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Talk Shop Anytime
AUTOPRO WORKSHOP
Vol. 135, No. 1

TECHNICAL

UNDERSTANDING HYDROGEN FUEL CELL TECHNOLOGY

TAKE A LOOK INSIDE THE TOYOTA MIRAI AND HYUNDAI TUCSON

TRENDING

TECH RECOGNIZED FOR 25 YEARS OF SERVICE

Motor Age contributor values ASE training, quality work

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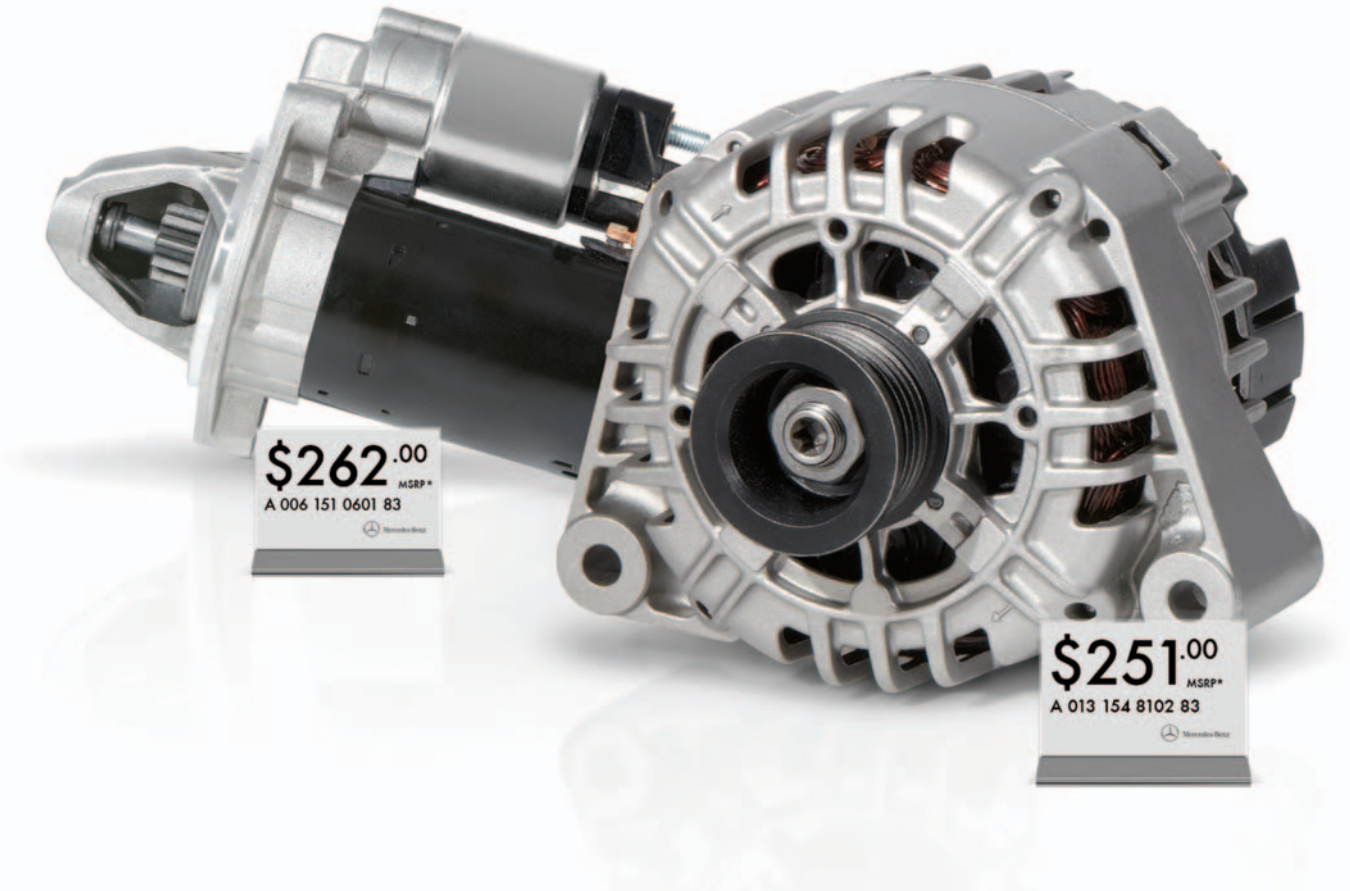

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Talk shop anytime

AUTOPRO WORKSHOP

MotorAge

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Make your work easier — let the tools do their job.

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The proposal would modernize NHTSA's current standards by taking into consideration new and emerging vehicle technologies.

»» MOTORAGE.COM/DOTSAFETY

AASP-MN ANNOUNCES ANNUAL MEETING AND LEADERSHIP CONFERENCE

This year's event, which will be held April 14 in Minneapolis, offers a line-up of seminars that are specifically geared for mechanical and collision repair shop owners and managers.

»» MOTORAGE.COM/AASP-MN

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The Wiki features unbiased biographical information written by iATN's 84,000 members about the companies, products and services that serve the industry.

»» MOTORAGE.COM/AUTOPROWIKI

MITCHELL 1 INTRODUCES EMISSION CONTROL GUIDE

The guide covers domestic and import cars, light trucks, vans (diesel engines) and Class 'A' motor homes with gasoline engines, model years 1966-2016.

»» MOTORAGE.COM/EMISSIONGUIDE

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The 12 VERSUS Edge Training Solutions modules are designed to help navigate the features and functionality of the latest diagnostic tool.

»» MOTORAGE.COM/SNAPONVIDS

Longtime Motor Age contributor Richard McCuistian holds his award for being ASE certified for more than 25 years.

ASE TRAINING

Motor Age contributor recognized for 25 years of ASE certification

Richard McCuistian, a longtime *Motor Age* contributor with 11 ASE certifications (A1-A8, Light Vehicle Diesel, L1 Advanced Level Engine Performance and G1), recently received recognition for his 25th anniversary of being ASE certified. In honor of this prestigious milestone, we asked Richard to reflect on his expansive career in the service repair industry, including his passion for fixing vehicles, biggest challenges and advice for newcomers to the industry.

Motor Age: What has driven you throughout your career?

Richard McCuistian: My dad owned a shop, and from the time I was about four years old, I've always been drawn to grease, steel, sparks, switches, gears and bearings, hand cleaner, colorful cardboard boxes with new parts in them, and all the rest of it. I love using tools and fixing and maintaining vehicles, especially when the light bulb pops on over my head and I make the connection between the data and the fix. I like being the guy in a uniform who knows what to do when most others don't.

And most of all, nowadays, I love passing what I know along to the younger generation. We need new blood in this industry now more than ever, and I like being a part of that process.

Motor Age: What has been the biggest challenge you've faced throughout your career?

McCuistian: Like most people my age who started out 40 years ago when electronic ignition was brand new and so many ignition systems were points-and-condenser, my biggest challenge throughout the years has been staying abreast of changing technologies as electronics have taken root in virtually every part of the vehicle. I spent most of my career at dealerships and got really great training there.

Now I'm teaching, so I have to make sure I stay up to date on what's going on with the more common makes and models that populate the area where my trainees will be wrenching.

Motor Age: What is the most important advice to pass on to someone who is new to the service repair industry?

McCuistian: To begin with, you WILL earn what you get paid in this industry. After your foundational training (and it's good to get that first), realize that speed and accuracy will be the engine and the transmission of your career. *Continue reading at MotorAge.com/25ASE.*

Photo: Richard McCuistian

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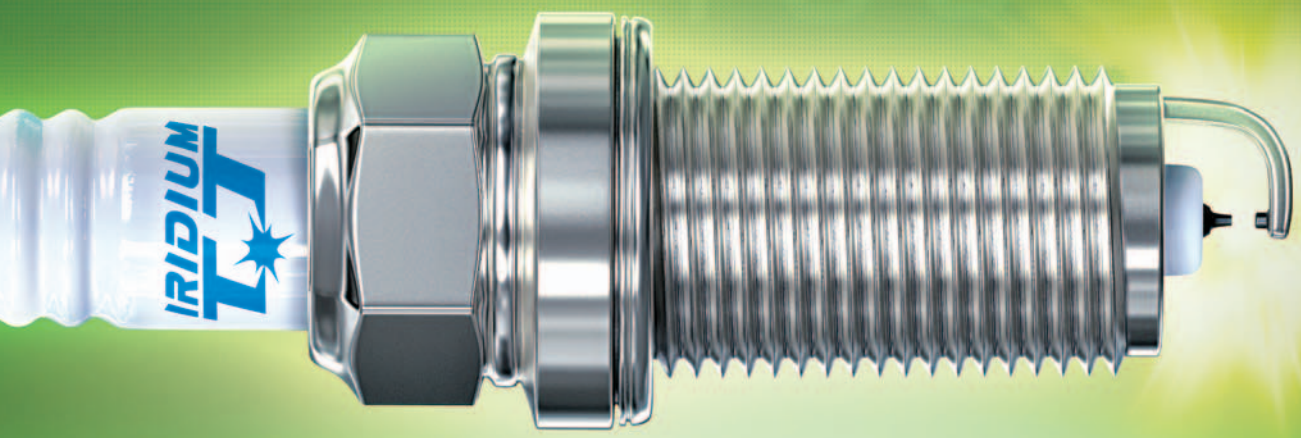

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DON'T LOSE GOOD CUSTOMERS OVER PRICE

THERE ARE NO PRICE OBJECTIONS, ONLY VALUE QUESTIONS

BY **CHRIS "CHUBBY" FREDERICK** | CONTRIBUTOR

IN MY 40 years plus in the automotive business, the one thing that still tears me apart is the slow death of an automotive repair shop. I take it personally when it happens on my watch or even when I was not involved in helping that owner with his or her business. Raising prices to stabilize margins to enable you to operate successfully in whatever type of business model you have chosen can be life or death.

