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Hybrid Vehicles: Separating Fact from Fiction

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How many times have you heard the following: Hybrid vehicles are a fad; the battery module will leak a significant amount of fluid if it is damaged; I will get electrocuted if I touch a hybrid after it has been in an accident or if it is submerged; it is difficult to disable the high voltage system; vehicle extrications will be greatly hampered by high-voltage wiring; and, special equipment is needed to fight hybrid vehicle fires.

Rising fuel costs have drawn a considerable amount of attention towards hybrid vehicles. As a result, many myths, such as the ones above, have circulated among the emergency services community surrounding the "dangers" of hybrid vehicles. Separating fact from fiction is paramount to the proper handling of these vehicles.

It is clear that hybrid vehicles should not be ignored by the emergency services community. In fact, some industry estimates place 5.2 million hybrid vehicles on the road by 2011 with over 50 models available to consumers by 2012. While hybrids do present certain new risks to emergency responders, proper education and training can minimize those concerns. If a department has proper response procedures in place for handling standard vehicle accidents, many of the precautions remain the same. SOPs, however, should be updated to include specific information on responding to incidents involving hybrid vehicles.

The following is a quick "overview" of the concepts involving responding to hybrid vehicle incidents. It is recommended that you seek out a formal training curriculum to fully address all aspects of necessary training.

What is a Hybrid Vehicle?

Hybrid vehicles use two different types of propulsion systems, a gasoline engine and electric motor, which work in conjunction to improve fuel efficiency. There are essentially three types of hybrids available on the market today: Full, Mild and Start/Stop hybrids.

The full hybrid technology is currently used by Toyota, Lexus, Mercury, Mazda, Ford and Nissan. A full hybrid has the ability to move forward at low speeds using only electric motors or at higher speeds using both the electric motors and gasoline engine. Honda utilizes what is typically considered a mild hybrid system, which allows the electric motors to assist the gasoline engine and operate in tandem. Saturn, Dodge, Chevrolet and GMC will be releasing their own full hybrid systems during the 2008 model year.

The third type, a start/stop hybrid, uses an electric motor to instantly start a vehicle's engine when it is shut down. While generally not considered a "true" hybrid, gas mileage increases due to the decreased amount of time a vehicle is idling when slowing to a stop or sitting at a traffic light. Research has indicated that this category will most likely be phased out a few model years as the trend toward full hybrids continues.

Available Models

Car manufacturers have invested large sums of development money into hybrid technology and it is here to stay. As more of these vehicles appear on the road, departments need to focus on providing quality training to their personnel.

Available Hybrid Cars
Honda Civic
Lexus GS 450h
Lexus LS 600H L
Nissan Altima
Toyota Camry
Toyota Prius
Available Hybrid SUV's
Ford Escape
Lexus RX 400h
Mercury Mariner
Saturn Vue Green Line
Mazda Tribute
Available Hybrid Trucks
GMC Sierra
Chevy Silverado
Dodge Ram (Fleet Vehicle Only)
Discontinued Models
Honda Accord 2007
Honda Insight 2006

Upcoming Hybrid Cars	
Chevy Malibu	2008
Saturn Aura Green Line	2008
Honda Fit	2009
Mercury Milan	2009
Ford Fusion	2009
Hyundai Accent	2009
Mercedes S-Class	2009
Porsche Panamera	2009
VW Jetta	2009
Ford Five-Hundred	TBD
Hyundai Sonata	TBD
Upcoming Hybrid SUVs, Trucks & Minivans	
Chevy Equinox	2008
Chevy Tahoe	2008
Dodge Durango	2008
GMC Yukon	2008
Audi Q7	2008
Cadillac Escalade	2008
Toyota Sienna	2009
VW Touareg	2010
Porsche Cayenne	2010
Chrysler Aspen	TBD
Ford Edge	TBD
Honda Pilot	TBD
Lincoln MKX	TBD

Identification

Since all but two of the hybrid models on the road today were designed using a pre-existing model chassis, emergency responders must always consider that even familiar looking vehicles could be a hybrid. The Honda Insight *(figure 1)* and the Toyota Prius *(figure 2)* are the only models designed specifically as a hybrid. The Insight is no longer being produced after the 2006 model year.

