may be covered by several questions. Other tasks are simple and narrow in scope; one question may cover several tasks.

The main purpose for listing the tasks is to describe accurately what is done on the job, not to make each task correspond to a particular test question.

LIGHT HYBRID/ELECTRIC VEHICLE SPECIALIST TEST TASK LIST

A. BATTERY SYSTEM

(11 questions)

Task 1 - Perform high voltage disconnect procedure; reconnect/enable high voltage system.
Task 2 - Select, test and use proper safety gloves.
Task 3 - Select, qualify and use proper DMM and leads.
Task 4 - Retrieve and diagnose DTCs; determine needed repairs.
Task 5 - Diagnose problems caused by damaged or failed harnesses, connectors, terminals and fuses.
Task 6 - Diagnose high voltage (HV) battery pack malfunctions.
Task 7 - Remove and install high voltage battery pack.
Task 8 - Test, diagnose and repair high voltage leaks / loss of isolation.
Task 9 - Test, diagnose and repair high voltage battery pack heating and cooling systems.
Task 10 - Test, diagnose, repair or replace high voltage battery pack internal components.

B. INTERNAL COMBUSTION ENGINE

(6 questions)

Task 1 - Retrieve and diagnose DTCs; determine needed repairs
Task 2 - Determine if the internal combustion engine (ICE) is in CRANK mode or RUN mode.
Task 3 - Differentiate between driveability problems caused by the internal combustion engine and/or hybrid drive system.
Task 4 - Perform internal combustion engine cranking compression test.
Task 5 - Keep the internal combustion engine running during service.
Task 6 - Diagnose internal combustion engine no-crank condition.
Task 7 - Diagnose internal combustion engine cranks/no-start condition.
Task 8 - Interpret vacuum and compression readings on Atkinson cycle engines.
Task 9 - Identify engine start/stop strategy; diagnose malfunctions.
Task 10 - Service engine cooling system.

C. DRIVE SYSTEMS

(9 questions)

Task 1 - Perform high voltage disconnect procedure; reconnect/enable high voltage system.
Task 2 - Select, test and use proper safety gloves.
Task 3 - Select, qualify and use proper DMM and leads.
Task 4 - Retrieve and diagnose DTCs; determine needed repairs.
Task 5 - Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.
Task 6 - Test, diagnose and repair high voltage leaks/loss of isolation.
Task 7 - Remove and install rotor from stator.
Task 8 - Diagnose motor-rotor position sensor (Resolver or Encoder type).
Task 9 - Diagnose drive/traction

motor-generator assembly for improper operation (such as an inoperative condition, noise, shudder, overheating, etc.).
Task 10 - Diagnose improper electrically actuated parking pawl operation; determine needed repair.
Task 11 - Identify transmission fluid and coolant fluid requirements; verify fluid levels.

D. POWER ELECTRONICS
(13 questions)
Task 1 - Perform high voltage disconnect procedure; reconnect/enable high voltage system.
Task 2 - Select, test and use proper safety gloves.
Task 3 - Select, qualify and use proper DMM and leads.
Task 4 - Retrieve and diagnose DTCs; determine needed repairs.
Task 5 - Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.
Task 6 - Identify procedures necessary to establish the proper vehicle operational power mode during service (OFF, ACCESSORY, POWER ON, READY TO DRIVE).
Task 7 - Diagnose the cause of a hybrid system warning displayed on the instrument panel and/or a driveability complaint.
Task 8 - Diagnose impact sensor problems: determine needed repair.
Task 9 - Diagnose AC/DC inverter overheating; determine needed repair.
Task 10 - Diagnose AC/DC inverter failure; determine needed repair.
Task 11 - Replace AC/DC inverter cooling pump.
Task 12 - Remove and install AC/DC inverter.
Task 13 - Diagnose failures in the data communications bus network; determine needed repair.
Task 14 - Locate and test the voltage level of capacitors.
Task 15 - Diagnose, locate and safely disable/enable safety interlocks.
Task 16 - Diagnose failed DC/DC converter; determine needed repair.
Task 17 - Remove and install DC/DC converter.
Task 18 - Test high voltage cable integrity and loss of isolation.
Task 19 - Perform 12-volt battery testing.
Task 20 - Diagnose system main relay(SMR)/contactor malfunctions; determine needed repairs.

E. HYBRID SUPPORTING SYSTEMS
(6 questions)
Task 1 - Perform high voltage disconnect procedure; reconnect/enable high voltage system.
Task 2 - Select, test and use proper safety gloves.
Task 3 - Select, qualify and use proper DMM and leads.
Task 4 - Retrieve and diagnose DTCs; determine needed repairs.
Task 5 - Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.
Task 6 - Inspect, test and diagnose EVAP emission system components; determine needed repairs.
Task 7 - Observe and interpret driver indicators, power flow display and energy monitor; determine necessary action.
Task 8 - Test and diagnose high voltage air conditioning compressor malfunctions; diagnose system problems; determine needed repairs.
Task 9 - Remove and install high voltage air conditioning compressor; identify and select proper system oil.
Task 10 - Diagnose cabin heating system performance problems; determine needed repairs.
Task 11 - Diagnose and repair electric/electronic steering systems.
Task 12 - Diagnose brake system performance problems; differentiate between braking problems caused by hydraulic system and regenerative system malfunctions; determine needed repairs.
Task 13 - Deactivate brake system self-test prior to service.
Task 14 - Service liquid cooling system(s).

The preceding Task List details all of the related informational subject matter you are expect to know in order to sit for this ASE Certification Test. Your own years of experience as a technician in the professional automotive service repair trade also should provide you with added background.

Finally, a conscientious review of the self-study material provided in this Training for ASE Certification unit also should help you to be adequately prepared to take this test.

Notes

Hybrid Safety

This chapter contains information related to these sections and tasks: Section A, tasks 1-3; Section C, tasks 1-3; Section D, tasks 1-3, 6 and Section E, tasks 1-3.

Working on hybrid and electric vehicles incorporates many of the same systems technicians are used to from servicing, diagnosing and repairing vehicles with conventional drive systems. The addition of High Voltage (HV) systems, however, brings about entirely new challenges, and requires even more diligence to insure the technician's safety.

When performing service, diagnosis or repair on hybrid vehicles, technicians will be dealing with both AC (Alternating Current) and DC (Direct Current) HV systems and components. The high voltage systems in these vehicles requires a technician to observe certain safety procedures utilizing high voltage Personal Protection Equipment (PPE) and to have a full understanding of how to disable these high voltage systems before undertaking any service or repair. Failure to follow these safety guidelines can result in serious injury, even death.

Failure to follow safety guidelines can result in serious injury or death.

WARNING: Before working on hybrid/electric high voltage vehicle systems you will need to follow all safety procedures. Be sure to use Personal Protection Equipment before handling HV cables or components.

Because we are dealing with vehicles whose cables/wires and batteries carry lethal voltages capable of high current capacity, we should be able to identify what kinds of cables/wires we are dealing with.

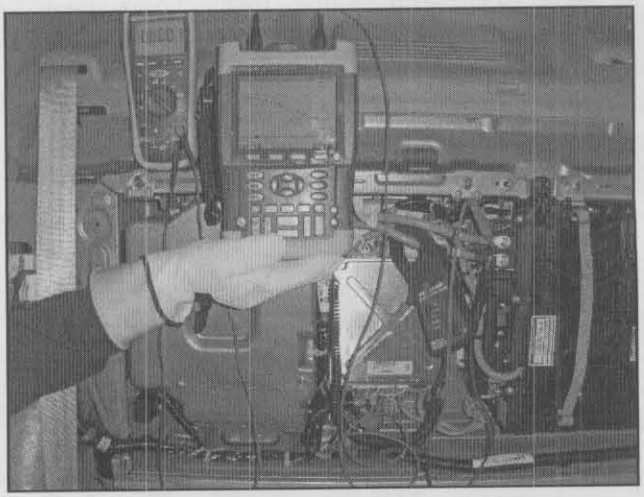
Low Voltage (Below 30V): RED or BLACK – These are wires any professional technician should already be used to working with. Normal service precautions, like not allowing them to contact any electrical ground point, should be followed.

Intermediate Voltage (Below 60V): BLUE or GREEN – These colors are commonly used in automotive wire harnesses, but if you see a cable-sized wire with either of these colors it's a good bet it is carrying a voltage high enough to hurt you. Follow the service precautions outlined by the vehicle manufacturer before disconnecting these intermediate voltage leads.

High Voltage (Above 60V): ORANGE – Orange cables are used to connect high voltage system components together, and often carry voltages of 144V or more. NEVER disconnect an orange cable or component without first following the manufacturers service procedures for isolating the HV (High Voltage) battery pack and ALWAYS use the appropriate Personal Protection Equipment.

HV Battery Disconnect/ Reconnect

Safety is very important, and preparing the HV system for repair or testing starts by isolating the HV battery. On most hybrid models, you disable the HV system by removing the HV interlock /service plug or shutting off the high voltage switch. Next, wait five to ten minutes to allow the system capacitors to drain. After waiting the allotted time, check the HV system with a Digital Multimeter rated CAT III (1000V) to make sure voltage is at a safe level (about 12 volts). The Digital Storage Oscilloscope (DSO) starts out at 158 volts and goes down to 15 volts in less than 45 seconds as the capacitors drain down.



The Digital Storage Oscilloscope (DSO) starts out at 158 volts and goes down to 15 volts in less than 45 seconds as the capacitors drain down.

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped with test leads and probe tips rated for CAT III use may result in damage to the equipment, and possible injury to the operator.*

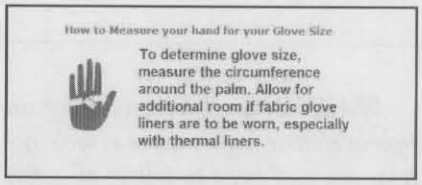
WARNING: *Always follow the OEM-approved procedure for disconnecting and reconnecting the HV battery to avoid serious personal injury or death.*

Reinstall the interlock /service plug or flip the switch back on to power the HV system back up.

Personal Protection Equipment

As a professional technician, you know and should already be following certain safety procedures. Among them is the need to always wear approved safety glasses for eye protection. When handling the HV battery, the use of a full face shield may be desirable.

Avoid wearing metal objects when servicing hybrid/electric vehicles. Remove jewelry, watches, belts with metal on them, phones or any other metal objects. Since metal objects increase contact surface area and conduct current, it increases your exposure to the dangers that come with electricity such as burns and electrocution. Furthermore, there are powerful magnets in hybrid components (such as the motor generators) that can attract metal objects as well as cause problems for those who use a pacemaker if they are working on the vehicle. While a recent study by the Mayo Clinic has revealed there is no risk for anyone with a pacemaker driving in a hybrid vehicle, it maybe another story for techs with a pacemaker to work on hybrid/electric vehicles. If you have a pacemaker, consult your physician before working on hybrids.



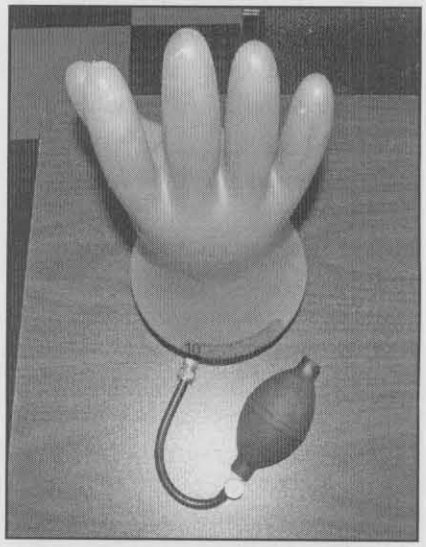
HV gloves should fit properly by using a glove fitment chart.

You'll also need a set of HV gloves (Class 0, rated at 1000V) and liners. HV gloves should fit properly by using a glove fitment chart.

Standard practice is to always check the gloves prior to starting to work on any hybrid/electric vehicle. If the gloves are suspected of being compromised they need to be checked immediately. If in doubt, throw them out!

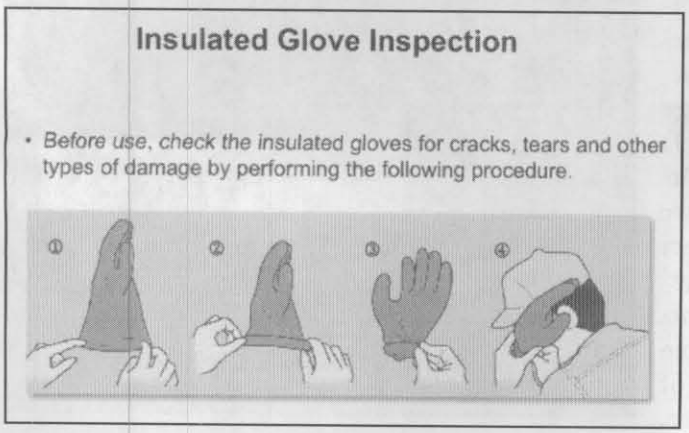
There are a few test procedures you can use to make sure that the HV gloves are in the proper condition so that they can be used on high voltage vehicles. The first test that is recommended is the "roll" method recommended by Toyota and other manufacturers (Figure 3.4). Use this procedure to properly test your gloves using this method:

- Visually inspect for punctures or other defects. Inspect the entire surface (inside and out) and roll gently between the hands to expose any defects.
- Stretch the cuffs to detect any abrasions or weak spots.
- To perform the air test on the gloves place the glove on its side, roll the opening up two or three times, trapping as much air as possible within the glove, then fold the opening in half to close it. This is followed by carefully listening for air escaping from the glove.



HV gloves can be tested using an air pump method.

Another method is the air pump method that is sold by many HV glove manufacturers. This is a lot easier than the "roll" method for checking for leaks. The glove can easily be pumped up with the bladder pump similar to what the doctor uses to check your blood pressure. The glove also can be submersed in water while observing for escaping air bubbles. Obviously if there is any pressure loss, or any air bubbles are viewed, the glove cannot be used.



Toyota recommends the "roll method" for testing HV gloves to make sure they are in proper condition.
(Courtesy: Toyota Motor Company, USA)

The last and best way to test the HV gloves is to send them out to a certified laboratory. The gloves will be tested at high voltage in a test tank that meets the ASTM D120/ IEC903 specifications.

Certified labs can test HV gloves to make sure they meet proper safety specifications.

Note: *HV Class 0 gloves need to be tested every 6 months whether or not they are suspected of damage.*

To ensure your safety and the integrity of the gloves, insulating gloves need to be worn along with outer protector gloves that are made of canvas or leather and meet the ASTM (American Society for Testing and Materials) standard specifications. The glove covers help protect the HV gloves from damage from sharp objects. The gloves and sleeves need to be stored properly when not in use in a protective canvas bag to prevent damage. Storing the gloves and covers properly means that gloves must not be folded, must be kept out of excessive heat, sunlight, humidity, ozone, and any chemical or substance that could damage the HV glove.

Insulating gloves need to be worn along with outer protector gloves made of canvas or leather.

Another commonly overlooked piece of PPE is a safety hook. Remember your old first aid training and what to do in case you witness someone being electrocuted? If you try to grab them to pull them away from the power source, you will only add yourself to the electrical circuit and become an additional victim! The pole is used for exactly this reason – to remove the victim from the source in order to be able to provide emergency treatment and possibly save their life. If you work on HV systems, there should be a clearly marked safety hook in your shop.

It won't take you long to notice that there are warning labels all over hybrid and EV vehicles put there by the vehicle manufacturers that tell you "serious injury or death" can be the result if precautions are not followed. But consider that every day utility companies work with high voltage power lines without anyone being injured. When was the last time you heard that a utility worker was shocked by high voltage? Most likely your answer will be never. The reason is utility workers are trained on how to work with high voltage and are provided with the proper equipment. Don't fear high voltage, respect it! If you follow basic safety rules and use the recommended safety equipment, you will be safe.

Hybrid Digital Multimeter Selection

The easiest step in checking high voltage levels is to connect a scan tool and review HV Parameter Identifiers (PIDs), always followed by checking the HV circuit with a special meter. In order to properly test HV cables and components, you will need to use a CAT III (1000V) Digital Multimeter (DMM) equipped with the same rated test leads and probe tips. In order to test the integrity of any HV cables/wires, you will need to use a CAT III MegOhm meter to perform insulation leak tests that will help pinpoint HV losses.

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped with test leads and probe tips rated for CAT III use may result in damage to the equipment, and possible injury to the operator.*

Another commonly overlooked piece of Personal Protection Equipment (PPE) is a safety hook.

If you're a scope user, you'll need CAT III-rated leads and probes before adding the scope to your testing tool arsenal.

Use of the DMM will be discussed in the chapter entitled "Testing HV-related Wiring Integrity".

Scan Tools

One of the most common tools

used in diagnosing vehicle problems is the scan tool. It's a great place to start as we stated above to check the HV levels, but more important and the most common use is to check for Diagnostic Trouble Codes (DTCs). But not all scan tools are created equally; some are better than others and sometimes the OE factory tool may be the only one that can provide you all the information you'll need, as well as all the bi-directional test functions that make diagnosing these systems a lot easier.

Other Hybrid Tools And Equipment Needs

In addition to the normal shop equipment you use every day to service conventional drive vehicles, you'll also need specialized equipment to service today's hybrids. Here are a few you may want to add to your shop:

- Good service information (OE (available from NASTF.org), ALLDATA, Mitchell, MotoLogic, Identifix, to name a few)
- Scan tools that have the proper software (in most cases the OE tool is the best to use)
- CAT III leads for your Digital Storage Oscilloscope (DSO)
- Amp clamps
- Insulated hand tools
- Engine hoist (used for some battery packs)
- Battery cradle hoist (special cradle used for the Chevy Volt, Nissan Leaf and Tesla)
- Chock blocks

Hybrid Power Modes

It was easy when an ignition key was used to operate the different electrical modes on a conventional gas or diesel powerplant. You choose from "OFF", "ACC", "RUN" or "START" by rotating the key to different positions. Hybrids (and many modern conventional designs) use slightly different terminology and methods for placing the vehicle into different operational modes.

WARNING: *Failure to successfully place a hybrid in "OFF" – "NOT Ready " mode could allow the Internal Combustion Engine (ICE) to start without warning. This could result in vehicle damage, and personal injury or death to the operator/technician.*

The different operation modes used by hybrids are:

OFF – All systems are off. Both the engine and electric drive systems are disabled.

ACCESSORY – Same as the "ACCESSORY" key position in a conventional vehicle. Power is available to select secondary systems but not to the engine or electric drive systems.

POWER ON – Equivalent to conventional "Key ON, Engine OFF". The ICE will not start on its own and the electric drive system will not function. Data from the Diagnostic Link Connector is available with a scan tool.

READY | READY TO DRIVE – Equivalent to conventional "Key ON, engine RUNNING". In this mode, the vehicle is ready to drive. The ICE is running, or ready to run if so commanded to charge the system battery. The electric drive system is also ready for a drive command.

It is important that the vehicle be in the "OFF" mode prior to performing any service work, even routine services like oil changes or tire service. Most hybrids will start off in Electric Only mode and only start the ICE when the battery requires charging. Imagine the engine starting when the vehicle is six feet in the air, with no oil in it!

Other maintenance/diagnostic services require that a vehicle's electrical system be powered up for testing. For example, to access the computer modules with your scan tool, the "Power On" mode will be needed. Other testing procedures may require the engine to run constantly, so the vehicle will need to be in "Ready" mode to make that happen. Some vehicles will require additional preparation to allow the engine to run continuously.

Hybrid Designs

Hybrid designs are many and varied, but nearly all of them can be classified by type. There are models that rely on the Internal Combustion Engine (ICE) for primary propulsion, using electric starter/alternators purely for the fuel savings realized by being able to shut the ICE off when stopped and then immediately restarting it when it's time to go. On the other end are hybrids that add the ability to run in "electric only" mode and add the instant torque of the electric motor/generator to the output of the ICE to improve overall performance.

Here are short descriptions of the different types and designs of hybrids you're likely to see:

Micro (no assist) | GM – Micro hybrid vehicles utilize an electric motor that provides engine stop/start, auxiliary power and regenerative braking (that is also used to charge the battery). This type of hybrid vehicle does not provide any extra torque when the ICE is *running*. The fuel savings for these vehicles range from 5 percent to 15 percent.

Mild (assist) | Honda | *GM 2007 (Generator/Starter type) – Mild hybrid vehicles also utilize an electric motor, but in this system the electric motor provides additional torque to the engine. The electric motor is never the sole power source that moves the vehicle; only about 10 percent is used to assist the engine. Mild hybrids provide engine stop/start, auxiliary power and regenerative braking. The fuel savings for these vehicles range from 15 percent to 25 percent.

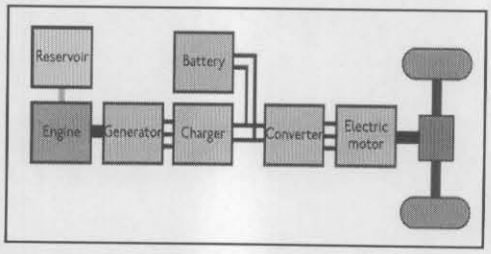
Full *(electric no ICE) | Ford | Honda (*2006 up) | Nissan | Toyota | others – Unlike the micro or the mild hybrid vehicles, these vehicles can be driven just by the electric motor or in conjunction with the ICE. The capability of a full hybrid includes engine stop/start, full electric drive mode, auxiliary power and regenerative braking. Most of the full hybrid vehicles use two electric motor generators while others use just one.

Generally, they use 40 percent of their maximum power for additional torque. Note that full hybrid vehicles are more complex than the other types of hybrids due to their bigger batteries and more powerful motors.

TYPES OF FULL HYBRIDS

SERIES DESIGN HYBRID

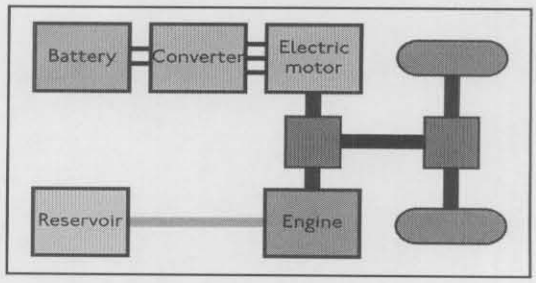
A power unit (ICE) turns a generator. This generator can either charge the batteries or power the electric motor to drive the transmission. This means there is NO mechanical connection between the hybrid's power unit and the wheels, thus the ICE never directly powers the vehicle. The Chevrolet Volt is an example of one such series extended-range electric hybrid.



Series Design Hybrid example.

PARALLEL DESIGN HYBRID

The parallel configuration uses a direct mechanical connection between the hybrid's power unit and the wheels. An AC motor attached to the crankshaft via a belt is also used, and it can drive the wheels at the same time as the power unit. The ICE is typically used with minimal electric assistance during normal highway driving.



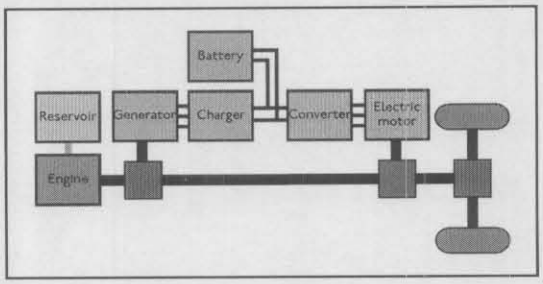
Parallel Design Hybrid example.

During acceleration, the ICE and electric motor can be used together for better acceleration (for more information on this, see the electric assist section later on.) The HV batteries are used to supply power to the AC motor. During deceleration, the motor acts as a generator (REGEN) and recharges the batteries. The converter converts the AC voltage to DC voltage. The engine's reservoir is a storage device for energy such as gasoline. The Honda Integrated Motor Assist (IMA) using one Motor/Generator (MG) design along with the GM alternator/generator belt style (BAS) design are parallel hybrids.