This month I am proud to bring you one of the best explanations of this life-or-death experience from Coach Eric Twiggs. I have heard every argument and witnessed every possible scenario on this subject; but I have never in all my years seen any more common sense written on the subject than this article by Eric. So I am proud to offer you our latest parts pricing matrix for those of you who were never sold on its implementation.

"I'm losing business because of your parts pricing matrix!" This is what a shop owner named Rich told me during our weekly coaching call. Both his car count and average repair order (ARO) were down from the previous year.

The shop is located in a rural section of the country with a high unemployment rate and low median income. The most expensive dealerships in Rich's area had a labor rate of $73 per hour.

These factors led Rich to believe he couldn't implement the parts matrix that he learned about while attending his ATI classes. When I would remind him of what he was taught on the topic, his response was always the same: "My shop is different!"

He had two service writers named Steve and Chris. Even though they had the same invoice count, Steve held a 61 percent parts margin and a $400 ARO, while Chris hovered around 45 percent and $230.

I had Rich make the "Where have you been?" follow-up calls to his database to determine why people weren't coming back. He spoke with 10 customers; five from each writer.

As suspected, he received feedback stating he was too expensive. Four previously loyal customers mentioned finding another shop with lower prices. Which seller do you think had the most complaints?

If you guessed Steve, guess again! None of his patrons mentioned the price. They had good things to say about him and the service. All of the complaints came from Chris' customers. Why would Chris' clientele complain even though Steve was charging more? Keep reading and you will learn three ways to lose your good customers over price.

Don't only mention what's wrong

Chris would only want to talk about what needed to be repaired on the car. Steve began his presentations by mentioning the positive findings from the courtesy check. His buyers felt their vehicle was worth investing in, while Chris often heard the following: "I'm getting rid of the car, so why spend the money?" His customers left without feeling the value of the service or of their vehicle.

I recommend using what I call "the good news opening" when presenting an estimate. It sounds like this: "Eric, I have some good news. We just completed the 30-point courtesy check and found that your tires are wearing

Photo: Thinkstock / IvelinRadkov

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evenly, your brakes are in good shape, and your battery is fully charged." Beginning your presentation by sharing the good news from the courtesy check puts the person at ease, sets a positive tone and sends a message that the car is worth investing in.

Show and tell

Steve did a vehicle walk around with everyone, which enabled him to reveal items like worn tires and wiper blades in need of replacement. He experienced less resistance because he and the customer had the evidence in front of them. Chris didn't believe in going out to the car. He would always say: "My people don't like going back outside!"

All things being equal, people prefer to do business with individuals they trust. Unfortunately, our industry has a bad reputation in this area, so the average person enters a repair facility with their guard up. The vehicle walk around gives you a great opportunity to establish rapport and will make your job easier.

Since Steve's clientele trusted him, they didn't have to call other shops to make sure they were getting the best price. Chris' customers would call the competition even when they had their vehicle apart in his bays!

Steve also had a habit of using pictures and visual aids to show the components he was referring to during the estimate presentation. According to a study done by communications expert Carmine Gallo, the average person is able to recall 10 percent of the information they receive via oral communication within 72 hours.

Gallo found that when the same information is presented using pictures, the recall rate jumps to 65 percent. In other words, consumers will remember more of what they see than what you say!

Explain the benefits

I bet I know which radio station your customers listen to. It's W.I.I.F.M., which stands for What's In It For Me? They want to know about the benefits and value they will receive by making the purchase. Chris focused his presentations on the technical aspects of the parts and labor. Steve, on the other hand, connected the services needed to the benefits that were important to the buyer. Since they didn't understand the benefits, Chris' clients used price as the criterion for their purchase decisions.

In his book, "Buying Trances: A New Psychology of Sales and Marketing," Joe Vitale lists the 26 reasons people buy anything. There are seven that specifically relate to selling automotive service. They are as follows:

- Save time
- Save money
- Make money
- Avoid effort
- Avoid pain
- Be safe and secure
- Increase happiness

As I reflect on the reasons people buy, I am reminded of an incident where Chris's inability to explain the benefits came to light. He quoted his customer Laura $530 for a distributor going on a 2004 Mitsubishi Eclipse. She responded with the following: "I can get it cheaper from the parts store down the street. You guys are too expensive — cancel everything!"

Rich, the owner, met with Laura in an effort to salvage the sale. What he told her proves the value of explaining the benefits: "Laura, the price you were quoted by the parts store is a do-it-yourself price. Ours is an installed service price, which comes with a two-year, 24,000-mile warranty, which is twice as long as the industry average. With the warranty, you get nationwide coverage in case something goes wrong while you are out of town. Can you find it cheaper? Probably. Will you be as happy with your investment? Probably not."

Laura's response surprised everyone: "I didn't realize everything I was getting. Go ahead and do it." Why did she change her mind even though the price stayed the same? Laura understood the benefits and felt the value. When the buyer feels the value they will pay the price!

By mentioning the installed service price, Rich touched on the benefits of saving time and avoiding effort. When he spoke about the warranty coverage, he helped Laura understand how she could avoid pain and remain safe and secure.

Summary

Several weeks later, Rich terminated Chris, replacing him with a restaurant industry veteran who knew nothing about cars, but had a great attitude. As a result, the price complaints decreased and the margins increased!

If you only mention what's wrong, don't do show and tell and refuse to explain the benefits, you will lose your good customers over price! If you are tired of losing profits because of your pricing, for a very limited time you can download your own copy of the ATI Parts Pricing Matrix by going to www.ationlinetraining.com/2016-01.

CHRIS "CHUBBY" FREDERICK
CONTRIBUTOR

Chris "Chubby" Frederick is the CEO and founder of the Automotive Training Institute. ATI's 115 associates train and coach more than 1,400 shop owners every week across North America to drive profits and dreams home to their families. Our associates love helping shop owners who are having the same struggle as many of them have had, and who are looking for the same answers — and in some cases looking for a lifeline. This month's article was written with the help of Coach Eric Twiggs.

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UMPQUA COMMUNITY COLLEGE INSTRUCTOR EARNS TOP ASE HONOR

BY **CHELSEA FREY** | SENIOR ASSOCIATE EDITOR

From testing as a student to training future generations to recognition for his dedication, an instructor now has all bases covered with his ASE experience.

David Wolf of Roseburg, Ore., was named the *Motor Age Training*/ASE Master L1 Training Specialist of the Year. Wolf serves as the lead instructor for the Toyota T-TEN program at Umpqua Community College, which is a two-year degree program that trains in all 8 ASE areas.

Wolf has not always been involved in the automotive industry — he earned degrees in music from the University of Illinois and the Cincinnati Conservatory of Music and then spent four years playing bass trombone as the founding member of the Skyline Brass. However, he has always been interested in solving problems, so his transition to the automotive industry made perfect sense.

"Automotive systems were interesting to me due to their complex nature, especially because there are mechanical and electrical systems that work together," Wolf explains.

Wolf's part-time interest in automotive repair transformed into a career in 1999 — he accepted a full-time position with Jim Rogers at Rogers Tune-up Shop in Roseburg. In his 16 years of being in the industry full time, most of Wolf's work experience has involved positions at independent repair shops. He also spent two years working as a dealership technician.

Now, Wolf is using his talents and passion to foster the next generation of technicians as an instructor. Since 2010, Wolf has been teaching automotive studies at Umpqua Community College. "Teaching has given me the opportunity to help students work toward a successful career by becoming competent entry-level technicians," he comments.

Wolf is the lead instructor for Umpqua's Toyota T-TEN program, which has been a part of the college for over 20 years. Umpqua's T-TEN students are employed by a sponsoring Toyota dealer as interns while they attend college. T-TEN uses a competency-based curriculum in which students alternate every term between the college and dealership internships.

The college also has a General Automotive program, which has recently been affiliated with Snap-on, nc3 and the Chrysler CAP local program.

Aside from teaching at the college, Wolf does consulting work for shops in Roseburg. Wolf also makes time to pursue his original passion, music; he and his wife Kathryn perform together as members of the Rogue Valley Symphony. They also enjoy traveling and hiking along the scenic North Umpqua River.

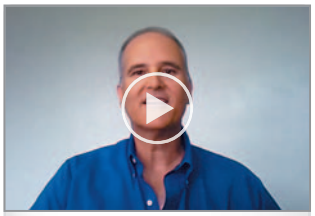
Upon hearing he had been chosen as the *Motor Age Training*/ASE Master L1 Training Specialist of the Year, Wolf was equally surprised and honored. He recalls, "I still remember taking my first three ASE tests and being excited when I received those 'pass' results in the mail. I never thought taking ASE tests would lead to more than keeping certifications current. Thanks to ASE and *Motor Age* for this award and your dedication to automotive technician excellence through certification."

"IT HAS BEEN REALLY WONDERFUL TO MEET A LOT OF VENDORS THAT WE HAVE HEARD ABOUT, BUT HAVE NEVER HAD THE CHANCE TO MEET FACE TO FACE."
—PAUL STOCK

[WATCH AND LEARN]

Measuring voltage on the ground side

MotorAge.com/Voltage



How to position your shop as the local expert

MotorAge.com/LocalExpert

How to recondition headlights

MotorAge.com/Recondition

Hold your ad vendors accountable

MotorAge.com/AdVendors

SOCIAL INSIGHTS

• Celebrating 20 years of innovation

As part of Mitchell 1 celebrating the 20th anniversary of its shop management solution, the company compiled 20 helpful tips for Manager SE users. They reviewed hundreds of ideas and selected the 20 best from shops who use the software every day. In their own words, the shop users discuss their experiences and ideas that make their workday better for all concerned.