Figure 1

Figure 2

Identification of a hybrid can essentially be broken down into two methods; formal and informal. Formal methods include the search for hybrid "badges" or logos while informal methods focus on those the characteristics of a hybrid which are not found on standard vehicles.

Although hybrid symbols are often the easiest and most obvious method of identification, they may be located in an area that could be damaged or rendered invisible after a collision. One should not assume that a vehicle is not a hybrid based on the lack of a readily visible emblem. Some models, such as the Lexus RX400h, *(figure 3)* may not utilize a traditional hybrid emblem; only the "h" in RX400h signifies the vehicle is a hybrid (some model years).

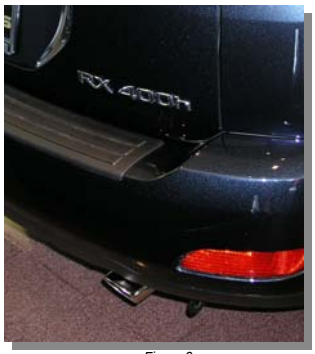

Figure 3

Figure 4

Figure 5

Hybrid logos are typically found on the rear of the vehicle, the front fenders, or on the front or rear doors. *(figures 4 –5)* On models where the logo only appears on the trunk or hatchback, the potential exists for it to become "hidden" in a rear end collision.

The words "Hybrid" or "IMA" can also be found on a plastic cowling in the engine compartment *(figures 6-7)*. You may also find these terms on the dashboard or display inside the vehicles *(figure 8)*

Figure 8

Figure 6

Figure 7

There are several informal identification methods which can also be helpful to responders. The most notable is the car manufacturer's use of the orange cable for high voltage lines. These cables can be found in the engine compartment, on the underside of the vehicle and the area where the battery is stored *(figures 9 –11)*.

Figure 9

Figure 10

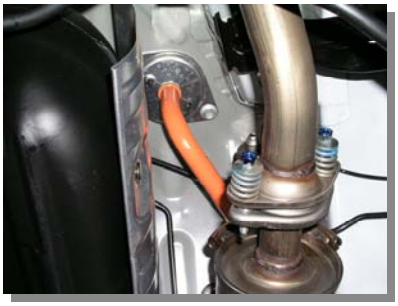

Figure 11

Care must be taken, however, when looking for the orange cable on the underside of the vehicle. Many manufacturers have covered up a good portion of the colored cable with cladding that is most often black. Several models, such as the Ford Escape/Mercury Mariner *(figure 12)* and the Toyota Highlander, have only a few inches of visible orange high voltage lines. On the Nissan Altima Hybrid, the high voltage lines under the vehicle are completely encased in a black plastic protector and no orange is visible.

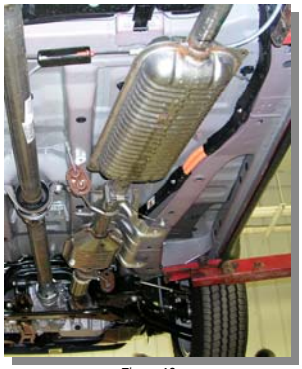

Figure 12

High voltage warning labels or symbols should also be visible in the areas where the orange cables are present. Hybrids may also use yellow medium voltage (34v-42v DC)

cables to power air conditioning and power steering features. Blue medium voltage cables can be found in some Start/Stop hybrid systems such as those found in the Saturn VUE Hybrid.

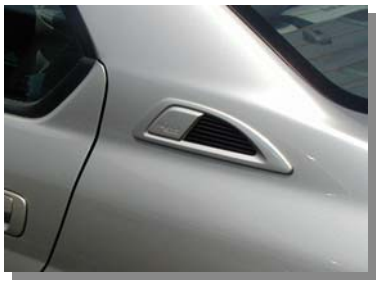

Figure 14

Another less obvious informal identification method includes visible battery vents. Since the continual discharge and recharge of the high voltage battery system produces heat, car designers have incorporated vents to help cool the batteries.