SERIES-PARALLEL DESIGN HYBRID

Series-parallel hybrids incorporate a power split device that

is similar to a clutch. This design allows for the power path from the engine to the wheels that can be connected by either the engine or Motor/Generator (MG). The Toyota Prius, Camry, Ford Escape and its Mercury cousin along with many other hybrid vehicles are examples of series-parallel designs. In fact, most hybrid vehicles are a series-parallel design.



Series-Parallel Design Hybrid example.

NOTE: *Due to the variance in design, the L3 tests uses a document entitled the Certification Test Reference to describe three different hybrid designs referenced as Type 1, Type 2 and Type 3. See the Appendix for a copy of this document and refer to the test-supplied copy when testing.*

Notes

Testing HV-Related Wiring Integrity

This chapter contains information related to these sections and tasks: Section A, tasks 5, 8; Section C, tasks 5-6; Section D, tasks 5, 18 and Section E, task 5.

Electricity is defined as "the movement of electrons in the same direction." This may immediately bring to mind Direct Current (DC), as an example. And you'd be right! That certainly qualifies. Alternating Current (AC) also qualifies, but with one minor difference – AC travels first in one direction and then the other.

Why is that important? Many of the components you'll be testing use AC instead of DC. And hybrid systems are combinations of AC and DC devices/components. In addition to the high voltages in use, there are components responsible for changing one to the other, or stepping up/down sources for use on other systems of the vehicle.

Testing the integrity of the paths connecting these components will utilize many of the testing methods you're used to as an A6 certified technician. But there are some testing methods specific to hybrids. Let's review those!

WARNING: *Be sure to use Personal Protection Equipment before handling HV cables or components.*

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped with test leads and probe tips rated for CAT III use may result in damage to the equipment, and possible injury to the operator.*

WARNING: *Always follow the OEM-approved procedure for disconnecting and reconnecting the HV battery to avoid serious personal injury or death.*

Isolating The HV Battery

Before performing any electrical system test on HV cables or components, it is best practice to first isolate the HV battery from the system (see Hybrid Safety page 9). On some models, a safety plug is accessed and removed to separate the battery pack from the rest of the HV components, while on others a switch is activated to perform this function. On many hybrid designs, it is then necessary to wait 5 to 10 minutes (depending on the manufacturer's recommendations) for any HV capacitors used in the system to discharge before you can safely begin testing.

Since each hybrid/electric vehicle is different, it is imperative that you consult the proper service information for the exact procedure in order to isolate the battery from the vehicle. Remember even though the battery has been turned off/isolated, there is still high voltage potential present in the pack. Think of isolating the HV battery as turning off a flashlight. When the flashlight is turned off, there is still battery voltage present. The switch merely acts as an open in the circuit preventing current flow, but the potential is still available.

With the caveats out of the way, let's take a look at a few of the most common methods of isolating the HV battery from the system. On a Honda hybrid you will need to access the HV battery by either removing the rear trunk deck lid or removing the rear seat. After exposing the HV component cover, locate the module switch lid (shut off switch cover) that is held in place with two bolts that need to be removed with a 10mm socket. After removing the cover, remove the red/orange color switch lock cover to expose the black switch. Flip the black switch to the "OFF" position, followed by reinstalling the red/orange lock back on the black switch that prevents the switch from being turned on accidently. After waiting five minutes, check the voltage at the red and black terminals of the HV battery making sure the voltage is below 30V DC.

Toyota Prius system HV shut down is accomplished by locating the service plug in the trunk area. In many cases the rear deck floor box (trunk rug/plastic box) will have to be removed to access the service plug (shut-off switch). Pull/slide up the service plug handle then move the handle to the left/horizontal position while pulling the service plug to complete the disconnect procedure. After waiting five to ten minutes (depending on the year and model vehicle) remove the inverter cover, connect the meter leads to the positive and negative terminals, and make sure the voltage level is at 0V DC.

On a Ford Escape hybrid, locate the service plug that is located under the rear cargo carpet on the right side of the trunk. The service plug has three positions; Lock, Unlock or Service Shipping. Rotate the service disconnect plug from the Lock position to the Unlock position, then remove the service

disconnect plug and place it in the Servicing Shipping position, then wait five minutes. Check the voltage levels at the right rear high voltage wire connection. The HV connection wires are located under the right rear seat cushion. Remove the HV cable cover and check for a safe voltage level before performing any HV service work.

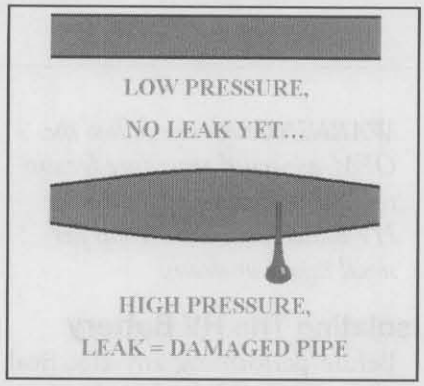
NOTE: *The OEM service procedure is ALWAYS the final authority on service procedures. Refer to the service information for the vehicle you are working on prior to attempting any service or repair of the HV system or its components.*

Insulation Testing

You've undoubtedly performed static resistance tests on dozens of conventional, 12V components and wiring using your DMM's ohmmeter function. The ohmmeter applies a small voltage to the wire and looks for the drop in voltage (caused by resistance) between the meter lead. It then converts that drop to a resistance measurement that is displayed on your DMM's screen.

Looking for opens, shorts or loss of insulation in HV cables or the internal wiring of a Motor/Generator is important not only for locating HV faults, but for the safety of the occupants and the technician working on the vehicle. There are many safety protocols in place used to isolate the HV battery from the vehicle should an HV leak be detected by the commanding control module, but finding exactly where the problem is located, what's causing it, and repairing the problem is up to you!

To perform an insulation test on HV cables or components, you'll need a MegOhm meter. These meters are typically incorporated into hybrid-ready DMMs, and perform similarly to a standard ohmmeter only using a much higher applied voltage to mimic the HV current flowing through the cables/components under normal use.



An insulation test uses relatively high voltage to make current leakage or integrity issues detectable.

Think about it in a simple way. Doing an insulation test is like pressure-testing a pipe. You look for leaks in a pipe by increasing pressure to a point where you see water or some other liquid shooting out somewhere, right? Well, in HV cables/components there's a lot of electrical pressure (voltage) rather than water pressure. An insulation test uses relatively high voltage to make current leakage or integrity issues detectable.

WARNING: *NEVER attempt to repair an HV cable or cable end by taping over damaged insulation or splicing broken cables together. ALWAYS replace damaged cable/wiring with new.*

WARNING: *For the following procedures, make sure that the ignition is OFF, the 12-volt battery is disconnected and the HV system is powered down before performing any test on the HV system.*

Testing HV Cables For Open Circuits

Test HV cables for open circuits using the MegOhm meter by following these steps:

1. Make sure the HV is powered down.
2. Disconnect the cables from the HV battery and the Inverter.
3. Select the 500 or 1000-volt range on the meter depending on the vehicle manufacturer's recommendations.
4. Connect the red lead of the meter to the disconnected HV battery cable.
5. Attached the black lead of the meter to the cable's other end that is disconnected from the inverter.
6. Press the white button on the red probe.
7. Check the meter display reading.

A reading of 0 volts indicates a good cable. A reading of 1020 volts/2.2 gig ohms indicates a completely open circuit. Any other reading indicates a leak in the cable.

The objective of this test is to see if any of the 1000 volts that the meter puts out leaks from the cable or any HV component that the technician is testing. This test is similar to a standard Ohmmeter test, if the meter reads "OL", the cable being tested has infinite resistance, aka open circuit (break in the wire.)

Testing HV Cables For Shorts To Ground

Test HV cables for shorts to ground using the MegOhm meter by following these steps:

1. Make sure the HV is powered down and disconnect the cables from the HV battery and the Inverter.
2. Connect the test leads from the MegOhm meter to the cable being tested.
3. Select the 500 or 1000-volt range on the meter depending on OE recommendations.
4. Connect the red lead of the meter to the disconnected HV battery cable.

Test HV cables for shorts to ground using a MegOhm meter.

5. Attach the black lead of the meter to the ground.
6. Move the black lead to the adjacent cable.
7. Press the red lead's white button.
8. Check the meter display reading.
9. Check both the copper wire and the shielding of the cable.

NOTE: *If the cable is still attached to ground on either end of the cable the test results will not be accurate when performing the shielding to ground test. Make sure to remove the cable ground hold downs before performing this test.*

A reading of 0 volts indicates a shorted cable. A reading of 1020 volts/2.2 gig ohms indicates a good cable that is isolated from ground. Any other reading indicates a leak to ground in the cable.

Testing MG Windings For Open Circuits

Test the windings of the Motor/Generator (MG) for open circuits using the MegOhm meter by following these steps:

1. Make sure the HV is powered down.
2. Disconnect the cables from the HV battery and the Inverter, including the wires to the Motor/Generators.
3. Select the 500 or 1000-volt range on the meter depending on the vehicle manufacturer's recommendations.

The following is an example from a Toyota Camry hybrid, other vehicle may have similar specifications. Always check for the exact information for the vehicle being tested.

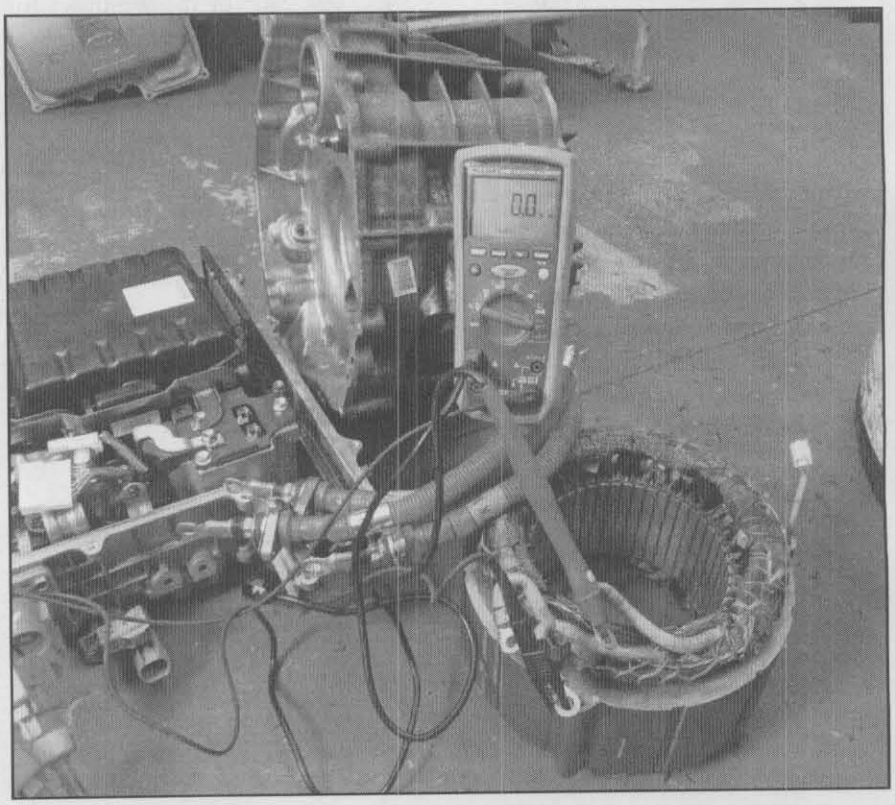
1. Connect the red probe lead of the meter to the U cable and the black lead to V, then press the white button on the probe. Acceptable readings will fall between 59 to 65 Meg ohms.
2. Connect the red probe lead to V cable and the black lead to W, then press the white button on the probe. Acceptable readings will fall between 56 to 62 Meg ohms.
3. Connect the red probe lead to W and the black lead to U, then press the white button on the red probe. Acceptable readings will fall between 56 to 62 Meg ohms.

A reading of within those specifications listed by the vehicle manufacturer indicates a good motor winding. A reading of 1020 volts / 2.2 gig ohms indicates a completely open motor winding.

Testing MG Windings For Shorts To Ground

Test the windings of the Motor/Generator (MG) for shorts to ground using the MegOhm meter by following these steps:

1. Attach the red probe meter lead to U and the black lead



Test the windings of the Motor/Generator (MG) for open circuits using the MegOhm meter. Readings should fall within OEM specifications to indicate a good motor winding.

to the body ground, followed by connecting the black lead to the shielded wire, while pressing the white button on the red probe for each test.

2. Attach the red probe meter lead to V and the black lead to the body ground, followed by connecting the black lead to the shielded wire, while pressing the white button on the red probe for each test.
3. Attach the red probe meter lead to W and the black lead to the body ground, followed by connecting the black lead to the shielded wire, while pressing the white button on the red probe for each test.

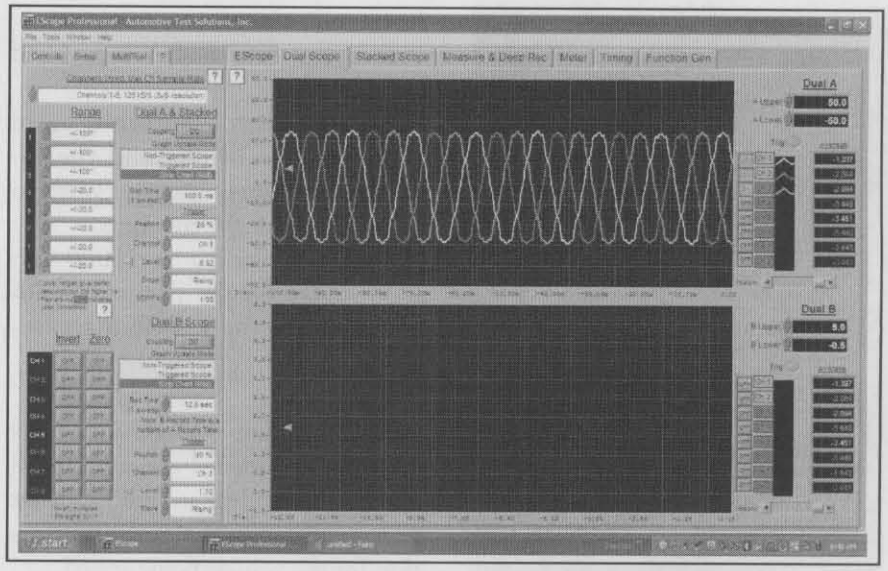
Refer to the vehicle manufacturer's specifications for acceptable test results. As an example, acceptable Toyota Camry hybrid reading for all of the MG leads to ground and shielded cable test is 100 Meg ohms or more using the 500-volt range.

Testing MG Windings For Internal Shorts (Winding to Winding)

Test the windings of the Motor/Generator (MG) for shorts to each other using the MegOhm meter by following these steps:

1. Connect the red probe lead to U and the black lead to V, then press the white button on the red probe.
2. Connect the red probe lead to V and the black lead to W, then press the white button on the red probe.
3. Connect the red probe lead to W and the black lead to U, then press the white button on the red probe.
4. Test each of the windings for a short to the metal frame of the MG (motor/generator) by connecting the red probe lead one at a time to either U, V or W and the black lead to the MG frame then pressing the white button on the red probe.

If there is a reading on the meter display other than 1020 volts / 2.2 gig ohms (meter set on 1000V), the MG windings are shorted to one another.



A Digital Storage Oscilloscope that meets CAT III requirements can also be used to check the integrity of the Motor/Generators (MG).

Scan Tool Data PIDs And Wiring Integrity

Many models utilize scan tool data Parameter Identifiers (PIDs) to display information on HV insulation/resistance faults. Often, DTCs referring to a decrease in resistance or short circuit indicate a problem with the HV cables or MG windings. But sometimes scan tools lie! So use the above testing methods to verify the data displayed and properly repair the vehicle.

In addition to the tests shared above, a Digital Storage Oscilloscope that meets CAT III requirements can also be used to check the integrity of the Motor/Generators (MG).

Scan Tool Diagnosis

This chapter contains information related to these sections and tasks: Section A, task 4; Section B, task 1; Section C, task 4; Section D, task 4 and Section E, task 4.

The data provided by a capable scan tool will augment your electrical and pinpoint testing, and often provide you with diagnostic information you will not be able to obtain otherwise.

Choosing A Scan Tool

The Global OBD II standards governing the Internal Combustion Engine (ICE), whether used in a hybrid or conventional design, have been in use since 1996. Certain Diagnostic Trouble Code (DTC) definitions are standardized and many more are manufacturer-specific. Even so, many drivability issues related to the ICE can be diagnosed using any scan tool capable of accessing the Global OBD II date Parameter Identifiers (PIDs).

Not so with hybrid-related systems. These systems will need to be accessed with a scan tool capable of enhanced communication (manufacturer specific) and aftermarket scan tool offerings vary widely on the PID coverage and bi-directional capabilities they are capable of. Be sure to review the capabilities of the tool(s) you are considering and make sure they will offer the coverage you need for the models you intend to service.

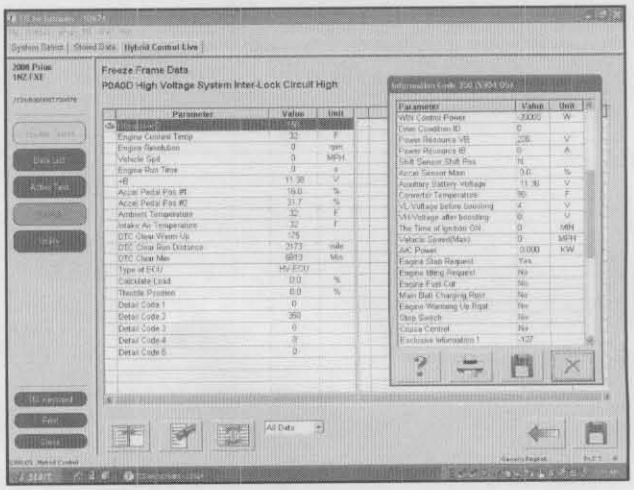
In some cases, only the OEM specific scan tool will fill the bill. In addition to having all the capabilities you need, you can also be assured of the ability to properly reprogram or initialize any component or module required in the course of your repair.

Basic Diagnostics With The Scan Tool

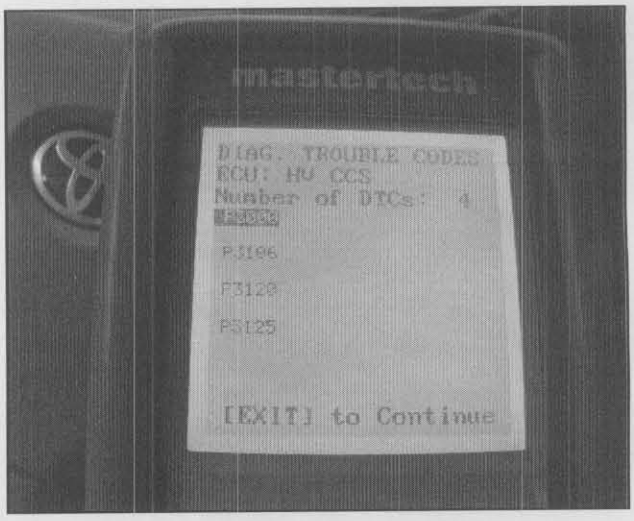
Scan tools are connected to the vehicle via the Diagnostic Link Connector (DLC). From here, it is best practice to request and retrieve any DTCs that may be stored in any of the modules on the vehicle. Often, a fault in one module, even if you think it is unrelated to the system you are troubleshooting, may provide the clues you need to ultimately repair the vehicle.

Diagnosing DTCs that turn on the traditional "Check Engine" light will already be familiar to you. Only those DTCs related to emissions are allowed to turn on this warning indicator. DTCs that activate the hybrid warning lights (typically an IMA, triangle or wrench symbol) will require accessing the module(s) specific to the hybrid system. Refer to the service information specific to the model you are working on to identify the module(s) used.

Best practices for DTC diagnosis, regardless of system involved, is to first record the DTCs found in the module(s) tested. Next, use a quality service information source to learn the code's definition (don't rely on the short description you see on the scan tool alone!) and the enabling criteria required for the controlling module to set the code. Often, understanding the method



These systems will need to be accessed with a scan tool capable of enhanced communication.



DTCs that activate the hybrid warning lights (typically an IMA, triangle or wrench symbol) will require accessing the module(s) specific to the hybrid system.

used by the controlling module to perform its self test will allow you to duplicate those tests during your own troubleshooting and provide you with insight into possible causes for the DTC.

With this step complete, use the service information to become completely familiar with the specifics related to system operation for the system and make you are attempting to repair. While there are some generalities across the hybrids offered, both safety and common sense dictate you insure you fully understand how the system you are working on today works and interacts with others on the vehicle.

Once you understand the code criteria and how the system functions, the next stop is the list of Technical Service Bulletins (TSBs) you'll find included in the service information system you're using. Many of the issues you face every day, conventional or hybrid, are only repaired by reprogramming the software in a system module. Others may require the use of a redesigned part, also announced by the OEM through TSBs (or recalls). At the very least, you'll find informative reading that will only help your understanding of the problem you are diagnosing in this valuable resource.

Diagnostic flowcharts, too, are often available for specific DTCs. Just be sure you understand why you are making the tests called for by these aids and don't skip any of the steps outlined or you may just blow over the problem and not realize it.

Once the problem has been identified and repaired, clear the DTC(s) and verify your repair.

HV Battery System Service & Repair

This chapter contains information related to these sections and tasks: Section A, tasks 6, 7, 9 and 10.

Look under the hood of many hybrids and you'll find a conventional 12V lead-acid or glass-mat battery, but it's not used for propulsion. It is still used in some designs to provide power to start the Internal Combustion Engine (ICE) and to power the vehicle's electrical system (infotainment, lighting, etc.).

Hybrid vehicles use NiMH (nickel metal hydride) or Li-ion (lithium ion) batteries. They are relatively lightweight, have no hazardous materials oozing out of them, have much higher energy density, and can charge rapidly (which is absolutely essential for the on-the-spot charging typical of hybrid/electric operation.)

There are two types of NiMH batteries: prismatic or "rectangle" and cylindrical.

Prismatic batteries are used in Toyotas and most extended range hybrids, as well as in full electric vehicles. In many earlier model Fords and Hondas, the NiMH batteries are cylindrical. They are D size (similar in dimension to the D-cells you use in your flashlight), but otherwise no different from the standard prismatic batteries. The capacity of both is ~6.5 AH (Amp Hour – a measurement of battery capacity) and both have an output of over 100 Amps. NiMH batteries can generate a lot of heat. Keeping them cool is imperative to prevent damage to the cells and ultimately, the battery pack.

Cylindrical cells look similar to run-of-the-mill D flashlight batteries. The major difference between the two is that the cylindrical NiMH batteries have high current connections capable of safely carrying more than 100A. Addition-

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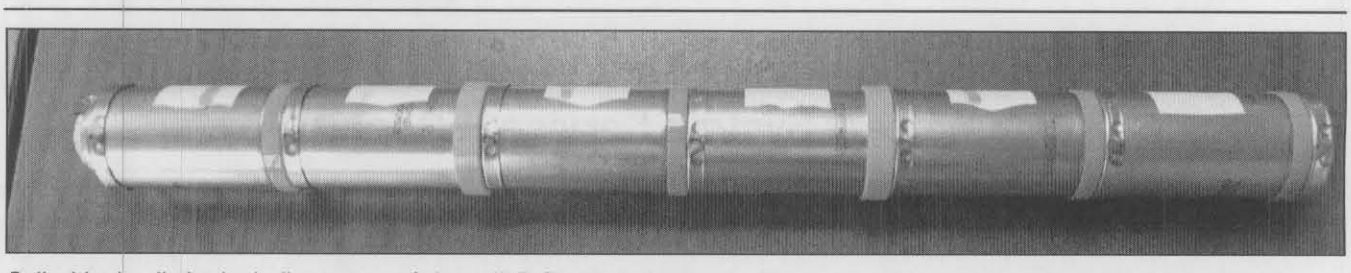


Cylindrical cells look similar to run-of-the-mill D flashlight batteries. The major difference between the two is that cylindrical NiMH batteries have high current connections capable of safely carrying more than 100A.

ally, cylindrical cells can withstand high internal pressures and can be mounted in any position as they do not have to be vented.