User Tip No. 1: What to do with a vehicle that the customer no longer wants

"I use Excel and MS Query to create custom mailing lists; works great. The problem is some customers have had 10+ cars over the years and these could have the same last-in date and address. I can de-dupe the list down to one address per customer with software, but that also removes any other active cars the customer brings here. I'd like to purge cars that have not been here for a long while. Any ideas? Thanks."

"We made up a separate account called 'Sold Vehicles.' If we know that the customer sold, junked or totalled a vehicle, we move it to this file. It helps to clean up customer accounts. Sometimes people get emails about vehicles they got rid of; so this helps with that situation. When moving it to 'Sold Vehicles' we do a few things: in Vehicle Memo we enter customer's name. We delete the license plate & copy any Recommendations into the Vehicle Memo (so they don't show on future follow-up reports). Then we delete the inspection date or move it to the memo (for same reason). Hope this helps." [To reduce errors, Change Ownership is only visible in the 3 tab file maintenance view]

The tips are published one at a time on the Mitchell 1 blog, so take a look at the first two and be sure to come back for the rest!

MotorAge.com/shopconnection

• CYA — A technician's most important acronym

On the *Motor Age* YouTube page, Director of Training Pete Meier discusses how in today's litigious society, a professional technician can be held criminally and civilly liable for his actions and in even some cases, his inactions. CYA — or cover your a** — is one of the most important things a tech needs to remember.

Billy R commented: This is probably the most sound advice I have ever heard on YouTube in any video. Big thumbs up to you sir!

Patw52pb1 commented: A few additional items for the mechanic/technician and shop owner to consider:
- Incorporate. Form a corporation, and perform all work as a corporation. There is a definite benefit in almost all situations to mitigate, limit or eliminate personal liability in the event of a mishap or loss. Consult a knowledgeable attorney for how to incorporate and what type is best for your business.
-Invest in pre-printed automotive repair/work order forms with sequential numbering, authorization, liability release, waivers, notice and disclaimers.
-Completely fill out the repair/work order, including customer and vehicle information and work to be performed.
-Always inspect the vehicle for any damage, deficiencies or missing components and note on repair/work order before accepting the vehicle and giving the customer their signed copy of the repair/work order.
-Have the customer sign the repair/work order before performing any procedure every time.
-Have a knowledgeable attorney draft and/or review any repair/work orders, disclaimers, contracts, agreements, employment policies, authorizations, waivers, liability releases, estimate policies, signs, notices and business practices.

All these steps will help protect you and help mitigate your loss/liability in the event of a mishap or if the customer does not want to pay you or wants to file a suit against you.

All of the above sounds scary and difficult, but it really isn't, and the financial security benefits are well worth the cost and effort.

When it doubt, seek professional guidance.

MotorAge.com/dec15trainer

TRAINING EVENTS

FEBRUARY 11-13
• MACS 2016; Caribe Royale
Orlando, Florida

MARCH 16-19
• ATI Super Conference 2016; Omni Amelia Island Plantation Resort
Amelia Island, Florida

MARCH 18-20
• ASA Northwest Automotive Training Expo (ATE); Doubletree
Seattle, Washington

MARCH 19
• TST Big Event; Ramada Inn
Fishkill, New York

APRIL 5-7
• 2016 AASA VISION Conference; Loews Chicago O'Hare Hotel
Chicago, Illinois

AUGUST 9-13
• 2016 AASA VISION Conference; Anaheim Convention Center
Anaheim, California

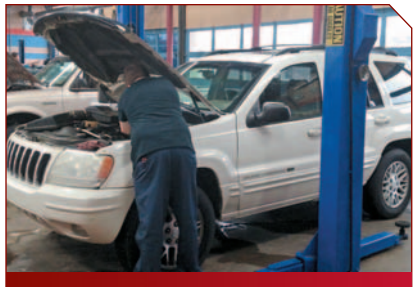
NO 100% GUARANTEE

YOU MIGHT GET A WARRANTY, BUT THERE IS NO SUCH THING AS A 100% GUARANTEE

BY **RICHARD MCCUISTIAN** | CONTRIBUTING EDITOR

Whenever somebody wants us to apply our expertise to give them peace of mind, it would be nice if we were able to offer a 100 percent guarantee, but no matter how good we think we are, time and chance can always get the upper hand. About 30 years ago, a relative of mine brought me his early 80s VW Rabbit for an inspection – he was taking it on a long trip, so I gave it the once over. I had done almost all of the maintenance on this vehicle, so I had carnal knowledge of the car, and I found nothing wrong.

While he was on his trip, the alternator died, and a shop down in Florida charged him $300 to diagnose and replace it, which was highway robbery in those days. When he returned from the trip, he chastised me because I didn't tell him the alternator was going to fail. Yeah, I know. I rolled my eyes too. I suppose if I had replaced the alternator, the starter, the battery, and who knows what all else, I could have averted the breakdown, but at what cost?



PULSE PROBLEM

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Vehicle Year/Make/Model

198,547
Mileage

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Engine

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Transmission

PULSATING BRAKES
Complaint

I remember my dad telling me about a very demanding elderly widow who came to his shop and told him she wanted him to do a comprehensive inspection of her vehicle every month and she would pay him generously each time. She then told him that if he agreed, anything that ever went wrong with her car would be 100 percent his fault and she would expect it to be repaired free of charge. He refused to even touch her car, and sent her on her way in search of a sucker, which he wasn't. Gotta love those folks who want us to "own" all of their future problems, right?

Recently, a young woman who is just beginning her adult life brought a vehicle to me so I could "look it over" to see what I thought of it before she bought it. I'm always kind of nervous in situations like this, because a used car is, after all, a used car, and we all know that no inspection we can do for free goes deep enough to give a 100 percent guarantee of anything.

In this case, I checked all the fluid levels, perused it above and below for leaks of any kind, checked the age, pressure and condition of the tires, examined brakes and suspension parts, all of which looked fine, but I had to kill a large and healthy brown widow spider that had webbed the area just inside the right rear wheel and was waiting for a kill. There wasn't much rust on the non-coated undercar components, so this car must have spent its life away from the coast and far enough south to avoid salt. I was most concerned about the timing belt, because that 2.7L isn't a free-spinning engine, and with just over 100K on the clock, I decided to remove the upper part of the cover to have a look. Yeah, I know it's usually difficult to look at a timing belt and say for sure how old it is, but this one had bright white part numbers on it and there was even a sticker on the shock tower proudly announcing the recent mileage at which the timing belt had been replaced. That put my timing belt fears to rest, and after checking for obvious electrical problems, I rounded out my inspection with a rubber stamp. The car seemed fine as far as I could tell.

She thanked me for the free inspection and bought the car. She drove it for about two weeks, and then one day she called me when I was at lunch to tell me that the engine had stopped running, and that she had coasted off to the side of the road. As I questioned her about it over the phone, she said the engine would spin but wouldn't start. I told her we'd get the car to the shop after lunch and have a look at it.

Photos: Richard McCuistian

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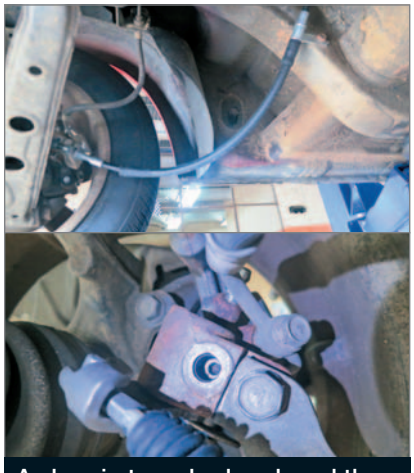
Her folks decided to take it to a shop they liked to use (I do not know this shop or the man who runs it), and after changing a couple of parts and charging them a Ben Franklin or two for those fruitless attempts, he pulled the entire timing cover and said pieces of an old timing belt were trapped in there and had caused damage to the wiring. Then a couple of days later she told me he had called to say that the engine was locked up and he wanted eleven more Ben Franklins to replace it.

Busy times

My people are predictably happy when we have plenty of work. This time around it's transmissions, brakes and steering/suspension, and we've had quite a lot of it. I had a couple of guys doing a go-through on a 4L60E as a bench job just for the experience of tearing it down and reassembling it, then I surprised them by having them stuff it in a 2001 Chevy trainer truck we have on hand just to see if it'd pull. It didn't, and all the pressures were low. They ran some tests before reinstalling the original transmission with the notion that they'd tear down and re-evaluate the one that didn't work. We also had a 2004 Dodge Stratus with an incorrect gear ratio in 3rd gear code, and that one's still underway — it performed okay on the test drive except for a chatter on the 1-2 shift, so it's coming back out to tear down and re-check for proper assembly.



A shop in town had replaced the park brake cables on this Miata, but the park brakes wouldn't stay adjusted. What the cable replacer didn't know was that this adjustment screw (normally hidden by a cover bolt) would adjust the park brakes the right way. We made the adjustment, but I told the Miata owner that we might have to adjust it again if the brakes got loose again.

We've done enough brake jobs over the past few weeks to fill my "old brake pads" bucket to capacity, and wheel alignments have been numerous and instructive. We've replaced multiple sets of ball joints, steering racks, pumps, leaking lines and even a front differential chunk. We had a park brake problem on a '91 cream puff Miata — the brake cables had been replaced by a shop in another town, but the park brakes kept getting loose, so we adjusted them the right way. We had the red '71 Eldorado convertible back in the shop with a steering pull and a pop noise when backing up that turned out to be a worn idler arm.