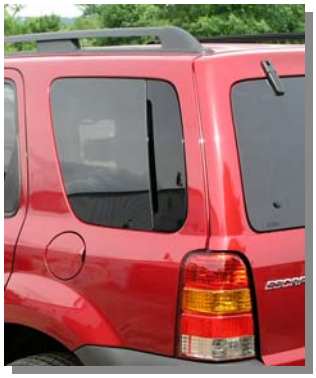

Figure 15

Not all models have vents which are visible, but responders should be on the lookout for the following. The early version of the Toyota Prius had a vent in the driver's side "C" post *(figure 14)*. The Ford Escape – Mercury Mariner has a vent which can be found in the driver's side rear quarter glass *(figure 15)*. The Toyota Highlander and the Lexus RX400h battery vents are visible under the rear passenger seat *(figure 16)* and several of the hybrid sedans incorporate vents into their rear decks *(figure 17)*. Typically these vents are located in the relative vicinity of the battery pack for efficiency.

Figure 16

Figure 17

Dashboard indicators, depending on the make and model, may include a battery "status" gauge which indicates whether it is being charged or assisting with vehicle propulsion *(figure 18)*. You may also come across a kW gauge which replaces the standard RPM gauge. Most models have incorporated some type of "Ready" indicator into their dash which indicates to the driver that the vehicle is on and ready to move even if the engine is off. *(figure 19)*.

Figure 18

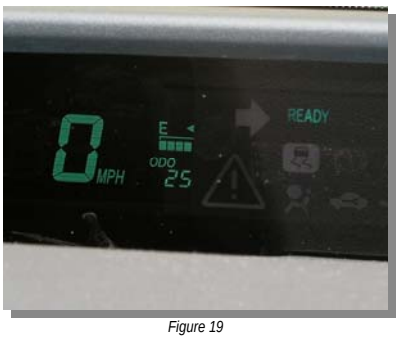

Figure 19

High Voltage Vehicle Components

The three major components of a hybrid system include the electric motor/ generator, the high voltage wiring and the high voltage Ni-Mh battery pack. The electric motor can assist in propulsion of the vehicle and recharges the batteries depending on the mode it is in. The batteries are recharged either using power from the gasoline engine or through regenerative braking, a process whereby the energy typically wasted during the braking process is used to drive the electric motor in its charging mode. High voltage electrical cables, which conduct the power from the battery to the electric motors and back, can be found in the engine compartment, on the underside of the vehicle and the area where the battery is stored.

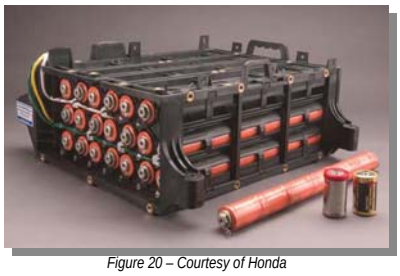

Figure 20 – Courtesy of Honda

The High-Voltage NiMH battery modules can range from 144v to 330v DC. A number of single HV cells are arranged into a "stick", several of these sticks are combined to make a battery module *(figure 20 – picture courtesy of Honda)*. Each individual cell is roughly the size of a "D" cell battery. The second generation Prius as well as many other hybrid models utilize a battery stack consisting of 38 prismatic NiMH modules connected in series. These are a series of flat battery cells "sandwiched" together. All of these NiMH batteries are considered a "dry cell" and do not present a significant spill hazard. The electrolyte, consisting of Potassium and Sodium Hydroxide, is absorbed into the cell plates to form a gel that will not normally leak, even after a collision. If the battery is crushed, however, it is possible for a small amount of electrolyte (drops) to leak. The industry is currently looking towards utilizing lithium ion and other battery technologies to improve the efficiency of the system.