So why don't all hybrids use cylindrical batteries? Because of their shape, cylindrical batteries cannot be cooled as well or packed as tightly as prismatic cells.

Diagnosing HV Battery Pack Faults

An indication of a HV battery problem on a Honda will be an illuminated MIL along with an IMA light with the following DTCs:

- 2000-2004 Insights with P1449 or Trouble Codes 77/78 (IMA Indicator ON) have battery module deterioration. To fix this, you may need to replace the HV battery, BCM (Battery Condition Module), and/or MCM (Motor Control Module).
- 2003-2005 Honda Civic P1569 / 70 Battery Module Failure, P1600 IMA System Malfunction
- 2009 Honda Civic P0A7F Hybrid Pack Deterioration

After confirming the DTC on a Honda hybrid vehicle the next step is to check the scan data PIDs. Data PIDs were limited on early Honda's only providing limited information, leaving out individual HV cell pack voltage level. If this is the case, check TSBs and bulletins, following Honda suggestions on replacing the HV battery pack. The choice for replacement HV batteries are rebuilt battery packs from Honda, aftermarket rebuilds or some technicians rebuilt the batteries themselves by using new or used battery sticks. Newer Honda's now provide HV battery cell stick data making the diagnosis of the battery pack easier.

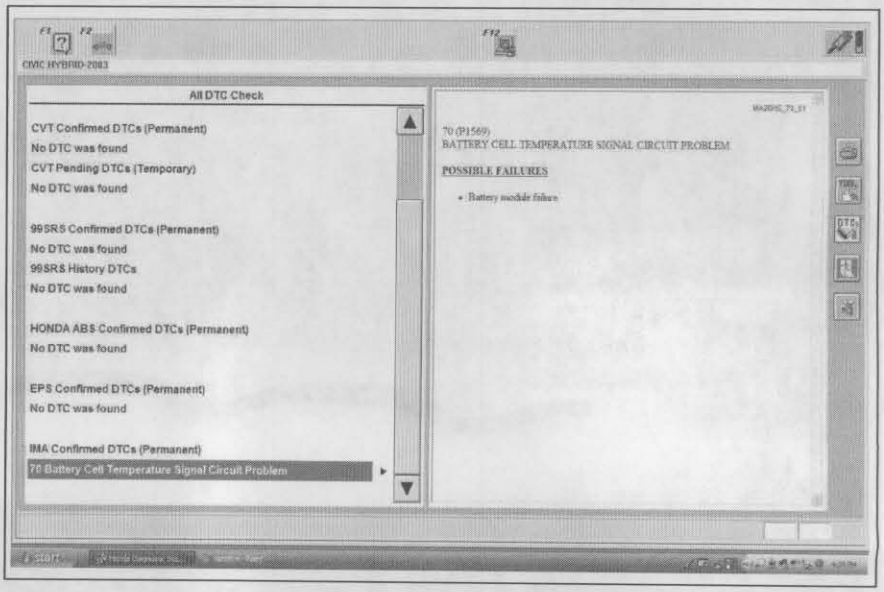
Toyota Prius P3000 HV Battery Malfunction can be caused by low HV battery voltage. The cause of the problem with sub code 388 can be from running out of fuel or leaving the vehicle in the "N" (neutral position), which drains the HV battery down. A DTC with the sub code 389 is a code for a dead HV battery or malfunction. Toyota HV battery packs can be replaced with a new Toyota HV pack, aftermarket remanufactured battery pack or can be rebuilt by using new or used battery blocks. Toyota vehicles have scan data PIDs that display battery pack (2 batteries per block) voltage readings that makes finding a weak battery block easy to find, test and repair.

The HV battery pack can be checked by using a scan tool, special HV battery tester, or a CAT III Digital Multimeter. When using the CAT III DMM, each individual cell block of the HV battery pack will need to be tested.

Removal and Installation of the HV Battery Assembly

WARNING: *Be sure to use Personal Protection Equipment before handling HV cables or components.*

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped*



After confirming the DTC on a Honda hybrid vehicle the next step is to check the scan data PIDs.

The HV battery pack can be checked by using a scan tool, special HV battery tester. *(Courtesy: Midtronics)*

with test leads and probe tips rated for CAT III use may result in damage to the equipment, and possible injury to the operator.

***WARNING:** Always follow the OEM-approved procedure for disconnecting and reconnecting the HV battery to avoid serious personal injury or death.*

The following example is from the most common hybrid on the road, the Toyota Prius. Procedures vary from manufacturer to manufacturer.

To remove the HV battery from a vehicle use the following steps:

1. Make sure the ignition is off (Not Ready) or key out of the ignition (other hybrids).
2. Remove the rear rug and compartments (floor boards).
3. Remove the negative 12 volt battery cable.
4. Remove the service plug by sliding/pulling up the handle and pulling it out towards the left fender/horizontal position. This step will isolate the high voltage battery pack from the HV system.
5. Wait 5-10 minutes (depending on the model year).
6. Remove the bolts from the left rear reinforcement bracket of the HV battery.
7. Test the voltage at the battery cables with a CAT III meter. This step will confirm that the battery is isolated.
8. Remove the HV battery from the vehicle and place it on a safe nonmetallic surface along with a warning sign that reads "Danger - High Voltage".

Other hybrid vehicles use a similar procedure, but typically have different means for isolating/connecting the HV battery pack to the HV system as well as having varying locations for these service points. All, though, share a basic routine: isolate the battery using the service disconnect provided, wait a short period of time for any HV capacitors to discharge, verify with a CAT III – rated DMM that the battery is isolated, and then follow the OEM specific procedures for battery removal.

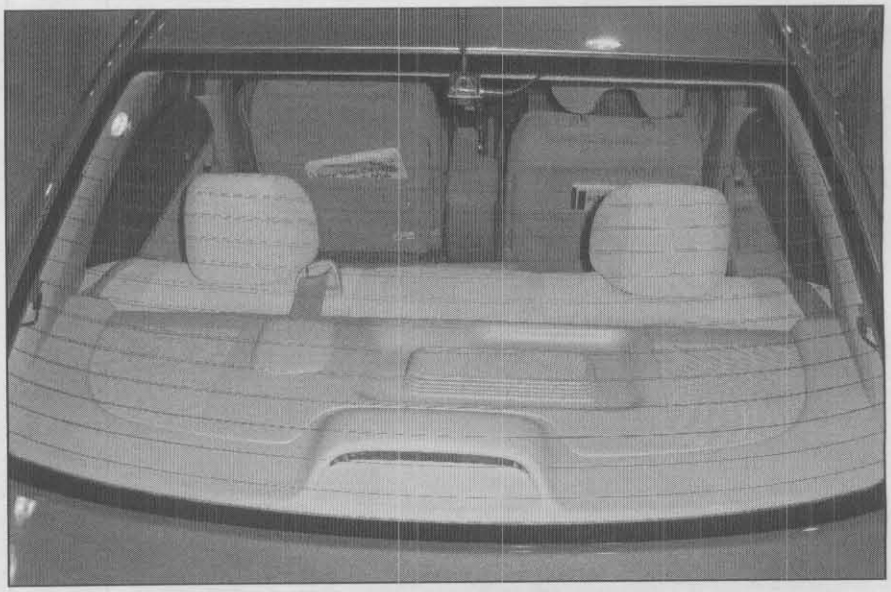
Heating and Cooling the HV Battery

Most hybrid vehicles use a cooling fan that distributes heat or cool air past the HV electronics and HV battery. It is important that the proper air flow is moved past the HV components and battery. Some vehicles use the air conditioning system to cool the HV components and battery such as Ford and Mercedes Benz.

An important component of a hybrid system is the cooling and heating system of the HV battery whether it is a NiMH or Li-ion battery. If either the cooling or heating system for the HV batteries is not performing properly, the battery life will be affected and shortened.

The simplest example is from a Honda Civic hybrid that is only air-cooled or heated. The vehicle has a vent that is mounted above the rear seat back. This vent must remain clear from all obstructions. If the vent is obstructed or the blower fan does not operate properly the performance of the battery will suffer and possible fail.

To cool the HV battery and electronics on the Escape /Mariner, a window vent brings in air to the battery past the filter element. The battery also can be cooled by the vehicle's air conditioning system. In the trunk near the battery box is the Battery Cooling Unit. This unit controls A/C operation for the cooling of the



The Honda Civic hybrid has a vent mounted above the rear seat back. Battery failure could occur if the vent is obstructed or blower fan operates poorly.

HV battery by engaging a solenoid valve which routes refrigerant from the vehicle system to the battery.

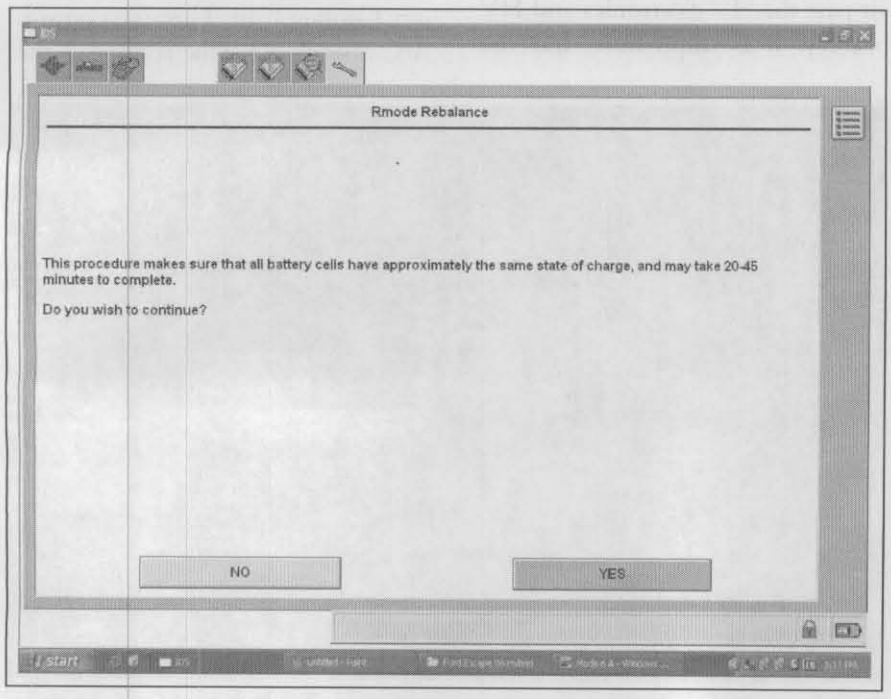
Because there are such a variety of methods used to maintain battery-operating temperatures in use, it is best to refer to the service information for complete description of the system, DTCs that may be detected and recorded by the commanding control module(s), and repair/troubleshooting procedures.

Servicing Battery Pack Cells and Components

Hybrid batteries are made up of individual cells that are, in reality, just a bunch of small batteries wired in series with one another. And just as having a dead cell in a 12v battery impacts the performance of the battery as a whole, so a weak cell (or "block") can effect the performance of the HV battery pack, sometimes to the point of setting performance-related DTCs.

Some OEs such as Ford, have a HV battery rebalance function that can be performed from the Ford IDS factory scan tool. To select this feature on the IDS, select tool box from the menu, next select Electrical, followed by selecting Rmode, on to selecting Rebalance from the drop down and side menu. Once the function is selected, a screen will be displayed that explains the Rmode Rebalance procedure. The Rmode Rebalance command/function makes sure that all of the HV battery cells have approximately the same state of charge. The Rebalance takes about 20 to 45 minutes to complete.

The manual method to balance other HV battery packs that do not have the option as a scan tool function is time and labor intensive. There are grid chargers made by the vehicle manufacturers, and a few grid chargers available from the aftermarket that allow you to perform a discharge and recharge cycle. These grid chargers are priced from $30k for an OEM unit, to $11k for one of the more complex aftermarket grid chargers and down to as low as $300 for some others. It is recommended that, while charging the HV battery, a cooling fan(s) is used and that the temperature is monitored while the battery is being charged.



Some OEs such as Ford, have a HV battery rebalance function that can be performed from the Ford IDS factory scan tool.

If a HV grid charger is not available, another way to test a HV battery is by checking each individual battery cell/pack with a CAT III voltmeter. After recording the voltage levels and starting with the lowest cell, the next step would be to discharge the block/cell with an appropriate discharger. After the discharge cycle is completed, re-charge and retest the battery block. This discharge, charge and test cycle will have to be repeated multiple times in order to get the battery block charged up. After the cycle is completed, the block should be rechecked making sure the proper voltage level has been reached. A Toyota prismatic individual cell (one), for example, is approximately 7.5 volts while the block of two will be about 15 volts.

Other Battery Issues

Sometimes the HV and/or 12v battery may be drained to the point where the vehicle will not start. Pushing them into your bay, or attempting to jump start them as you would a conventional ICE, could pose problems that you have never yet encountered.

For example, on a Ford Escape hybrid, a "wrench" light may illuminate warning the driver of a few different problems that may exist including a 12 volt battery problem. If this is the case the vehicle may not start. The Escape and Mariner hybrids, like any other vehicle, may need to be jump-started but unlike conventional vehicles their HV battery can jump-start the vehicle...meaning, they can jump-start themselves! Unlike Toyota hybrid vehicles that encountered a no start condition due to a HV battery issue or 12 volt problem, Ford came up with a unique

way of solving this problem. This is accomplished by making sure the ignition is off, opening the driver-side panel by removing the trim and pressing the button on the pull out knob. Wait at least eight minutes before attempting to start the engine. During this time, the 12V battery uses the HV battery to crank the ICE.

You will notice a green light on the button illuminate. After this, you can start the vehicle without a problem. Once the ICE starts, the MG will charge the HV battery. If this fails, try a regular jump start, but be aware that if both the 12V and HV batteries were dead, the modules in the vehicle may have lost their memory.

And remember, when the transaxle is turning on many hybrids, so is the permanent magnet in the Motor/Generator (MG) and that means high voltage AC is being produced and fed out on the MG cables, to the AC/DC Inverter and possibly back to the battery. If the battery has been removed, or cables disconnected for service, be sure to follow all OEM specific precautions.

The high-voltage batteries can be affected and damaged by excessively high temperatures. The temperature in some body shop paint booths can exceed 150° F. Therefore, during refinishing operations, the paint booth temperature must be set at or below 150° F. Some hybrids have a sticker to remind the technician or body tech of the maximum temperature. If that is the case, make sure to follow the recommendations listed on the sticker located on the vehicle's door jam.

Notes

Internal Combustion Engine Service & Repair

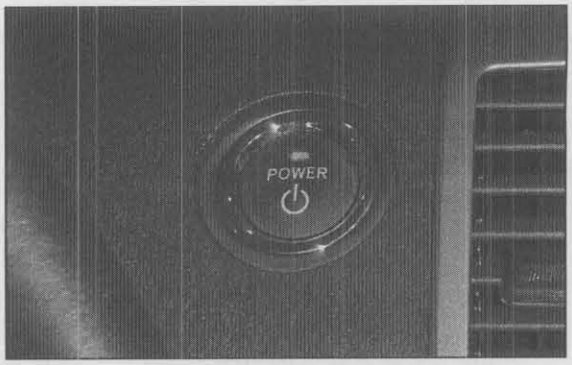
This chapter contains information related to these sections and tasks: Section B, tasks 3-10.

Most of the hybrids on American roads today use a conventional Internal Combustion Engine, referred to as the "ICE" in most service literature. Service and repair of the ICE is not that much different from the service and repair of any other gasoline engine you are used to working on, with a few unique differences that will be discussed in this section.

Starting/Stopping A Hybrid ICE

On many hybrid models, the ICE is only allowed to run under certain conditions. This is why many first time hybrid drivers are surprised when the vehicle is ready to drive but no engine is heard running. It is also a common issue for untrained technicians to inadvertently begin performing service on the ICE only to have the engine magically begin running while six feet up in the air with no oil in it!

For example, to make sure the ICE will not start inadvertently on a Toyota Prius equipped with the "Smart Key" key fob, make sure the key fob is out of the vehicle and that the "Smart Key" button on the dash is "Off" (button pressed in). As long as the Prius is in "Ready/On" mode and has any gas in the tank, it will stop at nothing to keep its HV battery charge from getting too low. Thus, its ICE will engage without warning in order to charge the HV battery. If you drive it in your bay, put it in "Park", and don't observe the dash display carefully before putting it up on the lift...WATCH OUT! Additionally, if the Smart Key is anywhere in range of the vehicle's transmitter antennas without being properly shut down, the engine (ICE) can start up if the HV battery is too low, at any time whether it's on the ground or up on the lift.

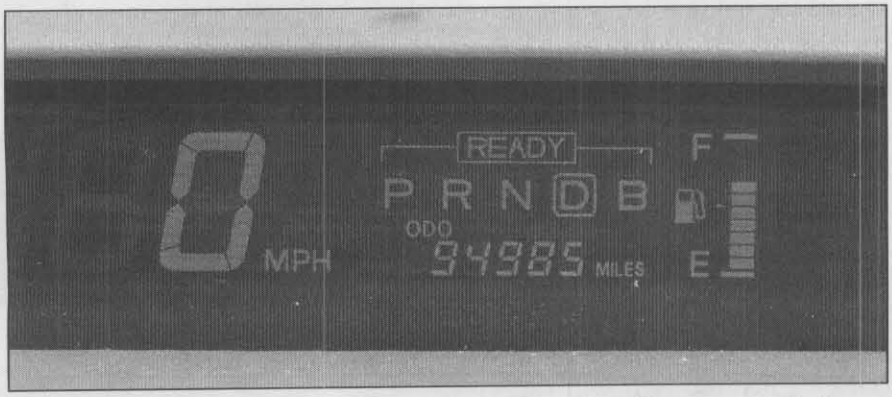


Power Button Illuminated Amber

Smart Key Modes:

- Power Button Not Illuminated: vehicle is "Off", ICE will not start.
- Power Button Illuminated Amber: (Auxiliary mode 1) radio only. To achieve this mode make sure the brake pedal is not depressed (foot off the brake) and press the Power button once.
- Power Button Illuminated Amber: (Auxiliary mode 2) all accessories and scan tool data. To achieve this mode make sure the brake pedal is not depressed (foot off the brake) press the Power button twice (or once more from the previous position).
- Power Button Illuminated momentarily Green than OFF (Not Illuminated): (Ready light "On") vehicle is ready to move either in electric-only mode or under the power of the ICE (if the HV battery charge is too low for electric-only mode). To achieve this mode, make sure the brake pedal is depressed (foot on the brake), press the Power button and hold it until the Ready light is illuminated. Vehicle is now ready to drive.

Pressing the button after the Ready light is displayed along with the Park button pressed/applied



As long as the Toyota Prius is in "Ready / On" mode and has any gas in the tank, it will stop at nothing to keep its HV battery charge from getting too low.

(illuminating green) will shut everything off.

If a Prius smart key fob battery is dead, use the following method to start the vehicle:

1. Touch the Toyota emblem side of the smart key to the power button.
2. Within the 5 seconds after the buzzer sounds, push the power button with the brake pedal depressed (the READY light will illuminate).

To place the Prius Gen 2 and 3 shifter in neutral with Ready off:

1. Press the Power button once until all lights on dash are illuminated EXCAPT Ready
2. Place your foot on the brake pedal while moving/shifting the gear selector to neutral until the N is displayed on the dash.

Diagnostic Testing When You Need the Engine to Run Continuously

Sometimes it becomes necessary to keep the ICE running constantly in order to perform certain diagnostic tests. The following examples describe the procedure as it applies to the Toyota Prius and Ford Escape models.

NOTE: *Always follow the OEM specific procedures for the vehicle you are working on.*

Toyota Prius | Method 1

Set the emergency brake, with vehicle in "Park" followed by pressing the Power button twice. Press the brake pedal and leave it there while, with your other foot, press the accelerator pedal to WOT (Wide Open Throttle) twice. Shift the shifter to "Neutral" (N), press the accelerator pedal twice again followed by pressing the "Park" button. Press the accelerator another two times followed by pressing the Power button once. The engine will start and run at 1000 rpms.

When finished using this mode, make sure to shut the vehicle down before driving the vehicle.

Toyota Prius | Method 2

Set the emergency brake with vehicle in "Park". Press the brake pedal with one foot while pressing the accelerator pedal with your other foot, keeping both of your feet on both. Next, the engine will start allowing you to move the shifter to the N (neutral) position. Now release the accelerator and brake pedal and the ICE should idle about 1000 rpm.

When finished using this mode make sure to shut the vehicle down before driving the vehicle.

Ford Escape Hybrid

Set the parking brake with the vehicle in "Park", engine off and key on. Within 5 seconds of moving the key to the "On" position, press the accelerator pedal to WOT and hold it there for 10 seconds or so. Release the accelerator pedal, shift to "Drive" and press the accelerator pedal to WOT within 5 seconds. Next continue to hold the pedal at WOT for 10 more seconds before releasing the accelerator pedal and shift to "Park". Look at the "Yellow Wrench" indicator light on the instrument cluster to flash at one second intervals, indicating the procedure was followed. Without turning off the ignition key, move it to the engine start position and the ICE should begin idling.

Always exit this mode by moving the shift lever and/or turning the ignition off.

Other hybrids have similar procedures. Some GM hybrids, for instance, allows the ICE to run when the hood is open. Honda IMA hybrids do not have a special procedure since the ICE will run at idle (non Idle Stop) when the brake pedal is in the released position. The above modes are sometimes called "Inspection Mode" by some automakers.

Even if you know what "Inspection Mode" is and how to enter it, never use it for normal driving. Always follow the manufacturers' recommended procedures to prevent personal injury and /or damage to the vehicle.

The above modes can also be used for cooling system service, engine diagnostics and other engine testing including 12-volt battery charging.

Hybrid Start/Stop Strategies

Every hybrid on the road today achieves its highest fuel economy gains through its ability to stop the ICE when the vehicle is not moving and then seamlessly restarting the ICE when the driver releases the brake pedal or pushes down on the accelerator. On nearly every model, the Motor Generator (MG) doubles as a starter motor to quickly spin the ICE for restart. This unique feature is referred to as "Autostop" or "Idle Stop" on hybrid vehicles.

Several parameters are monitored by the commanding control module to control the Idle Stop feature, and there are operating conditions that may temporarily suspend its use. Typically, the complaint from the customer is reduced fuel economy and they may not even realize the ICE is running continuously.

When dealing with these complaints, use the service information source specific to the model you are working on and become familiar with the operating parameters that allow Idle Stop to occur. You may find that its simply a matter of turning down the A/C blower motor speed from "4" to "3" or that the ICE is low on coolant.

Is it ICE or Electric Drive?

Knowing whether it's the ICE

or MGs is something that is not that difficult if you check the basics. Start by checking DTCs, fluid levels, PIDs for the ICE (keep the ICE running as outlined in the heading Diagnostic Testing when you need the engine to run continuously), and check the HV system. Isolate the ICE to perform normal engine diagnostic tests to confirm whether it's an ICE or hybrid problem. The following are a few examples that all can be diagnosed correctly if the basics are checked.

Honda Integrated Motor Assist (IMA) hybrids

Loss of power or a no electric start (starts only on the 12-volt starter) can be caused by a HV problem that includes a blown 20 amp fuse or HV battery problem.