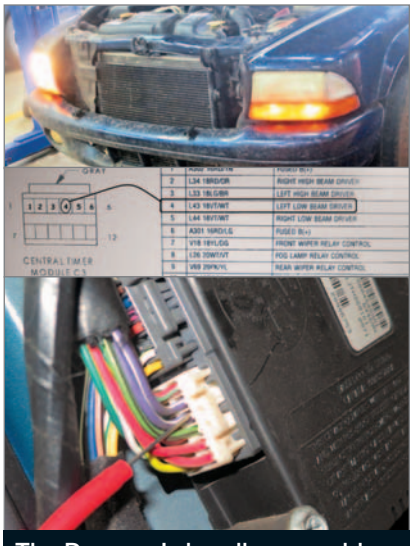
Then there was the wild card — a Dodge Durango that was shifting erratically and had one headlight that was going off at random — and it was off most of the time. The customer brought us a headlight connector, because when he replaced the bulb the problem remained. A simple transmission service took care of the erratic shift, and the headlight problem turned out to be in the BCM, which is totally responsible for the headlamps. I found him a replacement module on eBay.

The Jeep "brake" problem

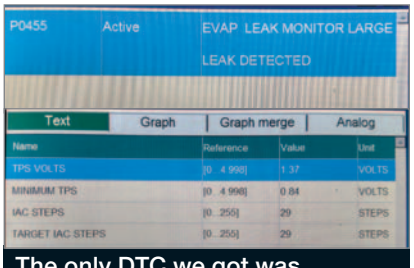
Our title vehicle came in for an alignment and what the driver described as a brake pulsation that "keeps pulsating even after I let off the brakes." That sounded kind of anomalous, but that's how I wrote it up. She left it with us, and later that morning I grabbed one of my guys and we launched our diagnosis.

The first thing I noticed as we started it in the service bay was a really high idle. As a matter of fact, the idle was so high I wondered if the foot feed was fouled by a wrinkled up floor mat (I've seen that more than once). I sent my guy to fetch a scan tool, and we retrieved the DTCs and found only a P0455 — no surprise on one of these — and then proceeded to hack into the live data, where we noticed right away that the reported throttle position sensor voltage was a lot higher than the baseline minimum. That would explain the high idle.

When the PCM wakes up on most platforms, it pegs the TPS voltage at key on and tags that number as the baseline for closed throttle. On some platforms, that number is stored as a part of the adaptive memory. But on the ones that re-read it at every key on, any voltage higher than the baseline after initial start is considered part throttle for the rest of that drive cycle, and at part throttle, the IAC steps will be high, poised for dashpot function (slow return to idle so as not to stall). As long as the TPS is con-



The Durango's headlamp problem wasn't as straightforward as the owner had imagined it would be. The module was sending voltage out to the light intermittently — it had an internal fault. We ordered a replacement module from Ebay, but there is no 100 percent guarantee it will be a good one.

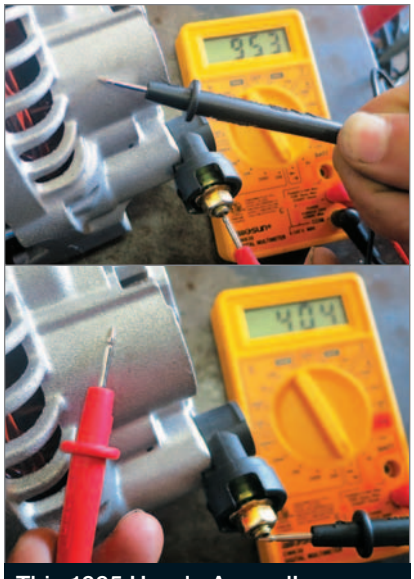


The only DTC we got was caused by a split hose — the live data showed (at idle) this TPS voltage. Note the difference between actual voltage and the benchmark minimum.

sidered to be at part throttle, the IAC will remain that way, which makes for a fast idle on non-electronic throttle body systems, even with the throttle plate closed.

After a moment or two, and a tap on the throttle (which is almost reflexive when the idle is high like this), the idle more or less normalized, and we backed out of the shop. When we had cleared the runway, wheels up and locked, we reached cruising speed on the four lane and slowed at the first turnaround to feel the brakes. We didn't feel a brake pulsation, but we did feel the engine laboring as the vehicle slowed — the transmission was in high gear and continued to quiver and labor even after we let off the brake before dropping back into low gear when we were almost stopped.

I had felt this kind of thing before on other vehicles — GM platforms, mostly — when the TCC solenoid was sticking and keeping the converter locked while the vehicle was coming to a stop. In one of those cases we did a transmission service and dumped some Sea Foam trans tune in there and fixed that one. In another case, we did the same thing to a 2008 Impala that was reportedly having screwball transmission issues, and it fixed that one too. Sometimes the quick and easy is the smart way. Sometimes the quick way is the only way when there isn't time for anything else.



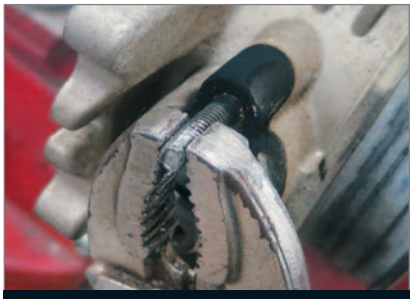
This 1995 Honda Accord's alternator was replaced back in July for a non-charging condition. It showed up again in October for draining the battery overnight. We traced a 5-amp drain to the new alternator and ran a diode test with a cheap meter—it shouldn't read both ways. Another replacement alternator took care of the draw. We had a warranty, but no guarantee that she wouldn't have to jump it off again at some later date.

In this case, with the TPS reading like it was, I reasoned that the controller might be confused enough by the faux part throttle reading to delay the downshifts, and so we sold the Jeep driver on the notion of planting a new TPS on the throttle body just to see what happened. I was convinced that it needed that anyway, and it'd be an easy beginning.

Not so easy

We obtained a replacement part from the parts store and my guy set about to remove the old one and install the new one. Well, he tried to remove the old one, anyway. He got the top screw out but couldn't move the bottom one. We all know these screws have thread locker on them and can be tough sometimes. GM Instructor Ellen Smith mentioned this annoyance in the CCC school I attended in 1981, suggesting the use of a soldering iron on the stubborn ones. We initially tried that strategy, but this one was ridiculously tough and destroyed two Torx bits, so we removed the throttle body and carefully mounted it in a vise. Nothing would move it, not even a good pair of Vise Grips. Sometimes even the easiest job can turn into a "monsta," and this was an extremely defiant little fastener. We heated the boss with a bottle torch and continued to tighten the Vise Grips to the sides of that domed screw head, but it still wouldn't turn. We then ground the head off with an abrasive cutter and removed the sensor to expose the screw shaft in hopes of getting a better grip, but it still wouldn't move — it was one with the throttle body. This was getting stupid.

Finally, I put away the bottle torch and hit the boss with a heat gun on high for about two minutes while applying Herculean pressure with the Vise Grips, and the shaft of that terribly stubborn screw finally began to turn. It amazed me to no end that the heat gun did what a blue flame wouldn't.



Back to the Jeep — this little TPS screw was surprisingly tough to get out. Early on, a pocket lighter had been used to heat the boss, then a bottle torch, and finally, a heat gun melted the thread locking compound enough so we could rock the cadaver of this bolt back and forth and finally get it out of its hole. The TPS took care of the high idle and the transmission's delayed downshift.

With the new TP sensor installed and the throttle body re-mounted, we re-drove the car, didn't feel anything untoward, and turned it back over to the driver. A week later she came back in for an alignment and reported that her perceived "brake pulsation" was gone. In a word, what she misidentified as a brake pulsation, we identified as an extremely late downshift, and our decision to treat the high idle/TPS problem turned out to be a surgical repair, and it felt good to get this one right the first time. And while we sometimes stumble around looking for the right fix, sensible decisions and surgical repairs are the benchmark of a true professional, but in our better moments, we all know there is no such thing as a 100 percent guarantee. This Jeep transmission fault may yet darken our door again.

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Don't believe everything you think

DON'T LET WHAT YOU THINK YOU KNOW BLIND YOU FROM SEEING WHAT IS REALLY CAUSING THE PROBLEM

BY **WAYNE COLONNA** | POWERTRAIN PRO PUBLISHER

NOT long ago I saw a bumper sticker that read, "Don't believe everything you think." It brought to mind another saying I once heard, "Someone's perception is their reality." Another quote that came to mind originated from the movie *American Beauty:* "Never underestimate the power of denial". These quotes relate to an old proverb that says, "Every way of a man is right in his own eyes."

In diagnosing problems with vehicles, every now and then what one thinks he or she knows blinds him or her from seeing what is really causing the problem. When this occurs, it typically takes place with a vehicle known for a common failure. When that vehicle arrives to a shop exhibiting all the typical symptoms related to this failure, the cause is immediately assumed.


Figure 1

Admittedly, the occurrence of fixing a common failure outweighs the few times one might be blinded by a pattern failure repair approach. At the end of the day, this does equate to more dollars in the bank. But the few times a proper diagnostic approach is missed, it can be costly in time, money and personal frustration.