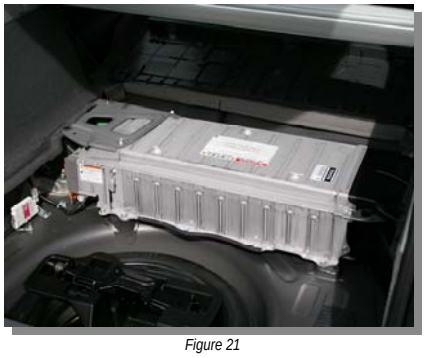

Figure 21

High voltage batteries are typically located behind the rear seat in the sedan models *(figure 21)*, under the rear seat or rear cargo area in the SUV models *(figure 22)*. All hybrid models also utilize a (12v) battery system to power low voltage vehicle systems that can be found in a normal vehicle.

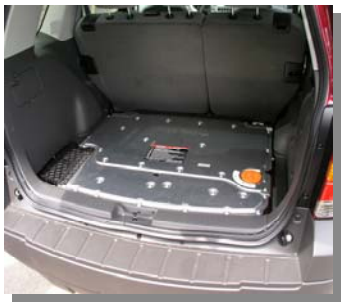

Figure 22

Hybrid Vehicle Safety Features

Hybrid vehicles utilize safety switches to automatically cut high voltage power to the system in the event of a collision sufficient to active the supplemental restraint systems. If the system short circuits, a fuse will open cutting off high voltage power from the battery. The positive and negative cables are isolated from the chassis to prevent any type of electrocution hazard from touching the chassis itself. The automatic shutdowns only shut off the high voltage from the battery to the electric motors, the batteries themselves remain energized. The hybrid system is also shut down when the ignition is turned off, the battery disconnected, or the High-Voltage system fuse is removed.

Hazards Posed by Hybrids

Death or serious injury can result from contact with high-voltage electricity. This danger however is minimal due to numerous safety systems and when proper handling procedures are utilized. As previously mentioned, the high voltage battery modules can range from 144v to 330v DC. Some models contain a boost converter which takes the DC power and coverts it to 650v AC for the electric motors to operate on. Testing has indicated that high voltage systems can remain energized after being subjected to fire. Avoid contact with high voltage components and never attempt to disconnect any high voltage connections. The same precautions should be utilized for any yellow or blue medium voltage cables as well. Avoid contact with damaged battery packs and any electrolyte that may have been released. The damaged battery pack could still be energized and the electrolyte can cause skin/eye irritations and burns.

Figure 23

The most common danger emergency responders will face is the hybrid's ability to move instantaneously even though the vehicle appears to be off. One of the energy saving features of a hybrid is its ability to shut down the gasoline engine when the vehicle is stopped. This could give the responder the impression that the vehicle is off, lulling one into a false sense of security when operating around the vehicle. Several models including those produced by Ford, Mercury, Toyota, Lexus, Nissan, Saturn and the Honda Insight have some type of ready light indicators on the dashboard to alert the occupant that the vehicle is in its "ready mode" and will move if the accelerator is depressed *(figure 23)*. Procedures should be established to control this potential movement prior to

rescuers placing themselves in front of or behind the vehicle. Controlling possible movement should always be a priority, regardless of whether or not the vehicle is a hybrid.

Safety and Response Procedures

MVAs and Extrications

Responses to an accident involving a hybrid vehicle should proceed almost exactly the same as a normal response. Responders will find that if they follow industry accepted procedures for handling motor vehicle accidents they will have already remedied the majority of the problems presented by hybrids.

At no time should a responder attempt to disconnect high voltage components, touch damaged or broken orange cables, cut high voltage lines, or touch a damaged battery. To ensure safety, always treat high voltage cables as if they are energized. There are no extrication techniques specific to hybrid vehicles, but operations must take into consideration the location of high voltage components. Manufacturers have placed the high voltage cables and batteries in locations that we generally do not consider cut points. However, depending on the extent of damage to the vehicle, the rescuer should always consider the possibility that in a vehicle which has suffered severe collision damage may have high-voltage components closer to necessary cut points.