Engine misfires that are not caused by the ICE or electric motor can be caused by CVT transmission that needs to be rebuilt.

Loss of mileage can be caused by using the wrong oil that prevents the Valve Pause System (VPS) from working properly. The VPS is used to shut the ICE valves off when the engine is running in electric mode or during regenerative braking (Regen).

If the Idle Stop does not work after the vehicle has met the warm up and the other needed criteria. This is not a problem with either the ICE or HV system but rather a problem from the brake switch.

Toyota Prius

No start can be cause by a 12-volt battery problem not allowing the System Main Relays (SMRs) to operate. Some Prius's have two while others have three SMRs.

A common cause of a no-start problem will be accompanied by a stored P0A0D (Open In Interlock Signal Circuit) DTC. The cause of this problem is the battery pack's service plug not being in the correct (all the way down and locked) position in the HV battery pack.

Vehicle dies as it's driven down the road followed by a no-start condition can be caused by a defective crank sensor.

Vehicle no-start complaint due to no fuel on Prius's that uses a bladder fuel tank may require a scan tool to clear the DTC before the ICE will start.

Basic ICE Testing

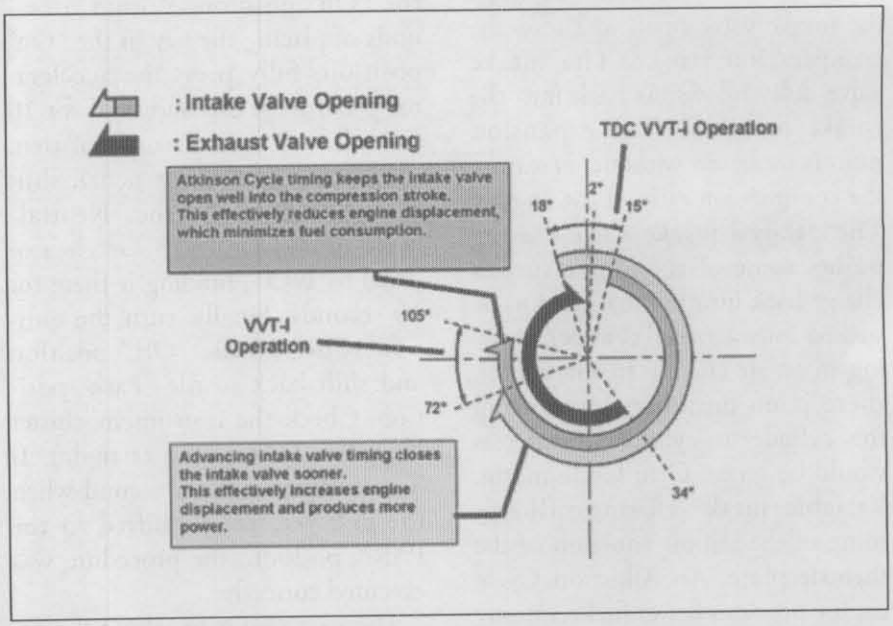
Most hybrid vehicles use an Atkinson Cycle engine that keeps the intake valve open well into the compression stroke. The intake valve delay allows air back into the intake manifold. The expansion ratio is increased without increasing the compression ratio of the engine. The delayed intake valve closing pushes some of the intake stroke charge back into the manifold to be sucked into another cylinder drawing in an air charge. In this motor there is no pumping loss during this cylinder-to-cylinder transfer as would be on an Otto Cycle motor. Variable intake closing offloads some of the airflow function of the throttle plate. This design impacts some of the basic testing you may already be used to.

Performing A Relative Compression Test

Relative compression testing on a conventional engine is simply a matter of disabling the fuel and cranking the engine over, while a Digital Storage Oscilloscope (DSO) is used to capture the current draw required by the starter motor, looking for small variations that indicate a low compression cylinder.

Performing a relative compression test on any hybrid vehicle is not a run of the mill procedure. The fuel to the ICE has to be shut off in order to perform this test and the ICE has to crank at a lower speed. This test can easily be performed on a Honda IMA and GM mild hybrids that use a 12-volt starter. The general procedure is to disable fuel while having a labscope connected to the battery cables by either the test lead (scope coupled to AC volts) or an amp clamp while cranking the ICE over.

Preforming the same test on a Ford Escape requires selecting the engine crank diagnostic mode using



Most hybrid vehicles use an Atkinson Cycle engine that keeps the intake valve open well into the compression stroke. *(Courtesy: Toyota Motor Co.)*

a factory (or aftermarket equivalent) scan tool with the fuel disabled.

Other factory-level scan tools may make the relative compression test available directly through the scan tool.

Refer to the vehicle-specific service procedure for the make and model you are servicing to determine if a relative compression test can be performed, and the method needed to perform it.

Vacuum and Conventional Compression Testing

When performing conventional vacuum testing (intake manifold vacuum) and compression testing (mechanical gauge – cranking, dry and wet tests) on most hybrids, it is important to refer to the listed specifications for test values and limits. Many hybrid ICE engines use the Atkinson Cycle as compared to the Otto Cycle you are used to on conventional gasoline engines. This results in lower compression readings and lower intake manifold vacuum readings, and may lead you to believe there is a mechanical issue with the ICE when none truly exists.

Atkinson Cycle engines keep the intake valve open well into the compression stroke. The intake *valve delay* allows air back into the intake manifold. The expansion ratio is increased without increasing the compression ratio of the engine. The delayed intake valve closing pushes some of the intake strokes charge back into the manifold to be sucked into another cylinder drawing in an air charge. In this motor, there is no pumping loss during this cylinder-to-cylinder transfer as would be on an Otto Cycle motor. Variable intake closing offloads some of the airflow function of the throttle plate. An Atkinson Cycle engine provides better fuel economy compared to an Otto Cycle engine. It also allows for a better transition of power from the ICE to the electric motor.

Performing the test on a "mild" hybrid like the Honda IMA or the GM BAS system is no different than performing the test on a conventional engine, with a few notable exceptions that you'll find in the service information system's procedures outline. For example, performing a compression test on a Honda hybrid is done by removing a 20 amp fuse from the under the hood fuse box or by turning off the IMA switch. Removing the fuse shuts down the high voltage that then allows the ICE to crank over on the 12-volt battery and starter.

Performing the test on full hybrids often requires the use of a factory (or factory equivalent) scan tool, or by placing the vehicle in a specific diagnostic mode. Preforming a compression test on a Ford Escape, for instance, requires selecting the engine crank diagnostic mode. To activate the cranking diagnostic mode, you need to apply the parking brake and place the gear selector in the "Park" position. Make sure the ignition key is in the "Off" position and then turn the key to the "On" position. Within 5 seconds of placing the key in the "On" position, fully press the accelerator pedal to WOT and hold for 10 seconds. Within 5 seconds of that, release the accelerator pedal, shift the gear selector to the "Neutral" position and return the accelerator pedal to WOT, holding it there for 10 seconds. Finally, turn the ignition switch to the "Off" position and shift back to the "Park" position. Check the instrument cluster hazard indicator (red triangle). If it is flashing once per second when the gear selector is shifted to the PARK position, the procedure was executed correctly.

The next step is to release the accelerator pedal and shift the gear selector to the PARK position. Now you're ready to remove a spark plug and install the compression gauge and crank the engine over for a minimum of 5 compression strokes (needle bounces) with the throttle plate in the wide open position. The engine will be cranked over at approximately 1000 rpms by the MG. Ford adds that if the brake pedal is not depressed and held prior to depressing the accelerator pedal, the throttle plate will fail to open. Crank the engine by depressing and holding the brake pedal. Fully depress and hold the accelerator pedal. Turn the key to the "Start" position and crank the engine a minimum of 5 compression strokes (needle bounces) and record the highest reading. Return the key to the "On" position. Release the accelerator pedal. Release the brake pedal.

If the HV battery is under 35 percent state of charge, the test cannot be performed.

If the ignition key stays in the START position for 15 seconds or longer, the PCM may set DTC P2535.

Position the key to the OFF position to deactivate the cranking diagnostic mode and clear all DTCs.

To perform a compression test on a Toyota Prius, remove the spark plug and install a compression gauge. Using the Toyota Techstream OEM scan tool (or equivalent), select the Powertrain / Hybrid Control / Active Test / Compression Test using the scan tool's menu board. Next, turn the power switch "On" while depressing the brake pedal. Now you're ready to record the compression readings. Note that an engine noise will be heard that sounds like there is a mechanical problem as the test is performed. The noise is normal as the engine is being cranked over by MG1. After performing all the procedures, be sure to clear any DTCs stored in the memory.

NOTE: *The OEM service information is ALWAYS the final authority on testing procedures and test specifications. Be sure to first read up on the procedures applicable to the vehicle you are servicing.*

Diagnosing ICE No Start Complaints

You're more than likely used to diagnosing No Start complaints and if so, you know they fall into two categories; "No Crank, No Start" and "Cranks, No Start." All of the conventional causes need to be considered, and since this is a study guide for the "Hybrid" certification, we are only going to focus on the causes of these complaints unique to hybrid platforms.

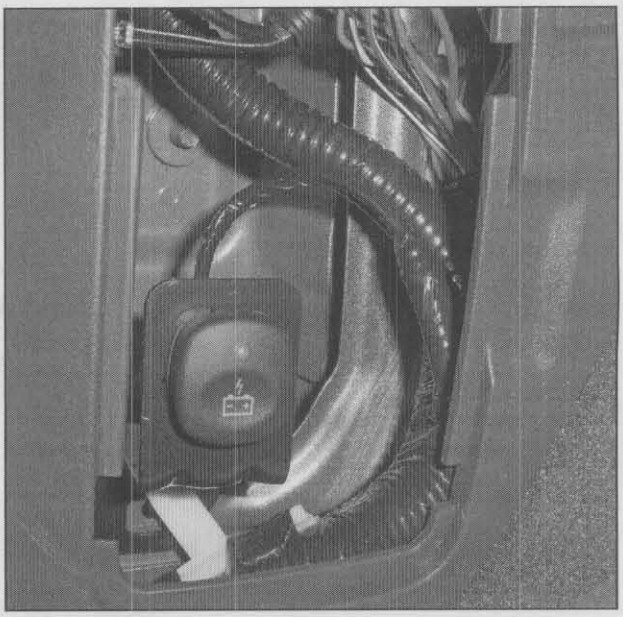
No Crank, No Start

When diagnosing a "No Crank, No Start" on a hybrid, first consider what supplies the power to crank the ICE. If it is a mild hybrid, using a conventional 12-volt battery and starter motor to initially start the car, use your conventional testing skills to isolate the cause. In those full hybrid designs that use a Motor/Generator to spin the ICE, make sure the ICE is free to rotate and has not suffered a mechanical failure. Then, using a capable scan tool, check the HV system for stored DTCs that would disable starting or the HV system.

As an example, on a Toyota Prius that has a no start condition, the diagnostic procedure should start with a check of the 12-volt battery and data PIDs for the HV battery. Check the battery pack's service key to make sure it is installed properly. Check the oil level to make sure it is not overfilled as this can prevent the ICE from starting.

On a Ford hybrid, if the inverter is overheated and a message is displayed "Stop Safely Now," the vehicle will not start until the inverter is cooled down. Recurring incidents of inverter overheating typically are caused by failing inverter cooling system pumps.

Ford hybrid no start and a stored B2172 Inertia Switch Input Circuit Open DTC can be caused by the HV inertia/cut out switch that has been tripped due to an impact. This switch is similar to the fuel cutoff switch that Ford has used for years.



The Escape and Mariner hybrids can use their HV battery to jump-start the vehicle by pressing the jump start switch button.

Cranks, No Start

Customer complaints of "Cranks, No Start" are typically caused by a fault related to the ICE itself. Use the same conventional testing procedures you learned earning your Engine Performance certification to isolate the cause. Verify the mechanical condition of the engine using relative compression, conventional compression or scan tool-based power balance tests. Inspect the fuel and ignition systems for proper operation.

Service Precautions You Need To Know

Always follow all the safety precautions that are covered in the Hybrid Safety section of this study guide. Never jump-start a hybrid vehicle without first consulting the proper service information as it may be different from vehicle to vehicle. Same goes for towing a hybrid. Any rotation of the Motor/Generator may generate high voltage AC current that, if the proper safety devices have been tampered with or disabled for servicing, could result in component damage or personal injury.

Ford, for example, has a special procedure on a vehicle that does not start. If the dash light in the shape of a wrench is illuminated, there are a few different problems that may exist including a 12-volt battery problem. The Escape and Mariner hybrids can use their HV battery to jump-start the vehicle by using the reserve voltage potential to attempt to charge the 12-volt battery. This is accomplished by making sure the ignition is "Off", opening the driver-side panel by removing the trim and pressing the jump start switch button. Wait at least eight minutes before attempting to start the engine. During this time, the 12V battery excites the HV battery, waking it up to crank the ICE over. Once the green light on the jump start switch button is illuminated, the vehicle should start up. Once the ICE starts, the MG will charge the HV battery up to the proper level. The best way to charge a HV battery up besides using a special

grid charger is to drive the vehicle. If this fails, try a regular jump start, but be aware that if both the 12V and HV batteries are dead, this may be a challenge.

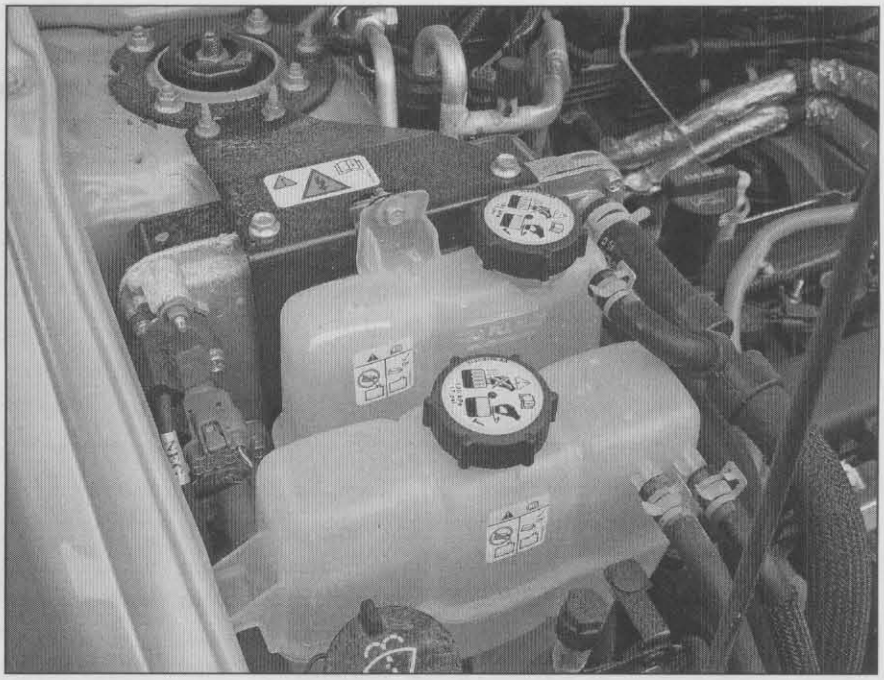
Towing a Hybrid Vehicle

Always remove all metal objects such as rings, watches, jewelry, cell phones, keys etcetera before handling the vehicle. In addition to this, always wear approved high voltage gloves with protective liners.

Only car carriers or light duty wreckers should be used to respond to a disabled hybrid car or light truck.

WARNING: *To avoid death or serious injury, disable/isolate the HV battery and wait at least 5 to 10 minutes after disabling the vehicle that has been in an accident before attempting a tow.*

Before towing a vehicle ALWAYS make sure you chock the wheels to prevent the vehicle from accidentally moving, which of course can be a safety and fire hazard. Afterward disable the HV only if the vehicle was in an accident. Disabling the power to the vehicle by turning the ignition key off and removing it when possible is the easiest way to eliminate any electrical potential. This will be the normal method for towing a vehicle that just won't start and has not been involved in an accident. Remember to keep the drive wheels off the ground if you are using the light duty wrecker. For example, on front-wheel drive hybrids, tow the vehicle from the front with the wheels off the ground. On all-wheel drive or four drive vehicles all the wheels MUST be raised off the ground before moving the vehicle to prevent transfer case/transaxle damage. Otherwise damage can occur to MGs and or HV battery.



Coolant reservoirs are often located close together. On some models, other fluid reservoirs are also co-located with the coolant reservoirs.

ICE Cooling System Service

Servicing a hybrid ICE's cooling system is not too much different from servicing a conventional ICE's cooling system. What is unique to most hybrids is the use of multiple, independent cooling systems – typically one for the ICE and one for the HV components, maybe even one for the battery itself.

WARNING: *Never service a "hot" cooling system. Cooling systems operate under pressure and opening a "hot" system could cause personal injury. Always wear suitable eye protection when servicing cooling systems.*

NOTE: *Air trapped in the cooling system can lead to overheating and damage to system components. Follow the OEM service procedures when servicing the cooling systems.*

NOTE: *Coolant used in service should meet OEM specifications to insure proper system operation and to avoid premature wear or damage to system components.*

Often, the coolant reservoirs for these systems are located close together. On some models, other fluid reservoirs are also co-located with the coolant reservoirs. This all makes it imperative that you are sure you are adding fluid to the correct reservoir when servicing.

In addition to multiple systems, some models are equipped with separate electric pumps and storage units to insure that hot coolant is available quickly to cold cabin occupants in cold weather. Remember, the ICE only runs under certain conditions and in colder weather, cabin heat is supplied by the ICE's cooling system in a conventional heater system.

These systems often include hose routing that makes it difficult to remove all the air without following a specific procedure, opening or closing system bleeder valves, or using a scan tool capable of bi-directional controls to turn on electric coolant pumps.

The OEM service information is the final authority on the procedures needed to properly service

their systems. Always follow the procedures so outlined.

Common Service Procedure Examples

On Gen 2 Priuses, the following procedure must be adhered to when adding coolant to the system.

1. Insert a temporary hose between the radiator bleed port and coolant overflow tank before loosening the radiator bleed plug.
2. Pour the Toyota SLLC coolant into the radiator and tighten the bleed plug and put the radiator cap back on.
3. Use a bi-directional scan tool to activate the water pump for half a minute.
4. Loosen the radiator bleed plug until it drips (3 full turns) and top off the system again.
5. Be sure to secure the radiator cap, and then repeat steps three and four until it does not result in dripping.
6. When step five is complete, run the engine for two minutes and then stop it (make sure READY is not lit up.) Then loosen the bleeder plug and remove the radiator cap and top off the system again like before.
7. Run the engine until it is warm and let the Prius sit for four hours.
8. Top off the coolant again and repeat steps six and seven until the system is full.

If during any of this the PCM turns on the coolant pump, a MIL might light up and/or codes P1151 and/or P2601 will be set. Be sure to clear these codes.

Because hybrids have electric pumps and valves, draining the coolant system is also different. You will need a bi-directional scan tool to make the electric coolant pump change valve states. Using warming and cooling cycles will assist in allowing air to escape the system.

In addition to the electric water pumps used to circulate coolant through the HV system components, some models also use an electric heater circulation pump used to keep the cabin heat working while the ICE is in Autostop mode, and to keep the engine itself at the proper operating temperature.

An alternative method to refilling the cooling system is to use an air lift or similar device. The air lift puts the system in a vacuum allowing the coolant to be suck in with air entering the system. Make sure to have more than the proper amount of coolant/antifreeze premix in a suitable container as so no air will enter the system. It's always a good idea to open up the bleeder on the inverter to check for air as well to monitor the temperature on a scan tool.

Notes

Hybrid Drive System Service & Repair

This chapter contains information related to these sections and tasks: Section C, tasks 7-11.

What makes a hybrid unique to conventional drives? The electric drive system, of course! This is the heart and soul of hybrid vehicles. And while all use 3-phase brushless AC motors, the nuances of how these motors are used is what distinguishes "micro" hybrids from "full" hybrids. In this section, we'll focus on hybrid Motor/Generators (MGs) and discuss the related system components later.

Motor/Generators got their name from the fact they can be used as either one. When voltage is applied to the stator windings, a magnetic field is developed that causes the permanent magnet rotor to turn, and the rotor can be used for propulsion. With no voltage applied, and the permanent magnet rotor locked and spinning, the magnetic field from the rotor induces current in the stator windings, providing an AC output just like a car's alternator (without the rectification!) that can be used to charge the HV battery. This feature is commonly used when the vehicle is slowing down and is called "regenerative braking" (see page 47, "Hybrid Support System Service and Repair").

Basic Motor/Generator Components

MGs are very much like the alternators you are used to servicing on conventional automobiles and light trucks. They are comprised of a 3-phase AC stator, typically wound in a "delta" or "Y" style, and a permanent magnet rotor. There are no brushes or excited fields used in hybrid MGs as of this writing.

When used to drive the vehicle, DC voltage from the HV battery is first converted, or rather "inverted", by the AC/DC inverter and then fed into the stator windings. With current passing through the stator windings, a powerful magnetic field is created that, in turn, causes the permanent magnet rotor to turn. Varying current levels passing through the windings controls the speed of the motor.

Under deceleration or braking, the permanent magnet rotor is used to produce AC current in the stator windings that is used to recharge the HV battery pack. In addition, there is a physical restriction to rotation caused by the magnetic field that aids in slowing the vehicle down. This is called "regenerative braking."

There are two MGs on the Toyota Prius (and similar systems); MG1 and MG2. MG 1 is a 3-phase permanent magnet AC motor that is connected to the sun gear of the planetary gear set. The generator power inverter (internal or external to the transaxle) receives a DC current from the HV battery. The DC current is inverted to an AC current that is computer controlled. The MG 1 is used to start the ICE, charge the HV battery and control engine speed.

The MG 2 or traction motor is also a 3-phase permanent magnet AC motor that is larger and connected to the ring gear of the planetary gear set. The MG 2 is connected to the drive wheels through a series of gears that rotates whenever the drive wheels rotate. The MG 2 motor power inverter receives a DC current from the HV battery that is inverted to an AC current that is computer controlled. The MG 2 can deliver positive torque that moves the vehicle in either the forward or reverse direction. It can also provide negative torque when it acts as a generator during the regenerative braking charging the HV battery up.

Diagnosing Motor/ Generator Faults

Problems with the Motor/ Generator(s) typically fall into one of three categories: inoperative, noise/vibration, or overheating.

The first step in diagnosing any of these conditions is to first follow a logical diagnostic process. Review the service information to familiarize yourself with the specifics of how the system you are troubleshooting works before even opening the hood or lifting the vehicle.

WARNING: *Be sure to use Personal Protection Equipment (PPE) before handling HV cables or components.*

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped with test leads and probe tips rated for CAT III use may result in damage to the equipment, and possible injury to the operator.*

WARNING: *Always follow the OEM-approved procedure for disconnecting and reconnecting the HV battery to avoid serious personal injury or death.*

Never forget you are working on a high voltage system that is more than capable of hurting, even killing, you if you don't follow the proper safety protocols. Refer to Hybrid Safety, page 9.

The next diagnostic step should be to visually inspect for any vehicle damage or abnormalities that could be affecting the customer's complaint. For example, if the complaint is an abnormal vibration, are the engine mounts in good condition? Follow up the visual inspection with a test drive to verify the nature of the customer's concern. Note what warning lights, if any, are illuminated on the instrument panel.

With the elementary steps completed, the next step would be to check for stored trouble codes (DTCs) in ALL onboard modules. Don't immediately assume the problem is in the HV drive or battery. Noise/vibration complaints can be the result of a problem with the ICE! If any DTCs are stored or pending, be sure to write them down and review any related Freeze Frame data while you're in there. Do NOT clear the codes until instructed to do so by the OEM service repair procedures OR until after you've completed your repairs and are ready to perform your final test drive and verification.