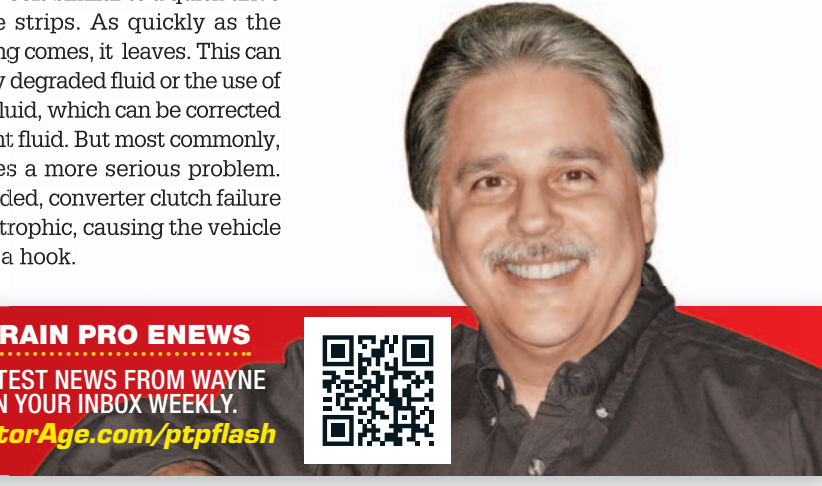
One example is Honda/Acura vehicles that experience converter clutch shudder and failure. The complaint is often described as a sudden shudder around 45 mph that feels similar to a quick drive over rumble strips. As quickly as the rumble feeling comes, it leaves. This can be caused by degraded fluid or the use of low quality fluid, which can be corrected with the right fluid. But most commonly, this indicates a more serious problem. Left unattended, converter clutch failure will be catastrophic, causing the vehicle to arrive on a hook.

This type of transmission is known to allow the converter clutch to drag when in the released position. As the clutch begins to get damaged, it shudders on the apply. Briefly speaking, there are problems related to the pressure system affecting proper converter pressures. In time, the converter overheats and turns bluish purple in color. Some of the causes of the problem can be pump wear, pressure regulator operation, leaking lock-up shift and lock-up control valve bore plugs or a restricted heat exchanger.

With Honda/Acura converter clutch shudder complaints being likened to the tip of an iceberg where bigger problems are lurking underneath, other possibilities are often overlooked and remain unknown.

This happened with Donald Holliday from Covington Automotive. The customer informed the technician that the shudder seems to occur whenever he saw the "ECO" Lamp illuminated. The "ECO" Lamp operation is tied into the i-VTEC Variable Cylinder Management (VCM) System found in V6 engines. The VCM is a strategy that automatically deactivates 1/3 or 1/2 of the cylinders, according to the driving conditions. This technology provides increased fuel economy, which when activated will inform the driver by illuminating the "ECO" lamp.

When the vehicle is running on three



WAYNE COLONNA
is President of the Automatic Transmission Service Group (ATSG) in Cutler Bay, Fla., and a frequent speaker/instructor for transmission training around the globe.

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cylinders, combustion pressure per cylinder also increases, which increases engine vibration. To absorb this vibration they use Active Control Engine mounts (ACM) as seen in Figure 1. These are liquid-filled mounts that an Engine Mount Control Unit controls to dampen harmonic vibration during VCM activation (see wiring going to the engine mount actuator inside the mount in Figure 2). As a result, Honda states that a slight vibration in "ECO" Mode is considered normal.

Over time these mounts begin to have issues. Whether an electrical problem arises or the mount itself has deteriorated, the compromised mount(s) can transmit a harmonic vibration through the car simulating a converter clutch shudder. The key here is whether or not the shudder occurs when the ECO light is illuminated. If so, this would indicate a failed mount as the cause.

You may find fluid leaking from the mounts as another clue. You may also find service codes stored as the ACM system is capable of storing generated trouble codes. Using a 2008 Honda Pilot 2WD V6-3.5L vehicle, some of the codes that can be pulled are P0A14 and P0AB6 are front and rear Mount Actuator Circuit Malfunctions; P0A15 and P0AB7 are front and rear Mount Actuator Control Circuit Low Current codes; P0A16 and P0AB8 are front and rear Mount Actuator Control Circuit Low Current codes; P15AB is an Engine Mount Control Unit Power Source Circuit Low Voltage code; and P15AC and P15AD are Engine Mount Control Unit Internal Circuit Malfunction codes.

A malfunctioning ACM can also generate other codes such as a Cylinder Pause Signal Malfunction codes.

Honda describes the system as follows: The engine mount control system controls the engine mounts electronically. The system consists of the engine mount actuators, the engine mount control unit, and the powertrain control module (PCM). The engine mount control unit uses the crankshaft and camshaft position sensor outputs (received from the PCM) to estimate engine vibration. The engine mount control unit then sends signals to the engine mount actuators to command the engine mounts to push and pull on the engine to counteract engine vibration. The engine mount control unit monitors the rear engine mount actuator, and when an abnormal condition continues for a set time, the engine mount control unit detects a malfunction and stores a DTC.

For this reason you will encounter Cam Shaft Position Sensor (CMP) and/or Crankshaft Positions Sensor (CKP) codes that could be caused by a failed Engine Mount Control Unit.

One other interesting point is that vehicles with the i-VTEC/VCM systems are also equipped with an Active Noise Cancellation (ANC) System. Along with a drive-by-wire system and the ANC System, the operation of the i-VTEC system operates fairly seamlessly, albeit the slight normal vibration. The ANC System uses front and rear sound sensors mounted in the vehicle ceiling, as well as an ANC Control Module under the dash. The ANC System utilizes the vehicle's radio speakers to cancel out noise by using an opposite phase sound.

There is a service bulletin by Honda entitled Excessive Vibration Between 30 and 65 MPH (14-078). It is important to note that this bulletin is not addressing a problem with the Active Control Engine mounts. It is addressing the timing of when the VCM is activated and when the torque converter clutch is being applied. The torque converter apply strategy goes from Off, to Partial Apply to Full Apply. This bulletin addresses excessive vibration between 30 and 65 mph under certain driving conditions. It sites possible causes for both 2WD and 4WD applications as a calibration VCM operation combined with the the lock up torque converter causing excessive vibration. With 4WD vehicles, the propeller shafts center support bearing bushing material may not effectively dampen vibrations in temperatures below 32°F. The corrective measures are to perform the inspections provided in the bulletin. Based on the results, a PCM program update may be needed. For 4WD vehicles, the propeller shaft may also need to be replaced.

The bulletin lists 2012 to 2015 Honda Pilot applications qualified by VIN range. It also stipulates that Honda vehicles use Keihin and Continental PCMs. Keihin PCMs contain two chips that require updating both the PGM-F1 and A/T system software. A software update for Continental PCMs was made available in January 2015.


Figure 2

The bulletin also provides what normal torque converter operation looks like and what a possible torque converter issue looks like.

A software update campaign 12-007 applies to 2010-2012 MDX and ZDX vehicles. This addresses a similar concern: A judder from the torque converter lock-up clutch may be felt while driving between 20-60 mph.

To minimize the opportunity for the judder to occur, a software update for the transmission is available. The VIN needs to be checked for eligibility. Part of this repair is to drain the ATF and refill with approximately 3.3 quarts of new fluid.

Here is a sampling of vehicles utilizing the Active Control Mount system:

2005-2007 Honda Accord Hybrid

2005-2010 Honda Odyssey ((EX, LX & Touring models only)

2006 & Later Civic Hybrid

2006 & Later Honda Pilot (2WD models only)

2008-2009 Honda Accord (Except EX, LX V6 & 6MT Coupe)

2010-2012 Honda Accord V6 (Except EX, LX V6 & 6MT Coupe)

2013 & Later Honda Accord V6 (Except 6MT Coupe)

2009 & Later Honda Pilot

2013 Honda Accord V6 (Except 6MT Coupe)

2011-2014 Honda Odyssey

2013 Acura RDX V6

2013 Acura RLX

2014 Acura MDX

2015 Acura RLX Sport Hybrid

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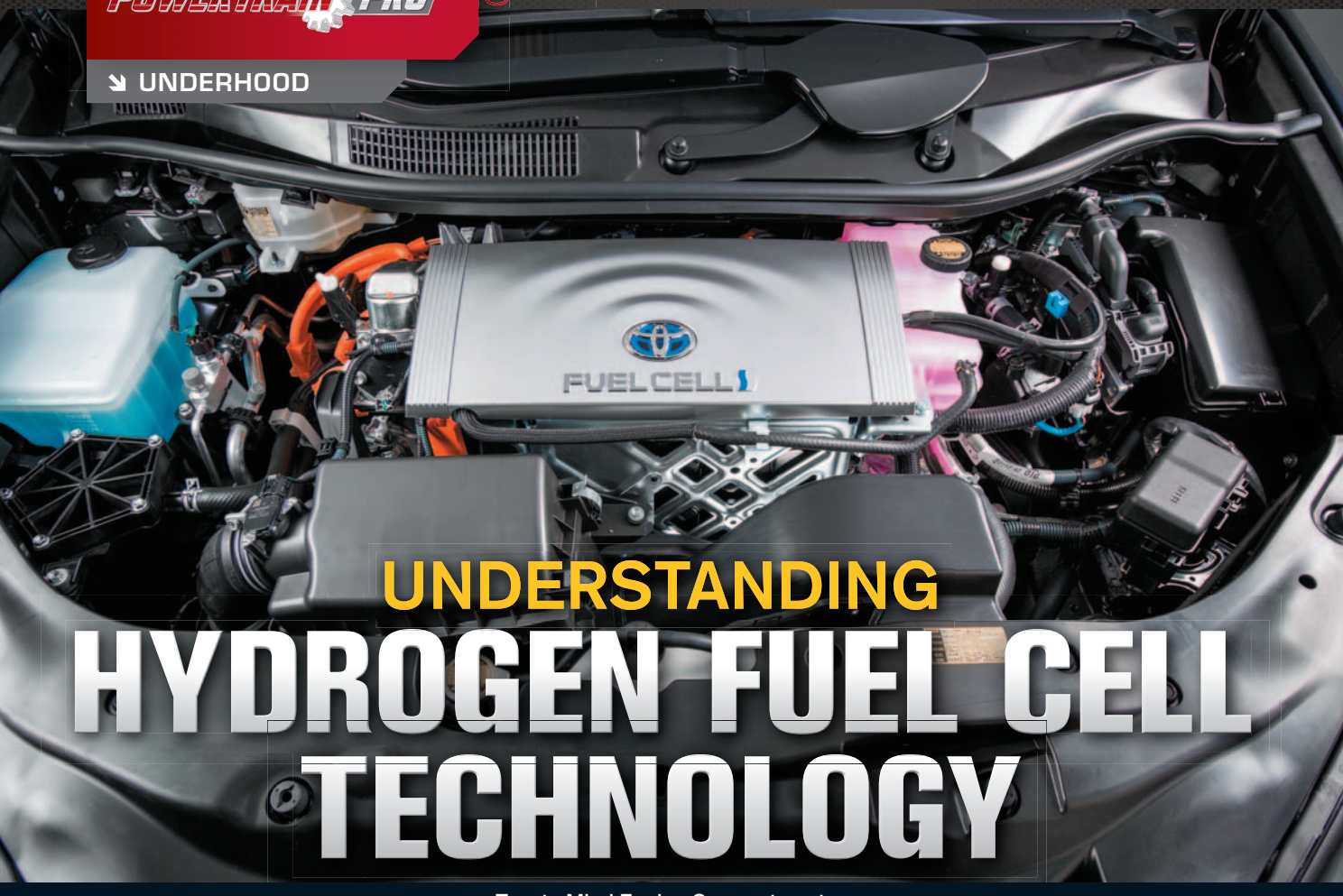