As in any accident, immediately upon arrival, the scene should be surveyed for hazards to prevent injury to emergency responders and further injury to the victims. During this scene survey process, look for the presence of a hybrid vehicle. As with standard vehicles never approach from the front or the rear until we are sure that it has been immobilized and disabled; this is especially true for hybrids. Immobilization can be achieved by chocking the vehicle, placing it in park and then setting the emergency brake.

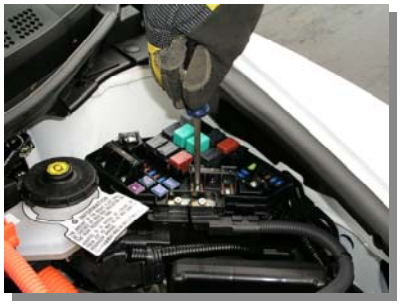

Figure 24

It is equally important to disable the vehicle and its high voltage system. Hybrid vehicle manufacturers recommend one of two options. The first method and the simplest, is to remove the key from the ignition and disconnect the 12v battery. Either of these steps causes a relay to open and prevents power from the high-voltage battery to energize the high voltage system. The second method, employed if access to the ignition key is not a

viable option, is to disconnect the 12v battery and to pull the high voltage system fuse in the engine compartment fuse box *(figure 24)*. Since it would be difficult for the first responder to always identify which is the proper fuse as the color coding is different between models, it is recommended that you pull all the fuses to ensure that the correct one is removed. This is not the actual high voltage line fuse it is simply the fuse that powers the relay in the high voltage system.

As mentioned, many existing standard vehicle response procedures address the issues posed by a hybrid. Department SOPs should already dictate that the key is removed from the ignition and the battery disconnected in order to shut down supplemental restraint systems. If this is the procedure in your department you are already handling the major concerns of dealing with a hybrid. Manufacturers have stated that bleed down times for the hybrid systems can be 5-10 minutes, depending on the manufacturer. Keep in mind, however, that this does not disable the high voltage battery, thus power remains in the NiMH battery module.

Specific to Model

There are several items to consider when dealing with specific models of hybrids. As this is a general overview, the manufacturers' ERGs should be consulted for specifics regarding the information addressed here. The Ford Escape and Mercury Mariner have battery service disconnects which are accessible to emergency responders under the rear cargo area carpet *(figure 25)*. Likewise, the Nissan Altima has a service disconnect in the trunk. Chevy Silverado and GMC Sierra also have a battery disconnect for its hybrid system under the rear seat on the passenger side of the vehicle.

Figure 25

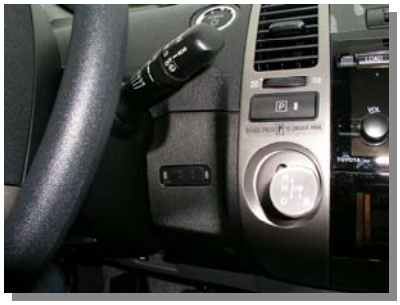

Figure 26

Vehicle ignition systems on certain hybrid models can also differ from what we are accustomed to. The Toyota Prius utilizes a slot in the dash *(figure 26)* which accepts a rectangular "key fob" and the vehicle is turned on using a power button. Another concern for responders is the "Smart" or "Intelligent" keys *(figure 27)*. These keys operate

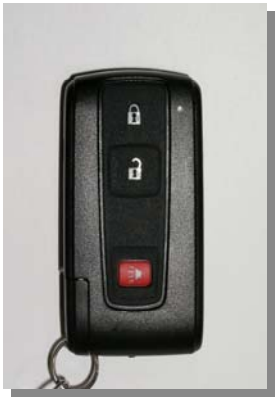

Figure 27

the door locks and the ignition remotely and only have to be in proximity to the vehicle to function. The ignition is turned on using a button on the dashboard and will only function when the key is present. These keys need to be removed to a minimum of 16' from the vehicle to prevent the ignition from being activated by the push button. These keys can be found in the Toyota Prius (optional) and Camry, Lexus 450h and Nissan Altima. The Prius has a disable button for this smart key system which can found on the dash under the steering column. This is the only hybrid vehicle that utilizes this disable feature.