With the basic information in hand, return to your service information system and review the OEM Technical Service Bulletins (TSBs) for any related to the symptoms or DTCs you are troubleshooting. Often a repair requires reprogramming of a control module's software, and traditional diagnostic methods will never lead you to bad programming! Additionally, there are an increasing number of diagnostic resources (iATN, Identifix, ALLDATA Community, Mitchell 1 Experienced-based Troubleshooting, etc.) that you can review to see if other techs have already found the solution to your customer's problem. But TEST, don't GUESS, before blindly following some "silver bullet" fix you found online.

Problems related to the MGs that result in inoperative conditions, performance issues, or noise/vibration can be caused by one or more stator windings shorting to ground or going open. These are most often accompanied by a related DTC, but not always. To check the stator windings themselves, you'll first have to isolate the HV battery and allow the system to power down before performing any tests. The transaxle containing the MG or the MG itself need not be removed from the vehicle to perform these tests. The basics of MG winding testing can be found in the Testing HV Wiring Integrity chapter of this study guide.

Overheating conditions can be traced to cooling system problems specific to the HV Inverter or system cooling circuits, included later in this chapter.

The few examples below are complaints from either a noise or vibration that may or may not be accompanied by DTCs.

A Prius with a vibration and noise from under the vehicle complaint was checked out and determined that the noise was coming from the drivetrain. Upon checking the vehicle out, it was found that the noise and vibration was not a HV component failure but rather a bad inner transaxle bearing.

Another Prius with a vibration and noise from under the vehicle came in that had a totally different problem. This time the noise and vibration that was coming from the transaxle was caused by a bad winding in MG2. The confirmation (besides a DTC) was a Megohm reading that displayed an open in the winding. The vehicle had a complaint of noise, vibration and low power. The MG problem was confirmed with a simple push test of the vehicle. When pushing a hybrid in neutral, the magnetic fields of a failed MG winding causes a thumping feeling, indicating a problem with the Motor Generator.

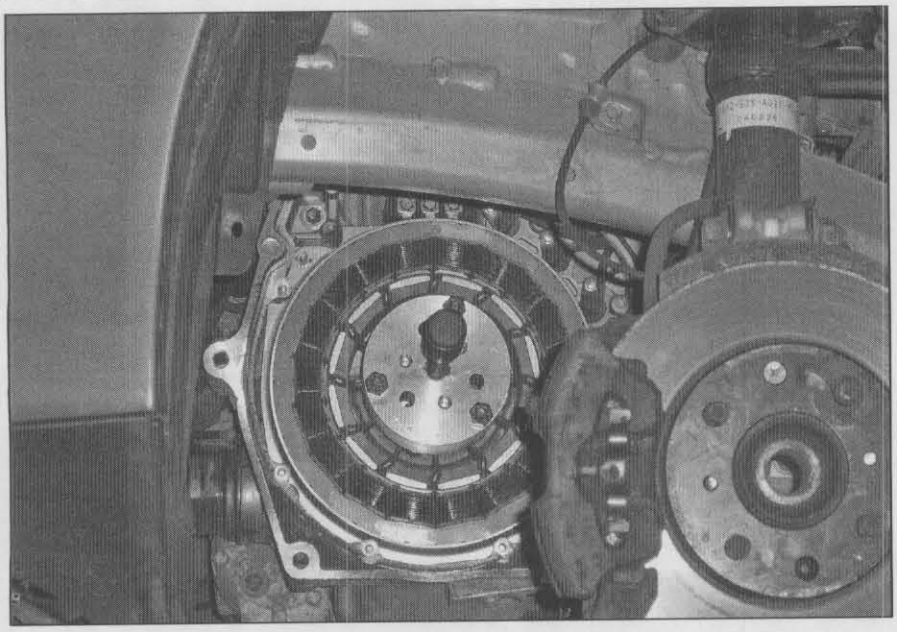
Yet another vibration problem on a Prius can be caused by an engine misfire. Even a slight misfire can cause a bad vibration that may seem like a MG problem is the cause. The engine misfire causes the two piece dampener (like a clutch plate) between the engine and transaxle to produce a banging noise along with an engine shake. Sometimes the noise is so loud, it sounds like an internal engine or transaxle problem. Using a scan tool to confirm misfires from DTCs, misfire counter or Mode $06 will help confirm the cylinder that is misfiring. Some of the engines had problems with water leaking down from the cowl grill right on to the Coil On Plug (COP) that causes the misfires. The fix is to seal up the cowl grill joint with RTV to prevent the problem from reoccurring.

Rotor Removal/Installation

The permanent magnet rotors used in most MGs are very strong, and require removal of the MG to access as well as special tools to avoid damage to the component and/or injury to the technician.

WARNING: *Always follow the vehicle-specific OEM service instructions for servicing the Motor/Generator and/or its components. Serious damage to components and/or personal injury could result if these service procedures are not followed.*

This example is from a Honda IMA hybrid. The special rotor puller (part # 07YAC-PHM010B) is available for loan or purchase from Honda. Honda even has a warning that the motor rotor



Always use a special tool to remove or install a motor rotor. Do not use the motor rotor if the fiberglass band is damaged.

contains very strong magnets and should be handled with special care. People with pacemakers or other sensitive medical devices should not handle the motor rotor. If the motor rotor is installed by hand, it may suddenly be pulled toward the motor stator with great force, causing serious hand or finger injury. Always use the special tool to remove or install a motor rotor. Do not use the motor rotor if the fiberglass band is damaged.

If the band breaks during use, magnets may come loose from the motor rotor. Keep the motor rotor away from magnetically sensitive devices. Store the rotor in the designated storage box and keep it away from sensitive devices during storage. Do not blow air near the rotor, as the metal particles may get on the magnet.

Diagnosing Rotor Position Sensors

As with any modern computer-controlled system, the HV Motor/Generator system has feedback devices that lets the control module know if the commands given have been successfully executed. One such device is the Resolver (Encoder) and is essentially a position sensor that lets the control module know how the MG is doing. The input from the sensor can also be used as a speed sensor for internal diagnostic needs.

NOTE: *For the purposes of the L3 certification, the terms Encoder and Resolver are interchangeable.*

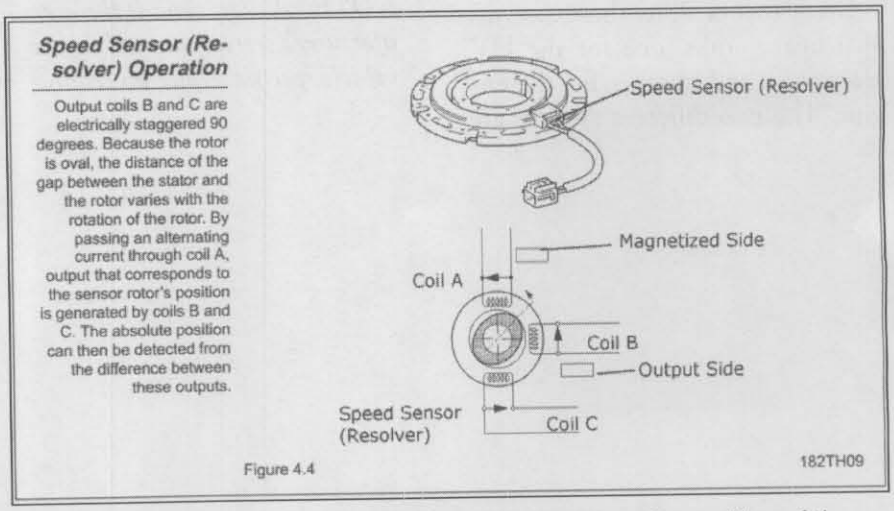
The Resolver is a sensor that detects the magnetic pole position of the motor generator. The Toyota example on the right shows that the sensor has a stator that contains three coils and is oval in shape that surrounds the rotor. The sensor acts as an rpm sensor that calculates the position variance within a predetermined time.

Each of the MGs, MG 1 and MG 2, have their own Resolvers. If there is a problem with the Resolver a DTC such as P0A4B Generator Position Sensor circuit will be set. Make sure to check the subcode as they relate to different problems. As an example subcode 253 Interphase short in Resolver circuit, 513 subcode Resolver output is out of range and 255 subcode Open or short in Resolver circuit will all require a different set of testing procedures. The Resolver can be check with a meter or labscope as any other AC crankshaft sensor is tested.

Servicing Drive System Fluids

Servicing the fluid systems related to hybrid drives is not all that different from servicing any other cooling or transmission fluid. The key is to use the RIGHT fluid for the application and follow any manufacturer-specific service procedure, especially when it comes to bleeding the cooling systems.

These are not the simple two-



The Resolver is a sensor that detects the magnetic pole position of the motor generator. *(Courtesy: Toyota Motor Co.)*

hose, one thermostat, one pump systems of the old days. Electric pumps, multiple lines and reservoirs, and even multiple thermostats are the norm, not the exception. It is critical, as you've seen mentioned several times over in this study guide, to follow the service procedures specific to the vehicle you are working on.

Here are a few examples illustrating differing designs.

The Chevy Volt is equipped with three fully independent cooling systems. The hybrid/EV electronics cooling system is dedicated to cooling the battery charger and the drive MG power inverter module. The hybrid/EV battery pack cooling system is dedicated to cooling and heating the high voltage hybrid/EV battery. The engine cooling system is dedicated to cooling the engine and providing heat to the passenger compartment. The antifreeze/coolant used in this system is a 50/50 mixture of Dex-Cool and de-ionized water.

NOTE: *Water is half of the mixture in ANY cooling system. Use either pre-mixed coolants OR use water that has been verified to meet the requirements for the OEM cooling system you are servicing.*

On a Toyota Prius there are two anti-freeze tanks, one for the HV electronics and another for the engine. The two different systems are to control ICE temperature, both MGs along with the inverter and converter. The antifreeze/coolant required for Toyota vehicles is the Toyota SLLC (Super LLC) premixed. The pre-mix takes the guessing game out of what water to use; assuring that the system is filled with the proper mixture.

NOTE: *When flushing a system it is very important to remove all excess water from the system to insure that the proper amount of the specific special antifreeze/coolant is installed in the system. Check the manufacturer's recommendation for the proper bleeding procedures.*

Transmission/Transaxle MG Fluid Service

Many hybrid MGs are incorporated in the same housing as the transmission and transaxle. These, of course, require periodic fluid inspection and maintenance. Some hybrids will use a check plug near the base of the transmission while others may use a traditional dipstick. Either may require that the transmission fluid be at a specified temperature before inspecting the fill level, or provide a chart listing different levels relative to transmission temperature.

NOTE: *Always consult the manufacturer's service manual for the vehicle-specific service procedure.*

Here are few examples of service procedures you may encounter.

In order to check a Toyota transaxle, first locate the proper check/filler plug to check the fluid level. Do not remove the MG cooling system drain plug as antifreeze/coolant will be removed and air will enter the system. Once the proper check/filler plug has been located, use a 10mm hexagon socket wrench (on most of their transaxles) and remove the plug checking that the fluid level is between 0 to 10 mm (0 to 0.394 in.) from the bottom lip of the filler plug opening. The drain plug is located on the lower end of the transaxle usually beneath the filler plug. The same size socket can be used to remove the drain plug. When filling the unit, only use the recommended Toyota ATF WS fluid.

The Chevy Volt uses a 4ET50 transaxle that has a check and drain plug similar to the Toyota unit. It uses the GM Dexron VI transmission fluid that has to be checked with the hood *open while the* engine is at idle. With the transmission in "Park," wait for 5 minutes to make sure that the dampener is full. Next, shift the transmission through all the gears before placing it back into "Park." Make sure the transmission is up to the recommended temperature (40-60°C /104-140°F) then shift though all the gears two more times. Remove the oil check plug to make sure that the fluid level is correct.

Power Electronics Service & Repair

This chapter contains information related to these sections and tasks: Section D, tasks 7-17, 19-20.

So far, we've covered the HV battery pack that is the energy source for the Motor/Generator. Only one problem, though. The battery pack is a DC voltage supply and the Motor/Generator requires AC voltage to operate. We'll need to add a component that can convert DC to AC to drive the motor, and from AC to DC so the MG can be used to replenish the battery. That's the job of the AC/DC inverter.

In addition, we need some way to step down the few hundred DC volt output of the HV battery to 12V so we can use some of that energy for conventional systems on the car. Perhaps a DC /DC converter would fit the bill?

And we'll need safety systems to protect the occupants in the event of a problem with the HV system, and to isolate the HV battery from the vehicle in the event of a collision. Last, we need a way to monitor it all and let the driver know when a fault occurs.

In this section, we'll cover these and additional systems and components that complete the hybrid drive.

The BUS and Hybrid Diagnosis

When diagnosing a communication problem on the BUS it is important to make sure that all of the modules are communicating. The first place to start is by connecting a scan tool that is capable of checking DTCs and performing a Network test. Network scan tests are available on most factory (or factory equivalent) scan tools. The Network test reports what modules are on the BUS, which ones have DTCs and which ones are not communicating. After retrieving the "U" DTCs and non-communicating modules, review the diagnostic procedure outlined in the service information specific to the make/model you are working on.

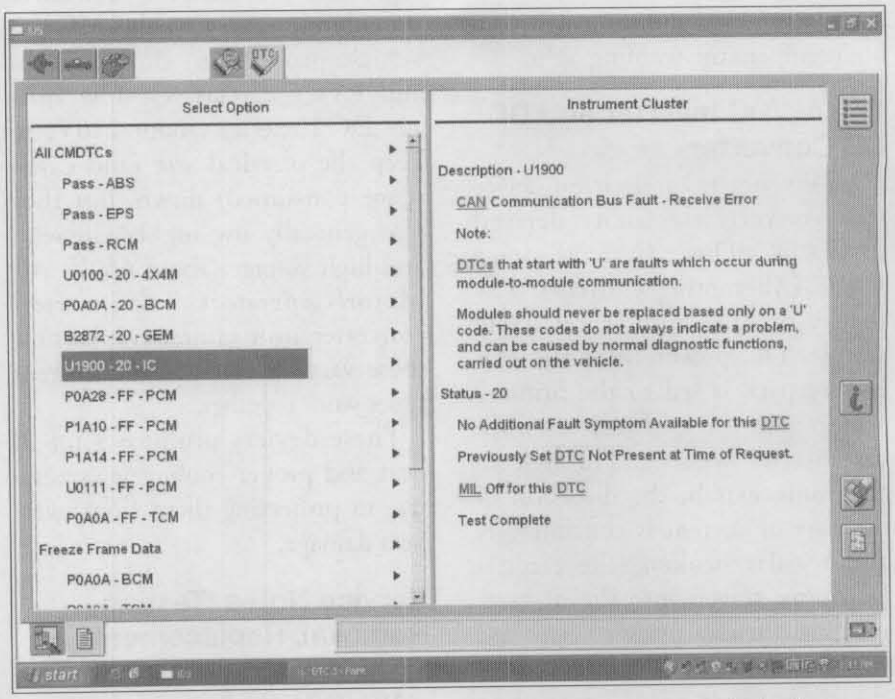
Always perform a visual inspection to make sure there are no aftermarket components wired or installed on the system. Check the power, grounds and all related connections to the effected module. Check to see if there are any loose or broken wires, or bad connections. Perform a voltage drop test on all the computer terminals and connections. Clean any connection with a computer terminal cleaner and apply a contact enhancer such as Stabilant 22, followed by applying dielectric lubricant to seal the connection from future moisture. Be careful not to apply any cleaner, enhancer or dielectric that may block an oxygen sensor circuit from working properly.

Hybrid Warning Lights And Their Meaning

The first and most important light that needs to be checked is the universal "Ready" light that is included on most hybrid vehicles. There are a few exceptions (such as the Honda (Integrated Motor Assist (IMA) hybrid system) but most other manufacturers from Audi, Mercedes Benz, GM, Ford and others all use the "Ready" indicator.

If an IMA light is illuminated on a Honda vehicle, it indicates a problem in the hybrid system.

On a Toyota, a Red Triangle is the



Network scan tests are available on most factory (or factory equivalent) scan tools. The Network test reports what modules are on the BUS, which ones have DTCs and which ones are not communicating.

Master Warning Light that indicates everything from a headlight being out to a High Voltage problem.

On a Ford vehicle, the yellow Wrench Light indicates a problem with a DTC, engine, hybrid, steering etc.

Nissan uses an icon of a vehicle with an explanation symbol that could indicate low fuel level or a problem in the HV system similar to the Toyotas' Red Triangle.

The Nissan EV icon indicates that the vehicle is being driven in electric mode.

A symbol with a vehicle and a double arrow underneath it indicates the vehicle is Ready to start or drive.

The above are a few examples from a few vehicles. To find out more about a vehicles dash symbols check the owner's manual or service information.

On Gen 1 Priuses, the "Turtle" dash light informs the driver that HV battery is low. If the vehicle is driven slowly, the battery will charge back up. The blue coolant temperature indicator symbol is illuminated when ICE temperature is cold and the red indicator light is a high temperature warning light.

The AC/DC Inverter and DC/DC Converter

An inverter is an electrical device that converts electricity derived from a DC (Direct Current) source to AC (Alternating Current). The theory of operation is relatively simple. DC power from the HV battery pack is fed to the primary winding in a transformer within the inverter housing. Through an electronic switch, the direction of the flow of current is continuously and regular broken (the electrical charge travels into the primary winding, then abruptly reverses and flows back out). The in/out flow of electricity produces AC current in the transformer's secondary winding circuit. Ultimately, this induced alternating current electricity is used to power the Motor/Generator.

The DC/DC converter changes the voltage (either AC or DC) of an electrical power source. There are two types of voltage converters: step up (which increases voltage) and step down (which decreases voltage). The most common use of a converter is to take a relatively low voltage source and step-it-up to high voltage for heavy-duty work in a high power consumption load, but they can also be used in reverse to reduce voltage for a light load source, like charging the 12-volt battery that typically powers the conventional vehicle systems (lights, infotainment, engine management, etc.)

An inverter/converter is one single unit that houses both an inverter and a converter. These are the devices that are used by both EVs and hybrids to manage their electric drive systems. Along with a built-in charge controller, the inverter/converter supplies current to the battery pack for recharging during regenerative braking, as well as to provide electricity to the MG for vehicle propulsion. Both hybrids and EVs use relatively low voltage DC batteries (about 210V) to keep the physical size (and cargo space consumed) down, but they also generally use highly efficient, and high voltage (about 650V) AC Motor/Generators. The inverter/converter unit choreographs how these varying voltages and current types work together.

These devices produce a lot of heat and proper cooling is imperative in protecting them from overheat damage.

Service Notes (Testing, Removal, Replacement)

WARNING: *Be sure to use Personal Protection Equipment before handling HV cables or components.*

WARNING: *Use of a Digital Multimeter (DMM) not rated CAT III (1000V) or not equipped with test leads and probe ends rated for CAT III use may result in damage to the equipment, and possible injury to the operator.*

WARNING: *Always follow the OEM-approved procedure for disconnecting and reconnecting the HV battery to avoid serious personal injury or death.*

Typically, you'll be responding to a direct customer complaint and/or a stored DTC when a failure of the inverter or converter occurs. An example of a customer complaint related to converter failure may be a discharged 12-volt battery that may or may not be accompanied by a "No Crank, No Start" issue. The most common lead-in to inverter or converter diagnostics, however, will be related to a system warning light and/or stored Diagnostic Trouble Code. As with any other code diagnostics, begin by reading up on the code definition and enabling criteria, followed by familiarizing yourself with the system operation and service/diagnostic procedures necessary.

If you do diagnose a failed component, it is likely that an outside factor played a part in its failure. For example, a common cause of Toyota inverter failures is failure of the hybrid cooling system; specifically, the inverter coolant pump. Failure to fix the ultimate cause will result in failure of the new component and a comeback to the shop.

Cooling System Service Notes

As discussed in the previous chapters, cooling systems on modern automobiles, especially hybrids, are more complex than ever and require more attention to detail to properly service and repair them. Addition-

ally, the high heat loads created by the HV battery and system components must be controlled to avoid permanent damage to very expensive parts.

First, the use of the proper coolant is a must. Second, using premixed coolant or water tested to insure that it meets the automakers specifications is critical in preventing internal corrosion or damage to system components. Third, following the proper air bleed procedure is paramount to make sure that all the air is removed from the system.

And remember! There are more than one cooling systems on most hybrids. Make sure you are working on the right one!

HV Capacitors

Capacitors are voltage storage devices that are similar to a battery, storing electrical energy. Capacitors are different than a battery in that they cannot produce voltage but rather just store it, for use when there is not sufficient battery voltage available. A capacitor's storage potential, or capacitance, is measured in units called farads. The Gen 1 Toyota Prius has three HV can coil-type 450V capacitors (old style) or (new style), while the Gen 2 has 3 epoxy-type with two 600V and one 750V capacitors. There are no separate DTCs for capacitors. If they are defective the Inverter/Converter has to be replaced as a complete unit.

Before testing capacitors follow all safety precautions including the wearing of Class 0 1000v HV gloves and covers. A typical way to test capacitors is to connect a CAT III Megohm meter's leads to the proper meter input terminals and to the positive and negative terminals of the capacitor, then reading the voltage level.

WARNING: *Make sure not to short the terminals together as the stored high voltage will caused a big voltage spike, explosive noise, destroy the meter lead end and possibly damage the capacitor.*

If the voltage has been drained down to "0" volts, change the meter to the appropriate Megohm meter input terminal, apply voltage from the meter to charge up the capacitor. As the meter supplies voltage to the capacitor the resistance reading should increase, if the reading stays at "0" or does not increase, the capacitor should be replaced.

Safety Interlocks

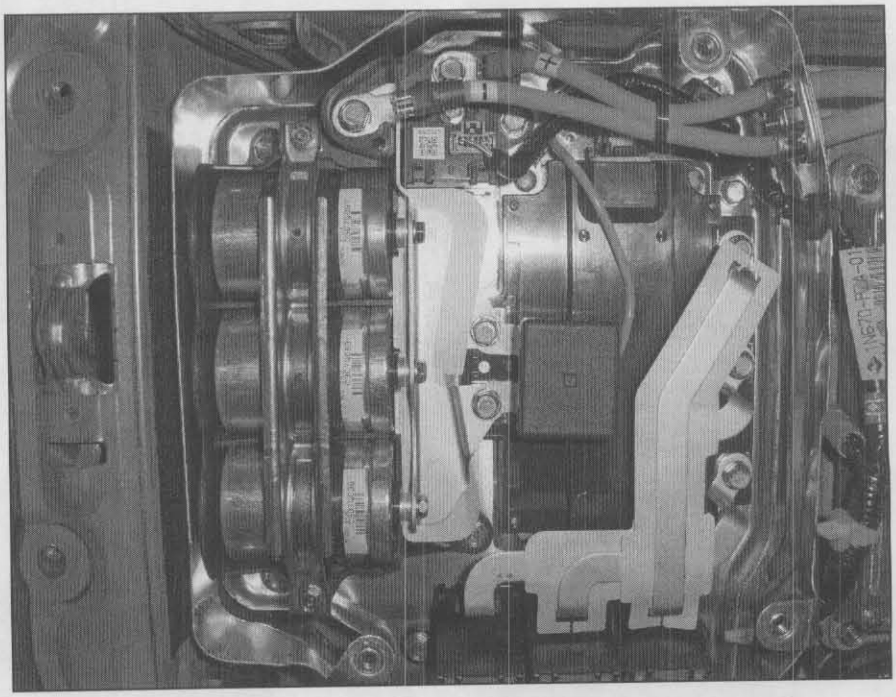
HV interlocks are located on the high voltage system to check for opens in the HV circuit via the relay that controls the low to high voltage connection. Interlock systems are installed to provide an extra safety point in powering down the high voltage. An example of a location of an interlock connection would be under the inverter cover. When the inverter cover is removed, the interlock connection pins are disconnected causing the HV voltage to be drained from the capacitors. Always use HV gloves and liners when working on this or any HV system. After waiting 10 minutes check the capacitors voltage level with a CAT III Digital voltmeter.