UNDERSTANDING HYDROGEN FUEL CELL TECHNOLOGY

Toyota Mirai Engine Compartment

TAKE A LOOK INSIDE THE TOYOTA MIRAI AND HYUNDAI TUCSON

BY **JEFF MINTER** | CONTRIBUTING EDITOR

Toyota was a leader in hybrid (HEV) and electric (EV) technology. Are they starting to move away from hybrids and beginning to embrace hydrogen fuel cells? Are other OEMs heading down this road? How does this technology work and how will it impact the aftermarket?

Wait! Don't roll your eyes and turn the page yet. This article isn't going to try to convince you that hydrogen fuel cell vehicles will be in your shop tomorrow. In fact, the data presented is likely to convince you otherwise. Does that mean you shouldn't care about fuel cell technology? There are similarities between current technology and fuel cell technology that make having a basic understanding of this technology very relevant. This article will focus on the following:

- Basics of fuel cell technology
- The current (slow paced) roll out of this technology
- Similarities between current vehicles and hydrogen fuel cell vehicles
- Basic facility considerations for shops that may eventually want to service vehicles that utilize lighter than air fuels (hydrogen, compressed natural gas [CNG], etc.)

To begin, let's take a look at some of the basics related to hydrogen fuel cell technology. Webster's Dictionary defines a hybrid as "something (such as a power plant, vehicle or electronic circuit) that has two different types of components performing essentially the same function." By that definition, a hydrogen fuel cell vehicle is technically a hybrid. A "traditional" hybrid vehicle is considered a hybrid because it has two sources of power. Those sources of power are the internal combustion engine and the high voltage battery. A fuel cell vehicle also has two sources of power: the high voltage battery and the hydrogen fuel cell. In essence, a hydrogen fuel cell vehicle is simply a hybrid that replaces the internal combustion engine with a fuel cell.

So what is a fuel cell? In simple terms, a fuel cell is a device that can use a combination of oxygen and hydrogen to create electricity. Polymer Electrolyte Membrane (PEM) fuel cells are currently the most common versions used for transportation. A PEM fuel cell contains a set of electrodes (an anode and a cathode) and an electrolyte, much like a typical battery. Unlike a battery however, the anode and

Photos: Toyota; Hyundai

cathode are separated by the PEM. To create electricity in a fuel cell, hydrogen gas is introduced. The hydrogen flows through a series of channels to the anode, where it reacts with a catalyst. The catalytic reaction causes the hydrogen to ionize. This means it separates the hydrogen molecule from the attached electrons. The result is a positively charged hydrogen molecule and negatively charged "free" electrons. The PEM that separates the anode from the cathode will only allow the positively charged hydrogen molecules to pass through. As a result of this selective passage, the electrons are left behind on the anode. The electrons develop a negative charge on the anode and the lack of electrons at the cathode (caused by the accumulation of the positively ionized hydrogen molecules) develops a positive charge. This charge difference should sound vaguely familiar, as it's very similar to the negative and positive terminals on a battery. As with a battery, if a circuit is provided to connect the negative and positively charged electrodes, electrical current will flow. In essence, a hydrogen fuel cell is a generator with no moving parts. The fuel for the generator is hydrogen and the exhaust emissions are limited to water vapor (H2O).

Hydrogen fuel cell vehicles have been in the press a lot in recent years. This may leave you wondering how many fuel cell vehicles are currently being sold in the United States, and what impact that may have on your future business. Currently, there are really only two fuel cell vehicles that are relevant to this discussion. Those two vehicles are the Hyundai Tucson Fuel Cell (introduced in 2014) and the Toyota Mirai (which, at press time, was planned for release in very late 2015).

While the Hyundai Tucson Fuel Cell is marketed as the first "mass produced" fuel cell vehicle, it's very limited in availability. In fact, you can't even buy this vehicle in the United States if you wanted to. Currently, the Tucson Fuel Cell is limited to three-year, 36,000-mile leases with no option to purchase. Even given those limitations, the bragging rights for this vehicle is that Hyundai has delivered over 75 (no that's not a misprint!) in the U.S. through September 2015. That's not exactly a number that would make you scramble to get ready for them in your shop, especially since they'll be under warranty throughout their lease!

The Toyota Mirai will change things slightly. It appears this will be the very first hydrogen fuel cell vehicle to actually be sold (versus leased) within the United States. That being said, the area potentially impacted will still be very small. These vehicle sales will likely be limited to the Southern California area (as has been the case with current leases) due to the current hydrogen fueling infrastructure and incentives for the automotive manufactures.

So why the discussion?

You may be wondering why you should care about fuel cell vehicles if you're unlikely to see them in your shop in the foreseeable future. It is not the fuel cell vehicles — at least not yet — that you should care about, but rather the technology in these fuel cell vehicles. From a practical standpoint the battery, electric machine(s) and inverter technology used in fuel cell vehicles isn't much different than that used in current hybrid and fully electric vehicles. If you haven't yet embraced hybrid/electric vehicle technology, you are, quite frankly, falling further behind every day. According to the Alternative Fuels Data Center, there were 73 hybrid and/or electric models offered for the 2015 model year. That's an increase from just eight models in 2005, which is over an 800 percent increase!

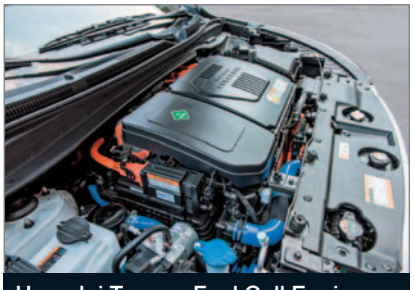
Let's take a look at the Toyota Mirai fuel cell vehicle for a comparison of technology. This is essentially an electric vehicle with an onboard generator in the form of a hydrogen fuel cell. I was surprised to find out just how much of the technology in this vehicle is a carryover from existing Toyota/Lexus hybrid vehicles. So what is being carried over?

- High voltage battery: The high voltage battery in the Mirai is a 244.8V NiMh battery. Toyota describes this as "an existing design" from a Toyota hybrid model. This battery consists of 34 modules, each rated at 7.2 volts. For those of you already familiar with hybrid technology, this should ring a bell, as those are the same specifications listed for a Toyota Camry hybrid.
- Electric Motor/Generator: Toyota states, "we chose an existing motor from one of our Lexus hybrid vehicles,

Hydrogen vehicle being fueled

Toyota Fuel Cell trim cover

Toyota Mirai at fueling station



Hyundai Tucson Fuel Cell Engine Compartment

Hyundai Tucson Fuel Cell vehicle being fueled

providing a history of reliability and reducing overall cost." While this component is more difficult to directly correlate to an existing make/model, the re-use of existing technology further highlights the ability to use existing diagnostic processes.

- Power Control Unit (PCU): While this unit appears to be unique to the Mirai, Toyota specifically states that it is based on the PCU found in the Prius.
- Inverter/Converter: Again, this unit appears to be unique to the Mirai with similarities to existing Toyota/Lexus hybrids. The unit is listed as a 4-phase boost converter allowing the battery voltage to be stepped up to approximately 650V. Much like the Prius (and other Toyota/Lexus models), this boosted voltage allows more power to be delivered from the electric machine when under peak demand.

So, what does all of this mean for shops looking to prepare for the future? To start, your technicians need training, but not for hydrogen fuel cell vehicles (at least not yet). The hydrogen fuel cell related training I'd consider relevant at this time is for the electric drive system. While the hydrogen system is interesting and makes great headlines with 10,000 PSI storage tanks and water as the only emission, getting training on that simply isn't practical. These vehicles will likely be very limited in number and will be under warranty for the foreseeable future. In fact, for the "lease only" vehicles, they will never be out of warranty. That means by the time you will see these vehicles in your shop (if you ever do), the hydrogen-related systems are likely to look much different than they do today. The electric drive portion, however, is relevant today because of the connections to hybrid and electric vehicles.

Hydrogen warning label

Hyundai Tucson Fuel Cell hydrogen tank fueling port

Your action plan

At a minimum, your technicians should receive high voltage systems safety training. Limiting training to that level, however, significantly reduces your shop's potential. I'd recommend going well beyond the basic safety training. In fact, I'd even recommend going well beyond the OEM training provided for hybrid and electric vehicles. To really prepare for the future, you should look into getting your technicians trained on the two major electric components that are most likely to experience problems — high voltage batteries and electric machines (motor/generators). These are both components that are destined to eventual failure due to normal wear and tear. Equipping your technicians with the knowledge and equipment to accurately diagnose these components both at the gross failure stage and ideally at the early/intermittent failure stage will help set up your shop for long-term success and will likely help set you apart from the dealership. In addition, you need to consider training your service advisors/managers on these vehicles to ensure they have the knowledge to explain the problems and related repairs to your customers.