Vehicle Fires

Vehicles fires in hybrids can be handled in accordance with the recommended practices of the NFPA, IFSTA and the National Fire Academy for vehicle fires. Water is the most suitable agent for extinguishment. Although the application of water to a high voltage electrical system is counter intuitive to firefighting personnel, there is no risk of the electricity traveling up the water stream and causing the electrocution of firefighting personnel. Although still dangerous, DC (direct current), unlike AC (alternating current) power sources commonly found in buildings, does not seek a path to ground. Rather, DC electricity follows a path out from the battery, along the electrical circuit and back to the battery. As such, the electrical current will not travel up the hose stream as it possile with a high voltage AC power source. The danger of electrocution exists when firefighters accidentally place themselves into the electrical circuit by touching both the negative and positive side of the circuit simultaneously with either their body or equipment. Responders should consider that it may be difficult to identify the vehicle as a hybrid depending on the extent of the damage of the vehicle from the fire.

It is generally recommended that a standard offensive attack be conducted unless the NiMH battery pack is on fire. If this becomes the case, live fire testing has indicated that it is better to allow the battery to burn out rather than attempt to extinguish it. The reason for this is two-fold; first it is nearly impossible to get enough water directly on to batteries because they are encased in protective shell. The only real access for water to the battery pack is via the battery vent and many vent designs do not allow easy access for this. Secondly, if you allow the battery pack to burn out, concerns regarding the hazmat properties of the residual electrolyte will be negated. Always make sure that the battery pack is cooled down enough to prevent re-ignition prior to releasing the vehicle. Thermal imaging cameras can be a valuable tool to determine if the battery pack is cooled down in vehicles where the battery pack can be accessed visually.

Attempts should be made to control runoff as the NiMH battery has cancer causing ingredients. If a defensive attack is warranted, pull back to safe distance and use a water stream to protect exposures and control the path of smoke. If the situation does not allow for a defensive attack such as a vehicle in a garage, appropriate actions should be taken.

High voltage components should never be overhauled as there is no guarantee that the system is de-energized. System safeties can be rendered inoperable by the effects of fire. Live fire testing has indicated that these components can remain live after a vehicle has been subjected to fire.

NiMH Battery Breaches

A catastrophic crash sufficient to breach both the battery pack case and the individual batteries would be rare. Since the electrolyte is absorbed into the cell plates, it does not normally spill or leak, even if the battery is cracked. If the battery is crushed it is possible to get a small amount of electrolyte to leak (drops). Contact with the electrolyte should be avoided as it is damaging to human tissue. CHEMTREC can be contacted for the MSDS sheets on the batteries if that becomes necessary. Toyota, Lexus and Nissan ERGs contain information on how to neutralize a leak and first aid treatments for electrolyte exposure.

Submerged Vehicles

Hybrid vehicle manufacturers recommend removing the vehicle from the water and utilizing standard disabling techniques. There is no risk of electric shock from touching the vehicle's body or framework in or out of the water. As with a vehicle out of the water, you should not touch high-voltage components or cables. All of the Hybrid ERGs address vehicles in the water.

Conclusion

As more and more hybrid models are released it is important that emergency responders educate themselves on the unique dangers they present and the methods by which to address them. Responders should not fear hybrid vehicles as they present minimal risk as long as we follow proper procedures. Department SOPs should be modified to address particular issues pertaining to hybrids.

Each manufacturer has produced emergency response guides (ERGs) to assist emergency responders in handling hybrids. These should be taken advantage of. The ERGs are readily available on the web or can be downloaded at www.etsrescue.com/hybrid_guides.exe Departments should make these guides and formal training available to their members to ensure that they get the proper information. As with anything in the fire service proper education is paramount.

Author's Note: As of January 1, 2008, the information contained in this document encompasses the models currently available. Due to the quickly changing nature of this technology and the availability of new models, emergency service personnel must continue to review new information as it becomes available. One of the best resources will continue to be the Emergency Response Guides produced by the car manufacturers.