System Main Relays

The automakers fully understand the potential risks associated with high voltage systems, and have built into their hybrid and EV offerings a variety of safety systems to insure that the vehicle occupants, and their rescuers, are safe in the event of an accident that causes the HV system to short to the vehicle body.

One such system is the System Main Relays. All hybrid/electric vehicles use at least two system relays to disconnect the high voltage from the HV system. These relays are typically controlled by the HV control module and are activated/deactivated in response to system criteria.

Here's an example using a 2010 (or later) Toyota Prius model that uses three contact-type System Main Relays (SMRs). Factory ser-



CHV Capacitors are voltage storage devices similar to a battery, storing electrical energy. Capacitors are different than a battery in that they cannot produce voltage but rather just store it for use when battery voltage is weak.

vice information labels the three as SMRB, SMRP and SMRG. The SMRB controls the positive side of the HV battery while SMRP and SMRG control the negative side. When the driver turns the vehicle to "Ready/On", the HV control module closes the HV circuit by performing these steps:

- The ECU first closes SMRB, then SMRP.
- The resistor in series with SMRP reduces initial current flow.
- Next, the ECU closes SMRG and opens SMRP.

This allows full HV battery current to enter the inverter. When the driver turns the power switch "Off", or a collision occurs, the airbags deploy, or an HV system fault is detected, the control module opens the HV circuit.

- The ECU opens SMRG and then verifies that the relay is open (contact points have not physically stuck closed).
- The ECU then opens SMRB and performs another check by closing SMRP to verify that SMRB is open (no current flow through circuit). If no problem is found, SMRP is opened.

Testing of the SMRs is similar to testing a conventional relay. The resistance of the control coil internal to the relay is measured and checked against specification, while the contacts are verified by measuring the resistance across them with the contacts open and closed. The relays may or may not be replaceable separately.

WARNING: *SMRs are part of the HV circuit. Use all the HV safety protocols you've reviewed so far, including proper isolation of the HV battery and the use of all Personal Protective Equipment (PPE).*

HV DC Fuses

Since DC just keeps on producing current, even through an air gap, hybrids require special DC fuses, switches, relays, and circuit breakers. This helps protect the vehicle's high voltage/current equipment. A high current DC fuse is built with a material inside that creates a non-conductive gas internally that quenches an arc.

NOTE: *Always replace hybrid/electric vehicle fuses and power components with OEM replacements to keep the system safe.*

The Role Of The 12-Volt Battery

Hybrids also use a conventional 12-volt battery to supply power to the more conventional systems; engine management systems (ignition, fuel pump and injectors, etc.), lighting, infotainment, power accessories (doors, windows, etc.) are just a few examples. Often, you'll notice that the 12-volt batteries are much smaller in dimension than what you are used to seeing. That's because they aren't needed for starting the engine. The MG takes care of that!

And while many hybrids are still using conventional Flooded Lead Acid (FLA) batteries, many more are making the move to Absorbed Glass Mat (AGM) batteries. It is also a growing trend among vehicles using conventional powertrains.

Outwardly, these battery designs make look identical but inside it's a whole different story. AGM batteries use a fibrous glass mat material separator that acts as a sponge for the electrolyte around the plates, which provides electrolyte coverage to a greater surface area. This "absorption" of electrolyte allows for more efficient use of the plate surface area. The result of this efficiency is a smaller, lighter, more effective battery.

In most AGM designs the mat is wrapped around the positive plate, which protects the plate from vibration and extended cycling. The AGM cells are housed in a sealed, maintenance-free, spill-proof hous-

Typically, battery chargers designed for use with AGM batteries differ from conventional chargers in how they control voltage and current to the battery. *(Courtesy: Bosch)*

ing with a one way pressure relief valve. AGM battery manufacturers use what is known as "recombinant" technology that takes the oxygen produced on the positive plate and combines it with hydrogen to produce water (H2O), making these batteries virtually "maintenance-free."

Because AGM batteries use the process of recombination, the charging rate has to be limited. Using just any old battery charger will typically result in a phenomenon known as thermal runaway. What happens here is the excessive voltage/amperage charging rate increases the temperature of the plates and results in a production of excessive hydrogen that cannot be recombined. The result of thermal runaway is an outgassing of the excessive hydrogen. Remember the one-way pressure relief valve? It is installed specifically for this situation. The problem is, it's irreversible. With the outgassing comes a loss of electrolyte rendering the battery a useless paperweight in most cases.

WARNING: *Only use shop charging equipment approved for use on AGM batteries or permanent battery damage will occur.*

Typically, battery chargers designed for use with AGM batteries differ from conventional chargers in how they control the voltage and current to the battery. FLA batteries can generally be charged at a high voltage/high current rate while AGM batteries typically use a low to moderate voltage/low current rate. Some new "smart chargers" pulse the current flow to the AGM battery during charging to speed up the charging process.

Testing the AGM is the same as testing the FLA with one exception. There is no access to perform a specific gravity test of the electrolyte. Conventional capacitance testing or load testing is acceptable.

To jump-start a hybrid vehicle, find the 12-volt battery post and properly connect a jumper pack. The Toyota Prius, for example, has a jump stud that is very small and located under the left side under the hood in the fuse box upper left corner. Remove the red cover and be careful attaching the positive clamp of the jumper pack to the small stud and the black clamp to ground.

Never push start a hybrid vehicle as it is not recommended by the manufacturers since it can damage HV components.

When towing a hybrid vehicle, make sure you chock the wheels to prevent the vehicle from accidentally moving. Many hybrid vehicles may appear to be off (no engine noise) but have the ability to move if they are in the electric (Ready) mode. Always make sure that the "Ready" light or ignition is in the "Off/Not Ready" position. If the vehicle has an electric shifter, you will need to have 12 volts power available in order to place the shifter in neutral. If the vehicle has been in an accident, follow all safety precautions to disable the HV voltage.

Keep the drive wheels off the ground at all times when towing with a light-duty wheel lift wrecker. For example, on front-wheel drive hybrids, tow the vehicle from the front with the wheels off the ground. On All-Wheel Drive (AWD) or 4-Wheel Drive (4WD) hybrid vehicles, make sure all the wheels are off the ground when using a standard light-duty wrecker (the use of 4-wheel lift dollies will be needed) or use a flatbed wrecker. If the drive wheels are pulled on the ground there is a potential of high voltage being produced along with damage to HV components.

Only flatbeds carriers or light duty wreckers (with wheel lifts for all/4-wheel drive) should be used to tow a disabled hybrid car or light truck.

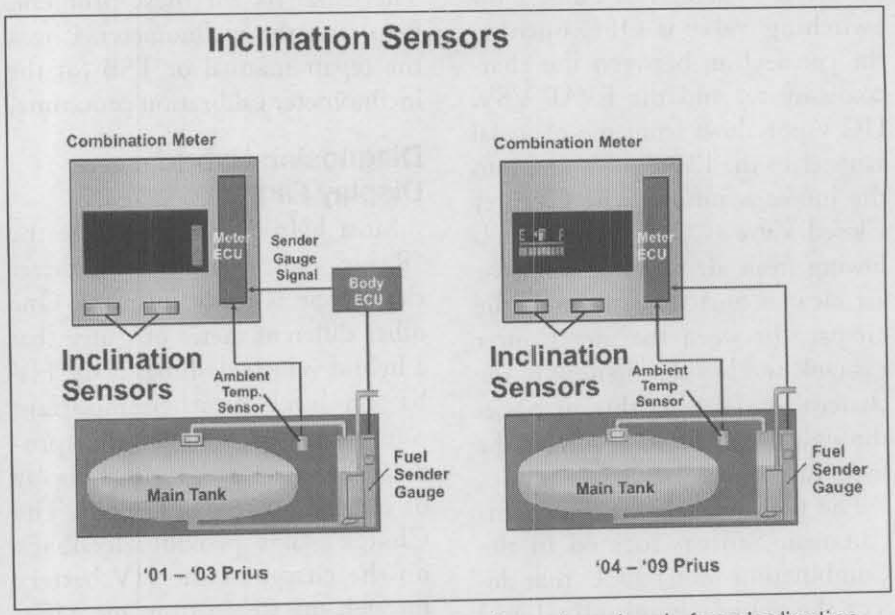
Notes

Hybrid Support System Service & Repair

This chapter contains information related to these sections and tasks: Section E, tasks 6-14.

Hybrids operating in "electric-only" mode posed some interesting design issues for engineers when they were first introduced. For example, how do we keep the occupants cool and comfortable on those hot summer days when they stop at a light and the engine-driven compressor stops turning? Another issue is steering a car without power steering assist (another engine-driven system).

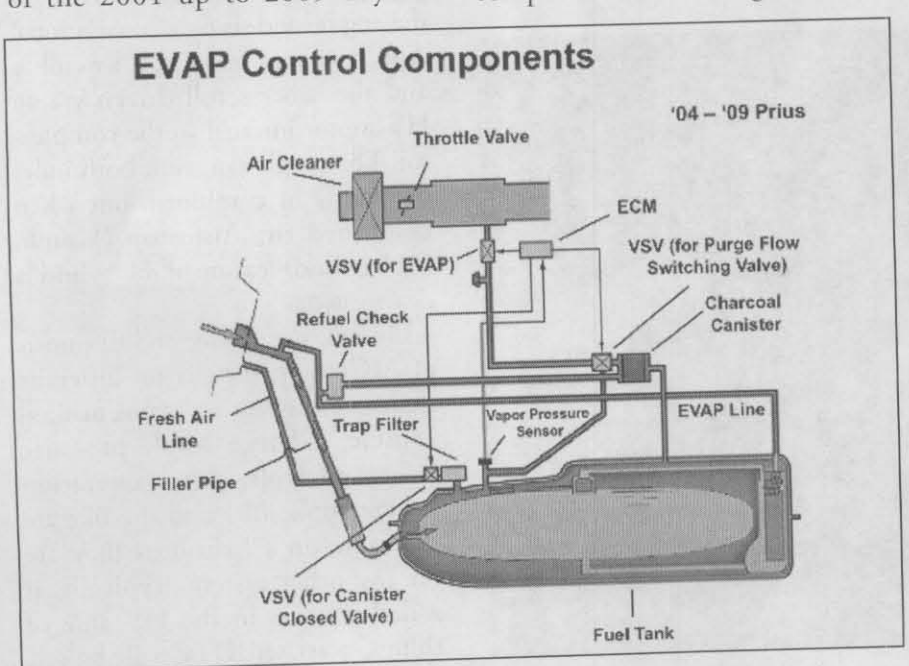
In this section, we'll cover systems in place that overcome the need for an ICE.



Fuel level corrections on the fuel gauge are based on signals from Inclination Sensors and an ambient temperature sensor. *(Courtesy: Toyota Motor Co.)*

Hybrid EVAP Systems

Most hybrid vehicles use a conventional Evaporative Emissions (EVAP) system with the exception of the 2001 up to 2009 Toyota Prius. We will focus on this system since the system is a bit different. As of 2010 the bladder tank is no longer used on the Prius because of complaints of fuel range and fuel level discrepancies by owners.



Toyota Prius EVAP uses a bladder tank that expands when fuel's added. *(Courtesy: Toyota Motor Co.)*

The early Toyota Prius EVAP uses a bladder tank that expands when fuel is added. When the fuel level is low in a bladder tank, it is sometimes difficult to add fuel. The bladder prevents hydrocarbon (HC) vapor from being stored keeping emission levels down. The EVAP vapors moves from the main tank to the secondary tank where the fuel pump is located. Vapors continue to move through the EVAP line to the charcoal canister where they are absorbed and stored. Air flows from the charcoal canister to the airspace between the metal outer part of the gas tank and bladder to the Canister Closed Valve. The Canister Closed Valve (CCV) is normally 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.

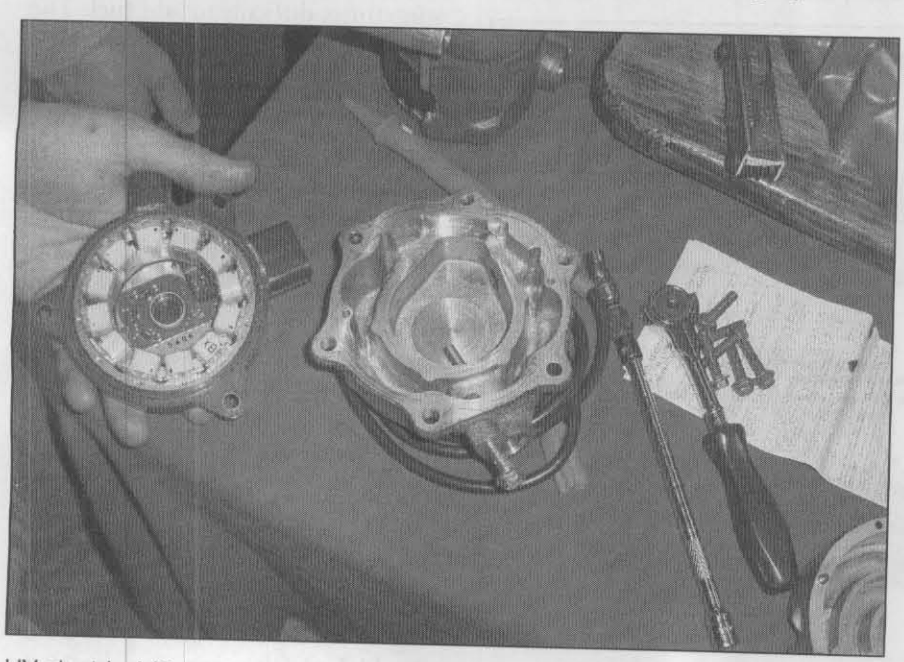
During normal purge operation the engine is running and the ECM duty cycles the EVAP Vacuum Switching Valve (VSV) ON and OFF, allowing vacuum from the intake manifold to pull air through the EVAP system. The Purge Flow Switching Valve is OFF, opening the connection between the charcoal canister and the 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 gas tank and bladder then up to the charcoal canister. As this air passes through the canister, it purges the hydrocarbon vapors.

The fuel tank also uses two Inclination Sensors located in the Combination Meter ECU that detect the vehicle longitudinal and latitudinal inclination to correct the fuel level calculation. Fuel level corrections on the fuel gauge are based on signals from the Inclination Sensors and the ambient temperature sensor located in the fuel tank. Problems that have been reported by some owners include complaints of only being able to pump a few gallons of gas into the tank and the vehicle runs out of gas while there are still three or four bars left on the fuel meter. The usual fix for these problems is to reset the inclinometer. Check the repair manual or TSB for the inclinometer calibration procedure.

Diagnosing Hybrid Display Faults

Most hybrid vehicles utilize the "Ready" light that alerts the driver the vehicle is ready to move. One other different meter or gauge that a hybrid vehicle dash has is the HV battery level. Another important one is the Assist meter that provides the driver with a visual display of electric power being used. The Charge gauge provides feedback on the charge of the HV battery through the Regen from the MGs. Obviously there are the other normal icons and gauges that are found on non-hybrid vehicles.

Most hybrids also have a screen display that pictures the HV components (Battery, MGs, wheels and energy flow) this displays if the HV battery energy is being used or recharged. These displays are not 100 percent accurate when it comes to displaying the HV battery level. Most HV batteries are only allowed to go down to 40 percent of charge and up to 80 percent when filled. There is an exception on Honda IMA HV batteries that can go down to 20 percent and up to 80 percent of charge. These charge rates are in place and controlled by the BCM (Battery Control Module) to protect the HV battery from being damaged.



HV electric A/C compressors eliminate the need for an A/C clutch or belt, and provide for full A/C operation even with the ICE off.

Diagnosing and Servicing Hybrid A/C Systems

Hybrid A/C systems are a different beast than non-hybrids. Toyota hybrids (2005 model year and up and Hondas 2006 and up) and most other hybrid/electric vehicles have HV electric A/C compressors. Fully electric compressors eliminate the need for an A/C clutch or belt, and provides for full A/C operation even with the ICE off. Many Honda, Ford, Nissan, and GM hybrids have dual scroll compressors that are really two compressors in one; with one scroll belt driven off the engine and using a conventional A/C compressor clutch assembly and the other scroll driven via an HV motor internal to the compressor. The scrolls can work both independently or combined, but when combined the Autostop (Honda IMA hybrid) feature of the hybrid is deactivated.

Overall, the service and diagnosis of A/C complaints is no different than dealing with a conventional vehicle. Charge level, pressure switch controls, clutch operation (where applicable) and the like are the same on a hybrid as they are on any other system. Typically, if a fault occurs in the HV side of things, a related DTC will be set, helping to provide some diagnostic direction. Just remember that this

is another HV component, and the same safety protocols you use when servicing the HV battery, AC/DC Inverter or any other HV component apply here as well.

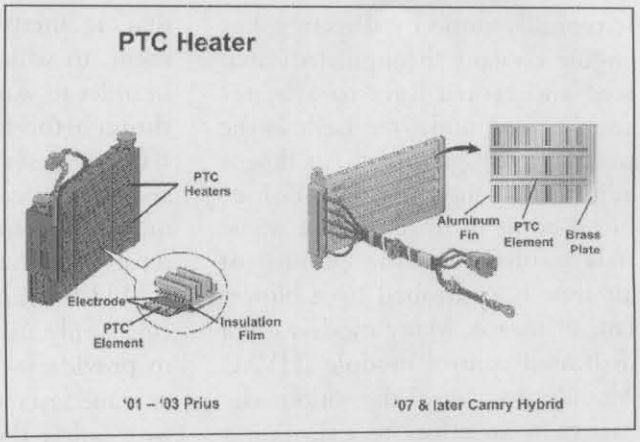
Another important difference is in the oil used to service HV A/C compressors. The PAG oil you are used to using on R134a systems is conductive and cannot be used in a high voltage application like the compressors used on many hybrids. Even a small amount (as little as 0.001 percent) introduced during service can be enough to cause damage to the compressor and result in a high voltage leak that will shut the system down. The most common cause of contamination is using a machine that has PAG oil in its lines to service a hybrid requiring POE (Polyol Ester). This oil typically enters the machine from the use of the onboard oil fill option or by oil being drawn into the hoses during the recovery or evacuation procedure.

Additionally, repair for oil contamination requires replacement of every component in the A/C system.

Best practices dictate that a separate A/C Recovery/Recycling/Recharging (RRR) machine is used to service hybrid models. Some machines are certified for use on both conventional and hybrid systems as long as a machine/line flushing procedure is used before connecting to the hybrid system. A new RRR machine can be placed into hybrid service as long as the oiling feature common to many has never been used.

Some aftermarket companies offer filtration systems intended to be placed in line with the RRR machine and the hybrid vehicle being serviced to prevent any cross contamination between machine and vehicle.

A/C maintenance is not something optional on some hybrids. Some vehicles such as Ford/Mercury, Mercedes and some other hybrid vehicles use the A/C system to actually cool's the HV battery and components. The HV battery is the most expensive HV component in the vehicle! So, it's important to make sure the A/C system is fully functional.



The PTC heater contains electrodes that are interposed with a PTC element.

Here are some examples of systems in use today.

Prius' uses an electric Inverter compressor consists of a spirally wound variable brushless motor scroll compressor. The unit contains a built-in oil separator that is able to separate the compressor oil that is mixed with the refrigerant. Toyota warns against using any refrigerant oil other ND-OIL 11. This oil ensures that the proper insulation of the internal high voltage portion of the compressor and the compressor housing is not compromised.

The Inverter supplies the HV voltage to the A/C compressor that varies by model:

- Gen 2 Prius uses a circuit within the hybrid inverter assembly to changes HV battery voltage (202V DC) into three-phase AC to power the air conditioning system's electric inverter compressor.
- Gen 3 Prius uses a circuit built into the Air Conditioning Compressor (dedicated inverter) to directly change HV battery voltage (202V DC) into three-phase AC to power the air conditioning system's electric inverter compressor.
- Highlander Hybrid uses a circuit built into the Air Conditioning Compressor (dedicated inverter) to directly change HV battery voltage (288V DC) into three-phase AC to power the air conditioning system's electric inverter compressor.
- Camry Hybrid uses a circuit built into the Air Conditioning Compressor (dedicated inverter) to directly change HV battery voltage (245V DC) into three-phase AC to power the air conditioning system's electric inverter compressor.
- The Volt A/C system uses R-134a refrigerant that is used to cool the passenger compartment and high voltage battery. The system uses an electronic climate control module and a Vehicle Integration Control Module (VICM) that will command the electric A/C compressor to a speed necessary to maintain a desired cooling level rather than cycle the electric A/C compressor on and off. The systems also flows refrigerant into the battery chiller that removes heat from the battery coolant that flowing inside the battery chiller. The battery coolant and refrigerant are separated by several plates that are inside the battery chiller.

Diagnosing and Servicing Hybrid Cabin Heating Systems

Keeping the occupants warm when the weather outside is cold

is typically done by directing hot engine coolant through dedicated feed and return lines to a heater core, located under the dash in the passenger compartment. Air flow is adjusted through the operation of blend doors to direct the air where it is wanted, and the amount of air flow is controlled by a blower fan, or motor. Many models use a dedicated control module (HVAC Module) to control the various elements in an effort to maintain a constant temperature in the cabin.

But what about hybrids or EVs where there is no engine, or the engine isn't running?

To overcome this problem, most hybrids use some form of electric heater to heat the coolant when the ICE isn't hot enough to do it, and others have a storage system to store heated coolant (kind of like a Thermos bottle!) for just such occasions.

The Chevy Volt HVAC system, for instance, uses both heated engine coolant and a high voltage heater to provide heat to the passenger compartment. The high voltage heater is used when passenger heat is requested but the ICE is not running. The heater provides different levels of heating, dependent on the amount of heat needed to meet the request and the outside air temperature. The HVAC control *module* turns on the coolant pump and monitors the temperature sensors in the passenger compartment, outside air, engine radiator, high voltage heater and the engine to determine the position of the flow control valve and if the high voltage heater is needed. The heated coolant, heated by the engine, the heater, or a combination of both, is then passed through a conventional heater core, heating the cabin.

Some Toyota Prius use a special heater core and a Positive Temperature Coefficient (PTC) heater, which is compact and lightweight. The PTC heater contains electrodes that are interposed with a PTC element, to which current is applied in order to warm the air that passes through the fins. Location of the PTC heater(s) varies with model and year; refer to the OEM service information for details and service/repair procedures.

Mild hybrids (Honda IMA, GM BAS) only use their hybrid drives to provide for idle stop/start and, in some instances, to assist the ICE with power flow when under load. These vehicles may or may not be equipped with electric heating systems, relying instead on the ICE alone to keep the coolant heated.

Additionally, some hybrid systems also use the heated coolant and an independent electric pump to keep the ICE at operating temperature when not in use. Cold engines run richer than a warm one does, and that means high fuel use and emissions. Can't have that!

Diagnosing and Servicing Hybrid Electronic Steering Systems

On all hybrid vehicles the power steering is electrically assisted, making no use of hydraulics. Electric Assist Power Steering (EPS) is a simple design, with motor amperage hitting about 59 amps when the wheels are at their locks. A scan tool is needed to extract DTCs from these systems as well as provide other information diagnostic information. Most EPS units are operated by a 12-volt brush-type motor while some other vehicles will use a 42-volt version of EPS that receives its voltage from the HV converter. Early units required replacement of the assembly to affect a proper repair, but now some models allow replacement of the component parts.