The last thing I'd recommend considering when it comes to the potential for servicing hydrogen fuel cell vehicles is your facility. While there isn't a reason to start planning renovations today to accommodate vehicles you're unlikely to see tomorrow, it is something you should keep in the back of your mind. The biggest thing to consider is that current repair facilities are virtually all set up to handle fuels that are heavier than air. If you look around your shop, you'll notice that all potential ignition sources are at least 18 inches from the ground (provided your facility is up to code). This was done because gasoline vapors can collect at the ground level. When looking at fuels such as hydrogen, however, this scenario changes. Hydrogen is actually the lightest element in the periodic table. If hydrogen was to leak from a vehicle in a service facility, it would accumulate near the ceiling, not the ground. So, walk out into your shop and look up at the ceiling. Do you see anything within 18 inches of the ceiling that could serve as an ignition source? Anything such as a light fixture, heater, fan, even a junction box could be a danger.

Of course, you're probably thinking with the limited number of hydrogen fuel cell vehicles likely to be seen in the aftermarket this consideration isn't worth worrying about. Keep in mind there are other fuels that are also lighter than air. One such fuel that has been making a comeback lately is Compressed Natural Gas (CNG). Much like hydrogen, a leak from a CNG-fueled vehicle can cause fuel to accumulate near the ceiling rather than at the floor. Depending on the level of service being done on these vehicles (hydrogen or CNG), whether vehicles are stored inside overnight, etc. the facility requirements change. If you are considering a new facility or a major renovation/expansion of your current facility, this may be something you want to keep in mind during the planning process. Be prepared, as the required modifications may include a significant expense. However, the alternative of servicing these vehicles without the proper modifications may expose you to significant liability.

The future of hydrogen fuel cell vehicles and the potential impact they will have on the aftermarket repair industry is still somewhat uncertain. Change within our industry, however, is virtually guaranteed and everyone will need to adapt to avoid becoming obsolete. Just try to avoid being distracted by the media hype when making your plans.

JEFF MINTER
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Jeff is currently serving as the service director for a group of dealerships in the heavy duty vehicle industry. He is an ASE certified Master/L1/L3/F1 technician with OEM training from numerous manufacturers.

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ELECTRICAL

Lithium 18650 cylindrical battery cell

LITHIUM BATTERY TECHNOLOGY

APPLICATIONS IN HYBRID, PLUG-IN HYBRID, ELECTRIC AND FUEL CELL VEHICLES

BY **MARK QUARTO** | CONTRIBUTING EDITOR

The Lithium-Ion family of battery technologies has quickly become the center stage product in the advanced technology vehicle market. Although Nickel Metal Hydride (NiMH) continues to be a staple product in the Hybrid Electric Vehicle (HEV) market, when it comes to applications that need additional energy storage for extending vehicle range, NiMH is not competitive with the Lithium family of battery technologies. Plug-In Hybrid (PHEV), Battery Electric Vehicle (BEV) and Fuel Cell Electric Vehicle (FCEV) applications need the additional capacity storage capability, coupled with the smaller weight and packaging of Lithium to provide increased vehicle fuel economy and/or range.

Why use Lithium?

As the advanced technology (electric propulsion) systems continue to populate the vehicle market, the Lithium family of battery products becomes the choice of manufacturers that have entered the market in the past 4-8 years, due to its superior energy storage capability. For the foreseeable future, Toyota/Lexus continues to enjoy the majority of the advanced technology market and the battery technology utilized in their vehicles is predominately NiMH. One of the primary reasons for utilizing NiMH is that it is a very stable chemistry (not prone to thermal events or problems with overcharging), there is a long record of use in industrial applications and it is a known quantity that is predictable in its operating and failure modes.

Lithium products are manufactured with two basic formats — cylindrical 18650 and pouch. The 18650 cell is slightly larger than a AA battery and the pouch style cell can be manufactured in many different size configurations, dependent upon application.

When compared to NiMH, the Lithium family of products has significant advantages when considering capacity, mass (weight), resistance and size. However, since Lithium products must be controlled within a much narrower charging/discharging voltage range, this becomes a disadvantage for systems due to the cost of adding sophisticated control systems. When considering the cost of the hardware and software systems that are required to monitor and control cell performance, Lithium battery systems cost can be significantly higher than NiMH.

Lithium battery families

Unlike NiMH, Lithium technology has numerous family categories. Each of these categories offer varied energy (capacity) and power characteristics. The primary families utilized in the automotive or medium/heavy duty market as of this printing are:

- Lithium Cobalt Oxide
- Lithium Manganese Oxide
- Lithium Manganese Cobalt Oxide
- Lithium Iron Phosphate
- Lithium Nickel Cobalt Aluminum Oxide
- Lithium Titanate

Each of these chemistries has a different characteristic (power, energy and discharge performance). The electrolytes can be significantly different, although each uses Lithium Salt as a basic element. Each may have different additives in the electrolyte that mitigate aging, permit enhanced performance, fire retardants, etc. Each of these additives will affect how the cell performs and its longevity. Unlike Lead Acid and NiMH batteries, which enjoyed stable and predictable performance metrics, the growing number of Lithium products with widely varying performance metrics will require technicians to more thoroughly understand failure modes and specialized diagnos-

Photos: Mark Quarto

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tic techniques. A quick internet search on the Battery University website can provide more detail on each chemistry.

The advantages of Lithium, when compared to NiMH are in the areas of mass and energy (how much capacity can be stored for a given size and mass). To assist with clarity, a comparison of the Toyota Prius (NiMH) and Hyundai Sonata Lithium battery packs' applications has been provided. Listed below are some of the key metrics of Lithium as compared to NiMH. To help understand the comparisons (written in engineering "speak") here are some definitions:

- W-hr./kg = Watt Hours per kilogram: How much energy can be stored for the given mass (weight) of a battery cell
- W-hr./L = Watt Hours per Liter: How much energy can be stored for the given physical cubic size of the battery cell

The comparisons of the NiMH and Lithium are very clear. In the examples, the Lithium cell voltage is 3.8 volts when compared to NiMH with 1.2 volts. Therefore, Lithium can achieve voltage levels with fewer cells. When comparing W-hr. per kilogram and Liter, the comparison is just as stellar. Lithium has approximately 2.60 – 3.50 times the W-hr. per kilogram (1 kilogram = pounds) so, it stores more energy for a given mass. And, Lithium has approximately 1.50 – 1.80 times the W-hr. per Liter, so it stores more energy for the physical cubic space it occupies. There are incredible differences and advantages for Lithium when compared to NiMH. Therefore, more battery cells can be placed in series and parallel to produce modules with much higher voltage than the traditional NiMH prismatic or cylindrical battery modules/sticks, such as a 32V Lithium module used in a Hyundai or Kia hybrid vehicle.

Lithium pouch battery cell

NiMH vs. Lithium Module Voltage & Energy Cell Comparisons			
Cell Type	Voltage / Cell	#of Cells	Cell Capacity (Amp-Hrs)
Hyundai Sonata Module - Lithium	3.8	72	5.3
Toyota Prius Module - NiMH	1.2	168	6.5

NiMH vs. Lithium cell comparison

Lithium technology: Basic vehicle level diagnostic application

With six basic Lithium chemistries currently used in the market, and more on the way, it is vital that technicians understand why it is important to know the differences between the technologies and how each will react to testing and the associated diagnostic results. Although the OEMs provide some basic information on how to test the vehicle battery packs by using the scan tool, the testing necessary for determining the actual battery condition (power and energy testing) goes far beyond the scan tool. To test a vehicle battery for power and energy, the testing protocol would begin with using the standard OEM process of acquiring DTCs, Freeze Frame Data, etc. From this point there may be some limited testing that can be performed through the scan tool, although most OEMs don't support enhanced battery pack testing via scan tool CAN output test messaging.

After the initial DTC, Freeze Frame and output tests have been performed, the technician would typically determine whether or not to remove the battery pack for replacement or, if the OEM supports battery pack internal repair, replace large block components of the battery pack. However, there are additional tests that can be performed to assist the technician in determining battery pack power and energy. The additional tests use the scan tool and other off-board equipment to test and determine if the battery pack needs to be "tuned" to ensure good performance and longevity.

Using only a scan tool, the technician could perform a battery stress test. A stress test is a testing method that our company (and some OEMs) have been using since the mid-1990s to determine if a battery pack has a reduction (or fade) in power or energy. A stress test is similar to a test performed by a cardiologist on the heart of a patient. In a stress test performed by a doctor, the patient is placed on a treadmill that will gradually increase the load placed on the heart, by changing tread angle and speed. An electro-cardiogram and an echo-cardiogram measure heart activity to determine how well it performs under load. In automotive diagnostic terms, the vehicle is driven with a specific drive cycle process to stress the battery pack for determining an overall performance and state of health (SOH) under load. This process is something currently not available via vehicle diagnostics (i.e., vehicle controller functional tests available through the scan tool). By documenting data before and after the stress test, and comparing and contrasting data, a solid picture of battery pack SOH can be determined.