Some of the common DTCs are C1511, C1512, and C1513 (Torque Sensor Malfunction). The problem areas are usually the torque sensor or the steering ECU. To diagnosis this problem, start with scan data and following up by checking service information to verify the proper voltage at specific ECM terminals. With a DVOM measure the voltage from the steering ECU pins while turning the steering wheel at

Most EPS units are operated by a 12-volt brush-type motor while some other vehicles will use a 42-volt version of EPS that receives its voltage from the HV converter.

different angles or as described in the service information. Look at the specific chart for the vehicle you are working on and remember that some vehicles utilize a 42-volt steering system where safety precaution must be followed.

Other common issues impacting EPS operation can occur during routine service on the suspension and/or steering components. Sensors must be "zero'd" in order for the steering ECU to know where the wheels are pointing, and this procedure requires a factory (or factory equivalent) scan tool.

Diagnosing Hybrid Braking Systems

Most hybrids use a standard hydraulic brake system that barely gets its brake pads worn down since most of the braking is down by the MGs through regenerative braking. There are a couple of systems that you should be aware of that are a bit different. One is on the Gen 2 Toyota Prius and the other is on the Ford Escape. It is important to always check service information and read up on a systems description to familiarize yourself with the working on the system.

The Gen 2 (only) brake system uses a unique brake system that utilizes a box of 12-volt capacitors that replaces the conventional booster. This box is black and is located on the right rear of the trunk next to the AGM 12 volt battery. Think of its power supply and capacitor bank as a "vacuum boost reservoir" which can even serve as a back-up system, though in limited circumstances. Basically, it is only enough for a stop or two if there is a 12-volt failure.

If there is a power problem, the Service Master Cut Valve 1 (SMC1 – the backup module for the Prius 2) and Service Master Cut Valve 2 (SMC2 – the electric set-up for the module) will offer no brake assist. You will have to resort to "limping home," so drive very slowly. There will still be conventional brakes in this mode but there will be no assist. This is a similar problem to what happens on a conventional vehicle when a power booster is not working.

When doing work on the brakes on a Ford Escape hybrid, take the following safety precaution. The brakes will pressurize unexpectedly, because the braking system does a self test, adding pressure to the lines, when the vehicle is off. So, the brakes MUST be disabled.

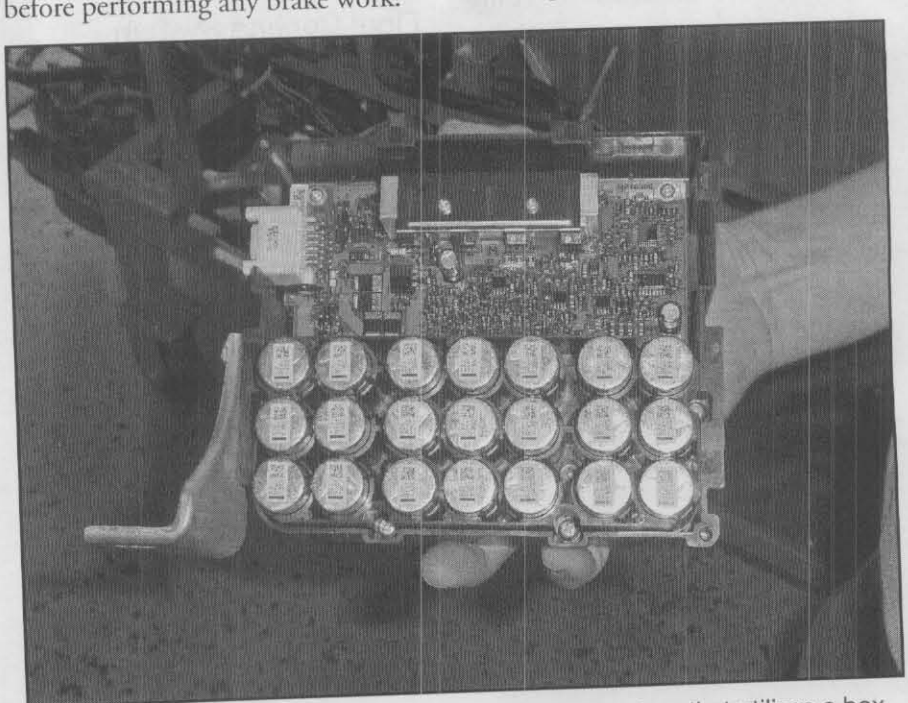
When bleeding the brake fluid on Ford hybrids, make sure to have a Ford Rotunda Drain Twin Pressure Bleeder (Part #261-00002) and a scan tool with special software handy. You will need it to deactivate and depressurize the brakes before performing any brake service. After the repair you will have to activate the brakes by using the Ford factory IDS scan tool or by turning the ignition key off then on. Another procedure from the Ford Shop Manual states to pull fuses 9 and 18 before performing any brake work.

If the proper software is not available there is a manual method that can be followed to disable the brake system.

Alternate Method for SBSM (Safe Brake Service Mode)

Complete the following steps:

1. Put the vehicle in Park with the ignition on.
2. Step on the brake pedal.
3. With your foot on the brake pedal, turn the key OFF and then ON three times. Afterward, release the brake pedal. This must be done in less than 3 seconds.
4. If the preceding was performed correctly, the brake warning lamp will flash as stored hydraulic pressure is released. It will remain illuminated once the pressure is fully released. If you apply the brakes, the brake warning light will flash.
5. You may now work on the brakes. After the repair you will have to activate the brakes again by turning the ignition key Off then On.



The Gen 2 (only) brake system uses a unique brake system that utilizes a box of 12-volt capacitors that replaces the conventional booster.

Leave it in the On position.

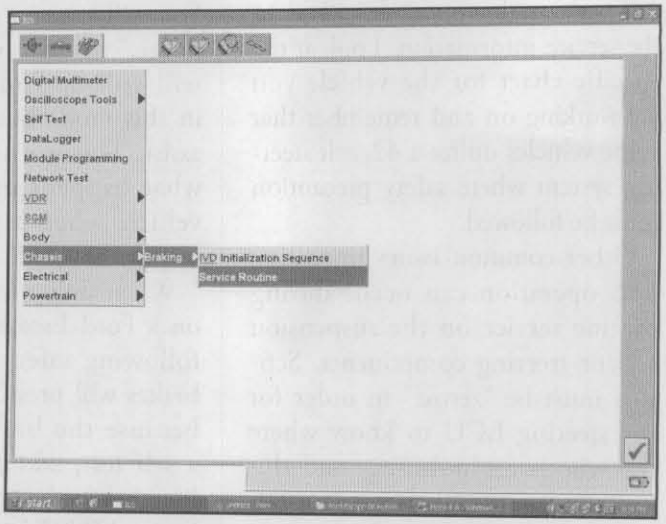
6. When you are done, you will need to exit SBSM. To do this, step on the brake pedal and hold it while you turn the ignition OFF then ON. This develops pressure in the system. The brake warning light should now go OFF and pressure will be in the brake system.
7. You can also exit the SBSM if you shift out of park, roll the vehicle in the shop with the key in the On position, or turn the ignition off and on. When the ABS system senses wheel movement it will reactivate the system.

WARNING: *Always read all safety and precaution procedures before working on any hybrid braking system.*

If the above procedures are not done properly or there is a failure a C1477 (High Pressure Hydraulic Circuit Leak Plausibility Failure) DTC will be present. The fix is to follow the recommended bleeding procedure in the service manual.

A Note on Hybrid Brake Systems

Since hybrids use a regenerative braking system in conjunction with the normal brake system to stop the vehicle, it is important to understand how braking is done. The MG driving the hybrid is also used to slow the vehicle down, acting as a generator to charge the HV battery. With the MG acting as a generator, the powerful magnetic field created in the process provides for negative torque that is used to slow the vehicle. The Antilock Braking System (ABS) system calculates the amount of speed reduction that is needed as the driver applies the brakes. The complete network (PCM, ABS, hybrid, TCM and others) is used to slow the vehicle down while also charging up the HV battery. If any problems in the systems are detected, normal ABS braking will be applied. Very little brake action utilizing the brake pads and/or shoes is done on a hybrid vehicle if all systems are operating properly.



Note that when repairing Ford Escape hybrid brakes they can pressurize unexpectedly.They MUST be disabled.

Final Cooling System Service Notes

Always use the correct recommend antifreeze/coolant, pre-mix (some OE use differ water in their mixtures, Deionized or Distilled) and bleeding procedures.

The HCAC (HC Adsorber and Catalyst System) and the VSV (Valve Vacuum Switch) are used on Prius GEN 1 – model years 2001 to 2003. The purpose of the system is to absorb and retain unburned HC during a cold start up. Once the engine is warmed the HC is released and purged through the now hot three-way catalyst. Its job is to improve emissions at low temperature.

The 2004 to 2009 Toyota Prius uses a Coolant Heat Storage Tank that can store hot coolant at 176 degrees F for up to three days. The tank is located at the front left bumper/fender that is covered by the inner fender cover. The system is uses this system for controlling cold start emissions. The system uses an auxiliary water pump that forces the hot coolant into the engine.

The 2010 and newer Prius use an Exhaust Heat Recirculation System. This system has done away with the coolant storage tank and uses the exhaust system to reduce exhaust emissions.

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

NOTE: The following questions are written in the ASE-style and are similar to the ones you will see on the ASE test. However, none of these questions *will* actually appear on the test.

1. How many cylinders are de-activated on the 2006 and up VPS (Valve Pausing System) Honda Civic hybrid?
A) 1 cylinder
B) 2 cylinders
C) 3 cylinders
D) 4 cylinders

2. What is the first step you perform in a 12V Compression/Start Test on a Gen 1 Honda Insight?
A) Turn off the IMA (Integrated Motor Assist) switch/HV (High Voltage) battery
B) Turn off the ignition switch
C) Remove the 15 Amp ignition fuse
D) Turn on the IMA switch/HV battery

3. The VPS (Valve Pause System) aids fuel economy by?
A) Controlling oil flow to the crankshaft
B) Delaying transmission shift points
C) Controlling oil flow to the rocker arms
D) All of the above

4. Technician A says "Inspection Mode" is used to shut the HV (High Voltage) power off. Technician B says "Inspection Mode" is used to shut the ICE (Internal Combustion Engine) off. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

5. Technician A says all hybrid vehicles have "Inspection Mode." Technician B says most hybrid vehicles have "Inspection Mode." Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

6. In order for a hybrid vehicle to be in the Autostop/Idle Stop it has to:
A) Be at the correct temperature
B) Meet the correct criteria
C) Both A & B
D) Neither A nor B

7. What prevents a hybrid vehicle from going into Autostop/Idle Stop?
A) The turn signal is active
B) The brake pedal is depressed
C) The accelerator pedal is depressed
D) None of the above

8. Which of the following can cause a Honda IMA (Integrated Motor Assist) hybrid vehicle from achieving the correct fuel economy?
A) The wrong engine oil
B) The wrong engine antifreeze/coolant
C) A blown 20 amp IMA fuse
D) Both A & C

9. Which of the following will cause a "No Start" on a Toyota hybrid vehicle?
A) Incorrect oil used in the ICE (Internal Combustion Engine)
B) HV (High Voltage) battery below 30% SOC (State Of Charge)
C) Open in Interlock Signal Circuit
D) "Ready" light illuminated on dash

10. Technician A says a Prius that has the engine oil level over filled may not start. Technician B says a Prius that has run out of fuel may not start. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

11. Technician A says that an SMR (System Main Relay) can prevent a hybrid vehicle from starting. Technician B says most hybrid vehicle have at least two SMRs. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

12. Most hybrid vehicle use an:
A) Otto cycle engine
B) Atkinson cycle engine
C) Walthingham cycle engine
D) Faulkner cycle engine

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

13. Technician A says when performing a compression test on the ICE (Internal Combustion Engine), a standard compression test procedure can always be used. Technician B says when performing a compression test on the ICE, a special procedure using a CAT III-rated DMM (Digital Multimeter) can be used. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

14. Which of the following is absolutely necessary for your shop to have when working on a hybrid HV (High Voltage) system?
A) Lineman's 1000-volt Class "O" gloves
B) CAT III-rated DMM (Digital Multimeter)
C) Both A and B
D) Neither A nor B

15. Technician A says that the HV (High Voltage) gloves should be rated at 1000 volts or Class "O". Technician B says that leather HV glove covers should be worn over the rubber gloves. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

16. If a hybrid vehicle "Ready" light is illuminated and the, ICE (Internal Combustion Engine) is not running, what may happen?
A) The ICE may start due to low 12-volt battery
B) The ICE may start due to low HV (High Voltage) battery voltage
C) Both A and B
D) Neither A nor B

17. All of the following are considered necessary safety equipment for working on hybrids EXCEPT?
A) HV rescue pole
B) Lineman's Class "0" gloves
C) Leather work apron
D) Eye protection

18. Before working on a hybrid HV (High Voltage) system you should:
A) Test the HV gloves for leaks
B) Test the 12-volt battery
C) Verify that the vehicle is in the "Ready" mode
D) None of the above

19. Orange wires on a hybrid vehicle indicates that the voltage is at least:
A) 12 volts
B) 36 volts
C) 60 volts
D) None of the above

20. A "Full" hybrid vehicle is defined as one:
A) That utilizes an electric motor
B) That can be driven in "electric only" mode
C) That has Autostop/Idle Stop
D) That utilizes a high voltage electric motor to provide engine stop/start

21. Technician A says that a Micro hybrid vehicle utilizes a Motor/Generator (MG) to provide engine stop/start. Technician B says that a Mild hybrid vehicle uses an Motor/Generator (MG) to provide additional torque to the engine. Who is correct?
A) Technician A
B) Technician B
C) Both Technicians
D) Neither Technician

22. The most common hybrid vehicle design is a?
A) Series style
B) Parallel style
C) A Series –Parallel style
D) A Parallel – Series style

23. The Chevy Volt is an example of a _____ hybrid design.
A) Series style
B) Parallel style
C) A Series –Parallel style
D) A Parallel – Series style

24. The Toyota Prius is an example of a _____ hybrid design.
A) Series style
B) Parallel style
C) A Series –Parallel style
D) A Parallel – Series style

25. Technician A says that the GM BAS (Belt Alternator/Starter) system is an example of a Mild hybrid . Technician B says that a Micro hybrid vehicle uses two Motor/Generators (MGs). Who is correct?
A) Technician A
B) Technician B
C) Both Technicians
D) Neither Technician

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

26. What test should be performed to find out whether a HV (High Voltage) wire is leaking voltage?
A) Insulation test
B) Voltage drop test
C) Hertz test
D) Resistance test

27. Before towing a hybrid, what precautions should you take?
A) Make sure the system is in "Off" mode
B) Chock the wheels
C) Use the right kind of tow truck
D) All of the above

28. HV (High Voltage) cables carrying 60 volts or more are what color?
A) Black
B) Orange
C) Red
D) Blue

29. Technician A says that a safe working voltage on a hybrid vehicle is anything under 60 volts. Technician B says that a safe working voltage on a Hybrid vehicle is anything under 15 volts. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

30. What color HV (High Voltage) cables carrying less than 60 volts but more than 30 volts?
A) Black
B) Orange
C) Red
D) Blue

31. Isolating the HV (High Voltage) battery from the system means?
A) Turning off the ignition
B) Turning off the HV switch
C) Removing/disconnecting the HV safety plug
D) All of the above

32. Technician A says that you should wait 5-10 minutes after isolating the HV (High Voltage) battery before servicing the HV system or components. Technician B says that you should always verify with a CAT III-rated DMM (Digital Multimeter) that the system has powered down before servicing the HV system. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

33. The Honda IMA hybrid "Shut Off" switch is?
A) Located behind the rear seat
B) Located in the trunk right rear
C) Is colored white
D) Is colored blue

34. The Toyota Prius hybrid service plug is?
A) Located behind the front seat
B) Located under the hood
C) Is colored orange
D) Is colored blue

35. Technician A says that a Ford Escape hybrid vehicle has an extra HV (High Voltage) shut off. Technician B says that a Ford Escape hybrid has a service plug that needs to be removed and placed in the Service/Shipping position. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

36. To isolate the HV (High Voltage) system on most hybrids, what should be done?
A) Disconnect the cables connected to the 12V battery
B) Remove, disconnect, or turn the service plug off
C) Make sure the vehicle ignition is off
D) Keep the Smart Key in your pocket

37. Hybrids HV (High Voltage) systems that are liquid cooled use what type of coolant?
A) Conventional IAT antifreeze
B) Dexcool
C) OEM specified coolant
D) Water only

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

38. NiMH (Nickel Metal Hydride) batteries are less forgiving than conventional lead acid batteries because:
A) NiMH batteries need to be cooled
B) NiMH batteries cannot be overcharged
C) NiMH batteries cannot be undercharged
D) Balance of the cells is critical to performance

39. Technician A says that all hybrid HV (High Voltage) batteries use cylindrical cells. Technician B says that all hybrid HV batteries use prismatic cells. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

40. Toyota Prius HV (High Voltage) batteries use _____ cells that resemble "D" cell flashlight batteries.
A) Cylindrical
B) Prismatic
C) Both A & B
D) None of the above

41. What HV (High Voltage) battery does the Gen 1 Honda Insight use?
A) A 128-volt cylindrical NiMH battery
B) A 144-volt cylindrical NiMH battery
C) A 128-volt cylindrical LiON battery
D) A 144-volt cylindrical LiON battery

42. Toyota Prius HV (High Voltage) batteries have a charge/discharge range of?
A) 20 to 60 percent capacity
B) 40 to 60 percent capacity
C) 40 to 80 percent capacity
D) 20 to 100 percent capacity

43. HV (High Voltage) cell pack voltage can be checked using a scan tool on?
A) 2006 MY and up Honda IMA hybrids
B) All Toyota Prius hybrids
C) All Ford hybrids
D) All of the above

44. Technician A says some hybrids use a vehicle's A/C system to cool the High Voltage (HV) battery. Technician B says some hybrids use a dedicated blower to cool the HV battery. Who is correct?
A) Technician A
B) Technician B
C) Both A & B
D) Neither A nor B

45. A hybrid Series-Parallel design is:
A) A hybrid that uses a power split device similar to a clutch
B) A hybrid design that is used on Toyota, Ford, Nissan and many others.
C) Both A and B
D) Neither A nor B

46. A "Full Hybrid" style vehicle is:
A) A hybrid vehicle that uses one Motor/Generator (MG)
B) A hybrid that can move the vehicle with no ICE (Internal Combustion Engine) assist
C) A hybrid that can move the vehicle with ICE (Internal Combustion Engine) assist
D) A hybrid vehicle that has no Idle Stop capability

47. Technician A says that most hybrids have a separate cooling system for the HV (High Voltage) electronics. Technician B says that most hybrids use the same cooling system as the engine does for cooling the HV (High Voltage) electronics. Who is correct?
A) Technician A
B) Technician B
C) Both A & B
D) Neither A nor B

48. The Prius uses an inverter pump that does what?
A) Cools the MGs (Motor/Generators)
B) Cools the AC/DC Inverter
C) Cools the DC/DC Converter
D) All of the above

49. Ford, Toyota and Nissan hybrids have a "heater circulator pump" that is used:
A) With Autostop
B) Specifically when the ICE is engaged
C) Only when the water pump is broken
D) None of the above

50. Technician A says a hard bump to the rear of Ford hybrids can cause the HV (High Voltage) system to shut down. Technician B says that a loose tire jack in the rear of Ford hybrids can cause the HV (High Voltage) system to shut down. Who is correct?
A) Technician A
B) Technician B
C) Both A & B
D) Neither A nor B

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

51. What causes a Ford Escape hybrid to display "STOP SAFELY NOW" on the dash?
A) A HV (High Voltage) voltage overheating problem
B) A failure in the 12-volt electrical system
C) An overheating ICE (Internal Combustion Engine)
D) A fuel level below ¼ tank

52. A technician is dealing with a HV (High Voltage) battery overheating concern on a Honda Civic IMA hybrid. He notes that there are several packages and a few coats stacked on the rear window deck. Could this be the cause of the overheating condition?
A) Yes, because the fresh air intake for the battery cooling fan is located there
B) Yes, because the outlet for the battery air conditioning duct is located there
C) No, because the battery is liquid cooled
D) No, because there is no relationship to the battery cooling system on this car

53. The HV (High Voltage) battery produces DC voltage, and the Motor/Generator outputs AC voltage that is converted to DC by the _____.
A) Inverter
B) Converter
C) Alternator
D) Battery Control Module

54. Technician A says the Converter converts AC voltage to DC voltage. Technician B says the Converter takes HV (High Voltage) DC and converts it to low voltage DC. Who is correct?
A) Technician A
B) Technician B
C) Both A & B
D) Neither A nor B

55. What charging current rate is suggested for the 12-volt Prius battery?
A) 2.5 amps
B) 3.5 amps
C) 4.5 amps
D) 5.5 amps

56. The Toyota Prius Hybrid requires uses _____ 12-volt battery.
A) Flooded lead acid 12-volt battery
B) Maintenance free lead acid 12-volt battery
C) NIMH (Nickel Metal Hydride) 12-volt battery
D) AGM (Absorbed Glass Mat)12-volt battery

57. Technician A says you can use a lead acid 12-volt battery in a Toyota Prius. Technician B says if you use a lead acid 12-volt battery you may encounter a Diagnostic Trouble Code (DTC). Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

58. Technician A says you can use a lead acid 12-volt battery in a Honda hybrid. Technician B says you must use a AGM (Absorbed Glass Mat)12-volt battery in a Honda hybrid. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

59. The Toyota Prius uses:
A) One Motor/Generator (MG)
B) Two Motor/Generators (MGs)
C) One AC electric motor and one AC electric generator
D) None of the above

60. Technician A says a Gen 2 Prius uses an Inverter that has three 450-volt capacitors. Technician B says a Gen 1 Prius uses an Inverter that has two 600-volt and one 750-volt capacitor. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

61. What is considered a "safe" voltage level?
A) No voltage level is safe. Always use HV gloves at all times.
B) Five or less volts
C) Ten or less volts
D) Fifteen or less volts

62. Technician A says all hybrid vehicles use a HV (High Voltage) electric air conditioning compressor. Technician B says some hybrid vehicles use a combination belt-drive/HV compressor. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

Prepare yourself for ASE testing with these questions on LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST

63. Technician A says Toyota DTCs (Diagnostic Trouble Codes) have information codes that must be used to diagnose a DTC. Technician B says Toyota DTCs have sub-codes that must be used to diagnose a DTC. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

64. Technician A says a special oil must be used in a HV (High Voltage) electric a/c compressor. Technician B says that if the incorrect oil is used in such a system and the system is run, every component in the system must be replaced. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

65. On GEN 1 Toyota Prius Hybrids, if the yellow "turtle" warning light illuminates on the dash, it means:
A) The HV (High Voltage) battery has a low charge level
B) The vacuum reservoir is leaking
C) That the ICE (Internal Combustion Engine) has a fault
D) The Motor/Generator(s) (MGs) are inoperative

66. Technician A says a Gen 2 Prius can be jump started from under the hood. Technician B says a Gen 2 Prius can be jump started from the trunk area. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

67. Technician A says a Gen 2 Prius use a conventional brake booster for the brake system. Technician B says a Gen 2 Prius uses high volt capacitors instead of a conventional brake booster. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

68. To start a Gen 2 Prius you have to:
A) Press the Power button twice while depressing the brake pedal
B) Press the Power button once while depressing the brake pedal
C) Hold the Power button while depressing the brake pedal
D) None of the above

69. Which switch can prevent the Autostop feature from functioning on the Chevrolet Volt?
A) Trunk-switch
B) Gas-switch
C) Hood ajar-switch
D) None of the above

70. Technician A says to jump start a Ford Escape hybrid, you have to attach the jump leads to the 12-volt battery. Technician B says to jump start a Ford Escape hybrid, you press a button that is located behind the left front kick panel. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

71. Technician A says when working on a Ford Escape hybrid there are special service precautions for the EPS (Electronic Power Steering) system. Technician B says when working on a Ford Escape hybrid there are special service precautions for the brake system. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

72. Technician A says you must put a Ford Escape hybrid in "Safe Brake Service" mode before attempting to work on the brak system. Technician B says failure to follow proper service procedures could result in unwanted activation of the brake system and cause possible injury to the tech. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

73. The Civic Hybrid uses what form of power steering?
A) Hydraulic power steering
B) EPS (Electronic Assist Power Steering)
C) Integrated Power Steering (Using both of the above)
D) None of the above

74. Technician says that on a Toyota Prius, a dark "Power" button (no illumination) can indicate the vehicle is ready to drive. Technician B says that you must look at the status of the "Ready" indicator to determine whether or not the vehicle is ready to drive. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

75. On a Toyota hybrid, a "Power" button with amber illumination indicates that:
A) The vehicle is On ready mode
B) The vehicle is in Accessory mode
C) The vehicle is Off
D) None of the above

76. Technician A says that a Toyota Prius must be put into Inspection Mode in order to test the ICE (Internal Combustion Engine). Technician B says that Inspection Mode is used to test the lights and wipers for proper operation. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

77. Technician A says Autostop means the hybrid vehicle has the capability to come to a full stop on its own, without driver input. Technician B says that Autostop is another term referring to the Start/Stop strategy of shutting down the ICE (Internal Combustion Engine) whenever the driver brings the car to a stop. Who is correct?
A) Technician A
B) Technician B
C) Both A and B
D) Neither A nor B

Notes

Answers to Study-Guide Test Questions

1. The correct answer is D. Since 2006, the Honda hybrid IMA ICE uses two VPS (Valve Pause System) solenoids that de-activate all cylinders.

2. The correct answer is A. On a Honda IMA hybrid when the IMA switch is switched Off the ICE can be cranked using the 12-volt starter allowing for a compression test.

3. The correct answer is C. On a Honda VPS system, oil flow (controlled by the VPS solenoids) to the rocker arm assembly, disconnecting it from the valve.

4. The correct answer is D. Inspection mode on full hybrid vehicles allows the ICE to stay running (regardless of the state of charge of the HV battery) for testing and repair.

5. The correct answer is B. An ICE on a mild hybrid, like the Honda IMA, can be started and run at any time by the operator.

6. The correct answer is C. For a hybrid vehicle to go into Autostop/Idle Stop mode the correct temperature as well as other criteria has to be met.

7. The correct answer is C. If the accelerator pedal is depressed, even if the vehicle is at a complete stop, the vehicle will not go into Autostop/Idle Stop mode.

8. The correct answer is D. The Honda ICE needs 0w20 oil in the engine so the VPS system can function properly. A blown or missing 20 amp fuse for the IMA system will prevent electric assist causing the ICE to do all the work.

9. The correct answer is C. An open circuit on the Interlock/Shut Off switch will prevent the MG from starting the vehicle or the Ready light from illuminating. Note if the Ready light is not present the vehicle will not start.

10. The correct answer is C. Overfilling an engine is never a good idea but in the case of a Toyota Prius a DTC P3101 will be set and the engine will not start. If a Prius with a bladder tank (2004 to 2009 vehicles) runs out a fuel a P3193 will prevent the vehicle from starting without slowly adding at least 3 gallons of fuel and clearing the DTC.

11. The correct answer is C. The SMR (System Main Relay) has to connect the low voltage to the HV. Most hybrids use at least two SMR for safety purposes, with some vehicles using three SMRs.

12. The correct answer is B. The Atkinson cycle design has lower torque and provides better full economy than the Otto cycle design used in conventional cars.

13. The correct answer is D. In order to perform a compression test on some full hybrid vehicles, a scan tool will need to be used in the bidirectional control section.

14. The correct answer is C. When working on a hybrid vehicle's HV system, the use of HV 1000-volt Class "O" gloves with the proper protective cover must be used. When testing any high voltage on a hybrid vehicle a CAT III meter with the 1000-volt rating must be used.

15. The correct answer is C. Both technicians are correct. When working on an HV (High Voltage) system, 1000-volt Class "O" gloves and leather covers must be worn.

16. The correct answer is B. When working on a hybrid vehicle, always check to see if the "Ready" light is illuminated. If the "Ready" light is on, the ICE (Internal Combustion Engine) can start at any time the HV (High Voltage) battery level is below the minimum required voltage. This can be an unsafe condition if the technician is not aware that the ICE can start.

17. The correct answer is C. Shops should have a rescue pole on hand, and each tech working on HV (High Voltage) systems should have gloves rated at 1000 volts, leather glove protectors and eye protection before servicing any HV component.

18. The correct answer is A. You should always wear protective equipment when servicing a "live" HV (High Voltage) system, including rubber lineman's gloves rated at 1000 volts. And you must check for leaks before using them each and every time. Even a small pinhole is enough to allow HV to enter and potentially harm you.

19. The correct answer is C. The lethal voltage that can stop your heart is 60 volts. Orange cables have at least 60 volts or more.

Answers to Study-Guide Test Questions

20. The correct answer is B. A Full hybrid is the only style that offers electric-only propulsion.

21. The correct answer is C. A Mild hybrid uses the one MG to start the engine (ICE), and provide extra torque to the engine (Honda IMA is an example). The Micro hybrid is only able to stop and start the engine (GM's BAS system is an example).

22. The correct answer is C. The most common style hybrid is the Full hybrid vehicle that is a Series-Parallel system.

23. The correct answer is A. The Chevy Volt is the only extended range/hybrid vehicle that is a Series style hybrid. A series style is a power unit (Internal Combustion Engine – ICE) that turns an HV (High Voltage) Motor/Generator (MG). There is no mechanical connection between the ICE and the wheels, and the ICE never directly powers the vehicle.

24. The correct answer is C. The most popular hybrid on the road uses a Series – Parallel design that incorporates a power split device that is similar to a clutch. This design allows for the power path from the engine to the wheels that can be connected to either the engine (ICE) or the Motor/Generator (MG).

25. The correct answer is D. The GM BAS system is a Micro hybrid provides for Idle Stop capability and the Motor/Generator (MG) is driven by a conventional accessory belt, similar to an alternator. Neither Micro nor Mild hybrids use more than one MG.

26. The correct answer is A. When working on a *hybrid* vehicle that has a Diagnostic Trouble Code (DTC) for any HV (High Voltage) leak, the next step is to use a CAT III-rated Megohm meter to perform an insulation test.

27. The correct answer is D. Before towing any hybrid vehicle it's a good practice to insure the vehicle is in "Off" mode, followed by chocking the wheels to prevent the vehicle from moving. All drive wheels should be off the ground (not allowed to roll) to prevent potential damage to the Motor/Generator (MGs) and production of AC voltage.

28. The correct answer is B. Any HV wire that has 60 volts or more are colored orange.

29. The correct answer is B. The safe voltage when working on a HV vehicle is 15 volts or under.

30. The correct answer is D. High voltages over 30 volts but less than 60 volts are identified by *blue cables.*

31. The correct answer is D. When working on the HV (High Voltage) system, it is a good practice to isolate the HV battery by first turning off the ignition (Ready Off), then turning off the HV switch and/or removing the service plug.

32. The correct answer is C. Most hybrid vehicles recommend waiting 5 to 10 minutes before working on the HV (High Voltage) system. After that time, a CAT III-rated DMM (Digital Multimeter) should be used to verify the HV battery has been successfully isolated.

33. The correct answer is A. On a Honda IMA, the hybrid the shut off is behind the upper rear seat back. On the Insight, it is located under the carpeting in the trunk.

34. The correct answer is C. Shut off/service disconnect plugs are generally located close to the HV (High Voltage) battery access area and are typically orange in color.

35. The correct answer is C. The Ford Escape hybrid vehicle has an inertia switch that is located in the right rear behind a plastic cover that is marked. The service plug for this vehicle is located in the trunk that has information on turning, removing and installing the service plug in Service/Shipping position.

36. The correct answer is B. To isolate the HV (High Voltage) battery from the system on most hybrids, shut off the HV switch or remove the HV service plug.

37. The correct answer is C. When working on any cooling system and especially hybrid HV systems, it is important to use the correct antifreeze/coolant.

38. The correct answer is D. Both *style* batteries cannot be allowed to be overheated, or over- or undercharged. NiMH hybrid batteries are made up of dozens of "cells", though, and the voltage variance between cells must be maintained or a battery failure Diagnostic Trouble Code (DTC) will be set.

39. The correct answer is D. Many Honda and some Ford hybrids use cylindrical cells while most new hybrids and extended range vehicle use the *prismatic* (flat) cells.

Answers to Study-Guide Test Questions

40. The correct answer is B. Toyota hybrid vehicle use prismatic cells.

41. The correct answer is B. The Honda Gen 1 Insight has 144-volt NiMH battery.

42. The correct answer is C. The charge and discharge range for a Toyota and most other hybrid vehicles (Honda 20% - 80%) is 40% - 80%. They should not totally discharge or charge.

43. The correct answer is D. HV (High Voltage) battery cell packs can be checked on scan data on almost all the hybrid vehicles except 2005 and older Hondas.

44. The correct answer is C. Both methods are in common use.

45. The correct answer is C. A Series-Parallel design vehicle incorporates a power split device that is similar to a clutch. This design allows for the power path to the wheels that can be connected to by either the engine (ICE or Motor/Generator (MG). It is the most commonly used hybrid design.

46. The correct answer is B. A "Full" hybrid is a vehicle that uses either or both the engine (ICE) and the Motor/Generators (MGs) to move the vehicle, though *typically* these designs can only move on electric-only for a limited time and speed.

47. The correct answer is A. Hybrid vehicle use their own coolant system that includes separate radiator, over flow tank and pump to cool the HV electronics such as the inverter, converter and MGs (Motor/Generators).

48. The correct answer is D. The Toyota Prius uses a separate coolant pump that runs on the 12-volt system of the vehicle. The job of the inverter pump is to circulate coolant from the inverter, converter and MGs to the radiator where it is cooled.

49. The correct answer is A. Heater circulator pumps are used on these model hybrids to heat the interior of the vehicle even when the ICE is off.

50. The correct answer is C. On a Ford Escape there is an extra shut off system that uses an inertia switch that is located in the right rear of the trunk behind a plastic panel. The switch looks just like the Ford fuel inertia switch and is designed to isolate the HV (High Voltage) battery in the case of an accident. However, any instance strong enough to trip the inertia switch will result in a "no start" condition.

51. The correct answer is A. If the "STOP SAFELY NOW" message appears on the dash display of a Ford hybrid, the vehicle's HV (High Voltage) electronics are overheating. The vehicle will slow down, shut off and will not start until the electronics are cooled down.

52. The correct answer is A. Honda hybrid vehicles use a blower fan and the cabin air temperature to cool the HV (High Voltage) battery and electronics. There is a vent that is located just below the rear window of the vehicle on most Hondas.

53. The correct answer is A. The inverter has the job of taking the DC voltage from the HV battery, boosting the voltage and converting it to AC voltage so the MGs can use it.

54. The correct answer is B. The job of the converter is to lower the HV battery's high voltage down to useable voltage that can be used for vehicle's 12-volt systems.

55. The correct answer is B. When charging a AGM (Absorbed Glass Mat) battery, it is recommended that a special charger be used that limits the current to 3.5 steady amps.

56. The correct answer is D. The Toyota Prius hybrid only uses an AGM (Absorbed Glass Mat) 12-volt battery at the time of this writing.

57. The correct answer is B. When replacing a 12-volt AGM (Absorbed Glass Mat) battery on a Prius, it is important to make sure to only replace it with the same type.

58. The correct answer is A. Honda hybrid uses a conventional battery as standard equipment and while you could replace a failed battery with an AGM (Absorbed Glass Mat) design, it is not required.

59. The correct answer is B. Toyota and most other "Full" hybrid vehicles use two Motor/Generators (MGs).

Answers to Study-Guide Test Questions

60. The correct answer is D. The Gen 1 uses three 450-volt capacitors while Gen 2 uses two 600-volt and one 750-volt capacitors.

61. The correct answer is D. When working on a hybrid vehicle, safe voltage is considered 15 volts or less.

62. The correct answer is B. Honda uses an air conditioning compressor that is both belt-driven and electric. The electric mode is used to maintain cabin comfort when the ICE (Internal Combustion Engine) is not running, as during Idle Stop mode.

63. The correct answer is C. When diagnosing a Toyota hybrid vehicle, it is important to check both the DTC and subcode DTC to efficiently pinpoint the problem area.

64. The correct answer is C. Using the incorrect oil may cause High Voltage (HV) leak codes and cause the HV system to shut down. Once the system has been run, the only way to correctly remove the contaminated oil is to replace the entire air conditioning system.

65. The correct answer is A. The GEN 1 Toyota Prius had a couple of different dash icons, one being the "Yellow Turtle" that means the vehicle will not develop full power due to a low HV battery charge.

66. The correct answer is C. Since the Gen 2 Prius has a jump-start terminal in the fuse box (located under the hood on the left side of the vehicle facing the fender) the vehicle can be jump started there. This is important if the 12-volt battery goes dead and the trunk cannot be opened (since the lock is electronic).

67. The correct answer is B. The Gen 2 Prius does not use a conventional power booster as does the Gen 1 and Gen 3 does. It uses a bank of 12-volt capacitors that replace the power booster.

68. The correct answer is B. To start a Gen 2 or 3 Prius, you have to depress the brake pedal and press the "Power" button once.

69. The correct answer is C. On a Chevrolet Volt, the fault in the "hood ajar" switch will cause the Autostop feature to disable until corrected.

70. The correct answer is B. When a Ford Escape will not start, check the 12-volt battery under the hood for proper voltage level. If the level is low, jump start or charge the battery followed by removal of the left from kick panel to access the button that will jump start the HV battery. Wait 8 minutes before trying to start the vehicle.

71. The correct answer is B. Ford Escapes use a special Teves brake system that can energize the brake system with the key out of the ignition. Follow service and safety precaution outline in this manual or in a service manual before working on the brake system.

72. The correct answer is C. The Ford Escape hybrid use a special method to disable the brakes system with will self-test even if the key is not in the ignition. Read the service information in this manual or in a service manual on how to perform the SBSM procedure before working on the brake system.

73. The correct answer is B. Honda (and all other hybrid and extended range vehicles) use EPS (Electronic Assist Power Steering) in order to provide steering assist when the ICE (Internal Combustion Engine) is not running.

74. The correct answer is C. On Toyota hybrid vehicle when the Power button is dark (off) and there is No Ready light the vehicle is off. When the Ready light is illuminated the Power button will also be dark (off).

75. The correct answer is B. On a Toyota hybrid vehicle a Start button that is illuminated Amber means the vehicle is in Accessory mode.

76. The correct answer is A. Inspection Mode allows the ICE to run at approximately 1,000 rpms.

77. The correct answer is B. When a hybrid vehicle comes to a stop the ICE should turn off and the vehicle should be silent in electric mode if the enable criteria have been met.

Notes

Notes

ASE LIGHT DUTY HYBRID/ELECTRIC VEHICLE SPECIALIST CERTIFICATION TEST REFERENCE

The block diagrams included in this document represent the power flow strategies used by the hybrid-drive systems included in the ASE Light Duty Hybrid/Electric Vehicle Specialist test. Although additional details may be provided in individual test questions, the following information should be considered common to each of these systems.

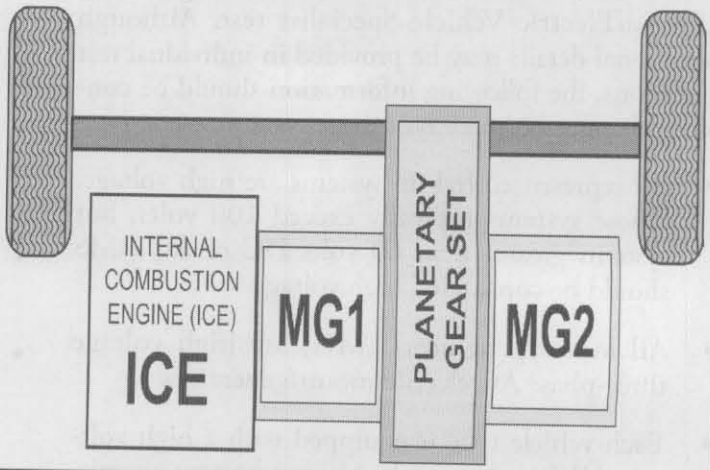
- All represented hybrid systems are high voltage. These systems typically exceed 100 volts, but systems greater than 60 volts DC or AC RMS should be considered high voltage.
- All motor/generators (MG) are high voltage three-phase AC electric motor/generators.
- Each vehicle type is equipped with a high voltage (HV) battery pack. Neither battery chemistry nor total battery pack voltage are defined in this general description document.
- Each system uses a DC/AC bi-directional inverter to provide AC current to and from the motor/generator(s).
- Each system uses a DC/DC converter. This converter supplies stepped-down voltage to the vehicle's 12-volt system and replaces the traditional generator (alternator).
- All systems are equipped with a 12-volt battery.
- Failures affecting the vehicle's electric drive system may result in the display of a "Hybrid System Warning" on the instrument panel.
- The terms Encoder and Resolver may be used interchangeably.
- Because of the variation in terminology used by different manufacturers when referring to the hybrid system's readiness state, ASE test questions will use the following to indicate the operational power modes.

OFF	All systems OFF. The engine and electric drive system are powered OFF.
ACCESSORY	Same as ACC on a conventional vehicle.
POWER ON	Equivalent to KOEO – Key ON/Engine OFF. In this mode, the engine will not run, nor will the vehicle move under electric power.
READY TO DRIVE	Equivalent to KOER – Key On/Engine Running. In this mode, the vehicle is ready to drive. The engine is running, or is OFF and ready to run, if so commanded. The electric drive system is also ready for a drive command.

Credit: National Institute for Automotive Service Excellence

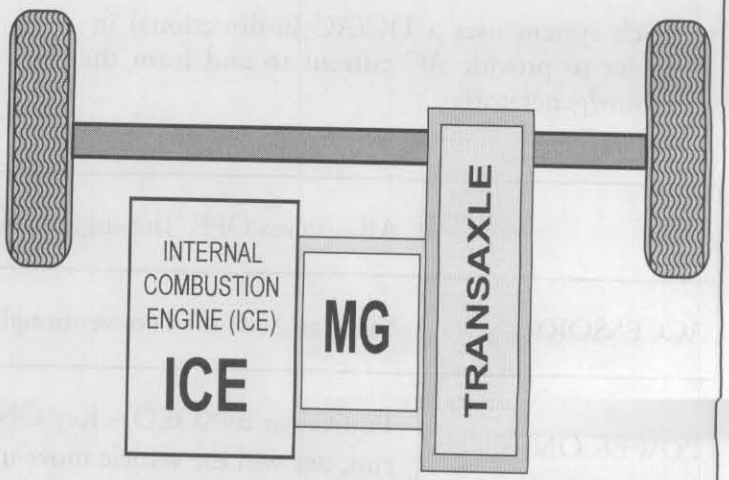
Type-1

The Type-1 hybrid-drive system uses power from the internal combustion engine (ICE) and/or motor/generator(s) to propel the vehicle. Power flow to the drive-wheels is blended as needed through a planetary gear set, with motor/generator 1 (MG1) serving as a reaction unit to control the effective ratio and direction of the gears. MG1 is used as the starter motor for the ICE, and conversely, it can be driven by the ICE to act as a generator. MG2 also serves as a generator during regenerative braking.



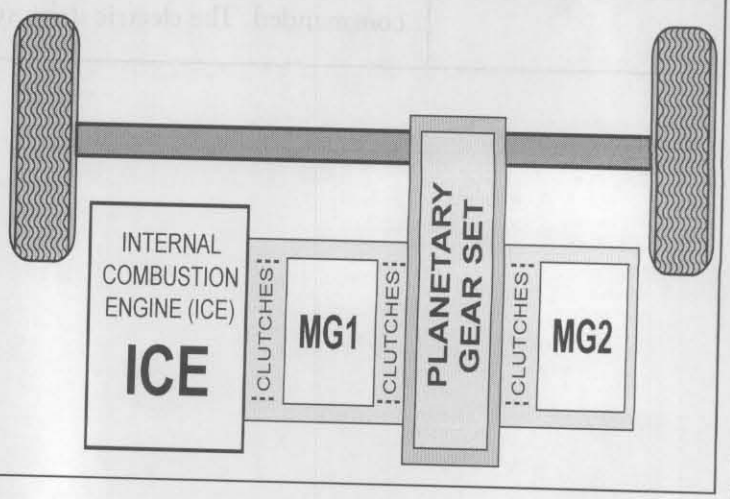
Type-2

The Type-2 hybrid-drive system uses a single motor/generator (MG) integrally mounted between the internal combustion engine (ICE) and the transmission. The ICE and MG are used together to maximize vehicle propulsion. During regenerative braking, the MG acts as a generator.Under most conditions, the MG serves as the starter motor for the ICE. Some Type-2 vehicles may be equipped with an auxiliary 12 V starter motor. Power flow to the drive wheels can be provided by a split-pulley/ steel belt continuously variable transmission (CVT), a conventional automatic transmission, or a standard transmission.



Type-3

The Type-3 hybrid-drive system is regarded as an extended range electric vehicle. MG2 provides vehicle propulsion and electrical regeneration while braking. In certain situations, MG1 assists MG2 by combining power flow through a planetary gear set to reduce the speed of MG2. When the high-voltage (HV) battery pack falls to a predetermined state-of-charge (SOC), the internal combustion engine (ICE) drives MG1 to generate sufficient current to power MG2 and maintain the HV battery pack.



Credit: National Institute for Automotive Service Excellence

Glossary of Terms

The reference materials and questions for this test use electronic and emission terms and acronyms that are consistent with the industry-wide SAE standards J1715, J1930, and J2012. Some of these terms are listed below.

Auto Stop - In the READY TO DRIVE (KOER) operational power mode, the internal combustion engine is automatically turned off when power demand is zero or negative, such as during vehicle stop, and then restarted automatically.

Battery Cell - An assembly of a positive electrode, a negative electrode, and other necessary electrochemical and structural components. A cell is a self-contained energy conversion device that delivers electrical energy to an external circuit via an internal chemical process.

Battery Module - A grouping of interconnected battery cells in a single mechanical and electrical unit.

Battery Pack/Traction Battery - Interconnected battery modules that have been configured for a specific energy storage application.

Battery System - Completely functional energy storage system consisting of the pack(s) and necessary ancillary subsystems for physical support, thermal management, and electronic control.

DC/DC Boost Converter - A power converter that produces an output voltage greater than (boost) or less than (buck) the input voltage.

Energy Monitor - A display that indicates the charge/discharge status of the high voltage battery.

Hybrid System Warning - A display on the instrument panel that is activated when failures affecting the vehicle's electric drive system are detected. This display is the same as a "Master Warning Light," "Service Hybrid System" message, "IMA Warning Light," etc.

ICE - Internal Combustion Engine.

IGBT - Insulated Gate Bipolar Transistor.

Motor/Generator - An electromechanical device that can operate in two modes without changing rotational direction. As a motor, it consumes electricity to produce mechanical power. As a generator, it consumes mechanical power to produce electricity.

Power Flow Display - An animated graphic indicating the direction of the flow of energy.

Service Life (years or cycles) - A general term that describes the length of time a battery can remain in service. Service life can be specified in terms of either time or duty cycles.

Service Plug - A high-voltage electrical disconnect device that is used when performing repairs on the high voltage hybrid/electric vehicle circuits.

Notes

Motor Age TRAINING

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