NiMH vs. Lithium Battery Cell Energy Comparisons		
Cell Type	NiMH	Lithium
Gravimetric Density (W-hr/kg)	46	**120 - 160
Volumetric Density (W-hr/L)	170	**250 - 320

NiMH vs. Lithium density comparison

Hyundai-Kia Lithium battery module

Also, the stress test can be used to evaluate battery pack SOH even if there are no DTCs. In more recent years, there are customers who are routinely bringing their hybrid vehicles to a repair business only because the fuel economy has dropped and/or there is a hesitation only during a more aggressive acceleration. This is a classic complaint for a high voltage battery pack-related power or energy problem. However, using a stress test is extremely hard on a battery pack. Therefore, prior to performing a stress test, you will need to know how to use the proper process and, more importantly, how to interpret the scan tool data once the test has been completed. This will ensure that no additional stress testing will be necessary that could lead to over-stressing the battery pack.

The stress test information (coupled with any DTC and Freeze Frame data if available) would provide enough information to determine how the battery pack performs during an extremely loaded condition. This would assist the technician in determining whether or not the battery pack would need to be removed for replacement or testing and

rebuilding. If a shop is specializing in HEV/BEV repair, testing and rebuilding are additional steps that would require additional equipment and training to ensure that the battery pack is properly rebuilt, balanced and has adequate power and energy.

Lithium technology: Specific diagnostic application

When working with the Lithium families of battery chemistries and performing stress testing, rebuilding or testing it is vital that a technician know which Lithium technology is being used in the vehicle. For example, when working with the Lithium Manganese battery families, the diagnostics and any stress testing would yield data that would look very different from a Lithium Iron Phosphate battery family, due to how the discharge voltage signatures are generated by the battery cells. For example, the Lithium Manganese families have a very linear discharge signature (similar to a Lead Acid battery) vs. the Iron Phosphate families, which discharge with an extremely flat discharge signature. This means battery capacity may or may not be easily interpreted for use in diagnosing battery pack module condition through recording battery module voltage data on the scan tool. Therefore, knowing how specific battery chemistries behave is critical in knowing how to interpret scan tool of discharging equipment data. Other battery chemistries have signatures that fall in between the flat and linear discharge voltage signatures. Whether a vehicle is HEV, PHEV, BEV or FCEV powered, is vital that technicians understand the performance characteristics of the Lithium families (and NiMH) being used by the OEMs and how to interpret whether or not the performance of the battery pack is acceptable (whether a DTC is present or not).

Other things to consider

Although both NiMH and Lithium technologies suffer from the effects of over temperature, cells drying out, etc., most of the Lithium technologies have one major disadvantage when compared to NiMH. Lithium must be kept within a very specific operating band during charging cell damage, and thermal events can occur. This means that expensive electronic circuits and software controls must be used within the battery pack system to maintain cell operation within these bands and for maintaining the optimum top-balancing voltage. This results in a much higher cost to implement Lithium into a vehicle system when compared to a NiMH system. There are some Lithium families that are much more tolerant to overcharging than others (such as Iron Phosphate) when compared to other chemistries that may have narrower operating boundaries. Although most HEVs today continue to utilize NiMH battery technology, all mainstream PHEV and BEV programs use the Lithium technology to take advantage of its significant advantage of energy storage (mass and volume) when compared to NiMH.

In summary, it will be vitally important that technicians begin to learn both NiMH and the Lithium family of battery systems. As battery technology continues to evolve, it is inevitable that there will be an overwhelming number of battery families and chemistries used to help the OEMs meet the target of 54.5 mile per gallon fuel economy and lower CO_2 emissions that must be achieved by 2025. Lithium battery systems will be an integral technology of how the OEMs reach these mandate targets. The HEV and PHEV vehicles are becoming a higher percentage of OEM product offerings, and the BEV and FCEV have now become more than a mere novelty in the OEM vehicle product lineup.

The time to start embracing the technology is now while there is still time to learn it without the pressure of trying to learn it on the fly. Wouldn't it be easier to start learning these systems now rather than waiting until the first advanced technology vehicle rolls into your service bay?

MARK QUARTO
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TECHNOLOGY
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RISING TO THE CHALLENGE

The team from Wheat Ridge poses with their entry in Detroit.

STUDENTS FROM WHEAT RIDGE HIGH SCHOOL DID JUST THAT – AND MORE!

BY **PETE MEIER** | DIRECTOR OF TRAINING

Last April, more than 1,000 college and high school students descended on the Motor City to participate in a very special competition, the Shell Eco-marathon. For more than 30 years, the competition has challenged the minds and talents of future automotive engineers to push the limits of automotive design. Not with speed or endurance as the final goal, but fuel efficiency as the primary objective. The team with the best fuel efficiency (miles per gallon equivalent) wins.

The 2015 event marked the 9th edition of the Shell Eco-marathon Americas and the first year for the event in Detroit. It was one of four world events held in 2015, with similar competitions in Europe, South Africa and Asia. The Americas event hosted teams from 100 different colleges and high schools (as the name suggests) from North, Central and South America. And while there were awards presented for off-track accomplishments like vehicle design and technical innovation, the real bragging rights would come from victory on the 0.9 mile track that wound through downtown Detroit, starting and ending in front of the Cobo Center.

There are two basic classes teams could enter: Prototype or Urban Concept. Prototype entries were designed primarily for ultimate efficiency and design, and can have three or four wheels. Urban Concept is a bit more challenging, requiring four wheels and all the related accessories needed to be "street legal." In addition to the two basic categories, each class is further broken down into the type of propulsion system used: gasoline, diesel, hydrogen fuel cell or battery/electric.

The high mileage winner was the team from the University of Toronto, besting defending champs from the Université Laval, and posting a winning efficiency equivalent of 3,421 miles per gallon in the Prototype Gasoline class. And while these two schools have been close competitors

Photo: Shell

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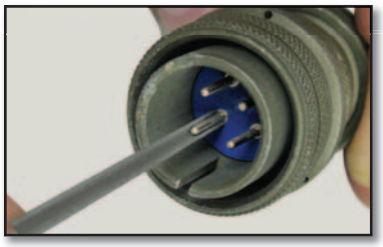

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the last several years, there is an even more exciting story I'd like to share with you.

A little town in Colorado

Roughly 1,300 miles to the west of Detroit is the small city of Wheat Ridge, a suburb of Denver, Colo. Sixteen-year veteran Wheat Ridge High School teacher and coach, Charles "Chuck" Sprague has been teaching drafting for more than 13 years and over that time, and with a little help from good friend Doug Gallagher, the projects his classes have taken on have continued to increase in scope and challenge. A little more than a year ago, Sprague took on the school's STEM/Engineering program. STEM stands for "Science, Technology, Engineering and Math" and is a whole lot more than the shop classes we took when we were kids. The program was brand new for the 2014-2015 school year, and Sprague tells me that, "I wanted to do a completely 'outside of the box' type class."

Many successful high school engineering programs use already created project kits, and Sprague admits that these kits are excellent ways for students to learn fundamental engineering principles. But that wasn't quite what Sprague had in mind for his students. "I wanted to get away from that and start at ground zero. I wanted to show the students the entire process from beginning to end of a large open-ended project."

But what kind of project?

Sprague tells the story this way: "Doug (Gallagher), along with Dr. Ron Rorrer from the University of Colorado-Denver asked if they could speak to my class to see if they would be interested in the Shell Eco-marathon. If there was enough interest we would proceed with their help and create a partnership between Wheat Ridge and UCD. If there wasn't enough interest then it wouldn't happen. After their presentation was done, 16 students' hands shot straight up in the air, and we were off and running with this very unique and new model between a high school and a university."

"As a side note, the students came in the next day and asked me what they do next. I looked at them shrugged my shoulders and told them, 'Well, you guys decided that you wanted to build a car from the ground up. I am here to help answer questions and guide you when you need help. But you all voted to do this project. So you better start working on it.' There was total silence as they waited to see if I was kidding. I just sat there."

The #218 on the streets of downtown Detroit and on its way to a win!

Wheat Ridge teammates begin laying out the carbon fiber body mold.

University of Colorado – Denver's Doug Gallagher shows the students how to use the CNC milling machine.

Photo (Top): Shell, Photo (Middle and Bottom): Wheat Ridge HS and Charles Sprague

The idea of building a competitive Prototype-class, hydrogen fuel cell-powered car from the ground up may have sounded exciting in the beginning to the 16 young men and women who would be taking on the challenge. Little did these students (some just starting their high school adventure and some entering their last year) know just how much of a challenge it would be, nor could they anticipate the obstacles they would have to overcome on their way to Detroit.

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The next 8 months

"The design process starts on the computer," shares Sprague. "Then the students have to take these designs and manufacture the molds and additional components (for the car). We also created small engineering groups within the class with each responsible for a different section of the car. They had to learn to work together just as they would in a small company, complete with collaboration, brainstorming sessions, problem solving and even resolving personality conflicts once in a while."

"Designing it on a computer and then trying to build it doesn't always work quite the way you think," observed Gallagher. That was OK for most of the students, though, since none of them had any prior experience in doing either. And even though the design segments were separated within the group, everyone helped everyone else.

"It was a team effort all the way around," according to Sprague.

The design phase took the students a full two months to complete. The next phase was to share those designs with computerized milling equipment, starting with the building of the car's body using carbon fiber as the shell. Then freshman Jacqueline Pedlow helped lead the team in this phase of the project. She explained the process for making the body mold in a live video interview I did with the students still attending Wheat Ridge.

Even though students were divided into divisions to handle different parts of the build, everyone took part in every phase. "It was a true team effort," according to Sprague.

Photo: Wheat Ridge HS and Charles Sprague

It starts with large foam blocks used to build a mold slightly larger than the designed body. A CNC mill is used to cut the foam blocks to the exact shape of the body — in sections and stacked — that becomes the mold for laying out the carbon fiber material. This final foam mold is sanded and smoothed. Any imperfections are filled and the mold is sanded again to prevent any bumps or surface irregularities in the final product.

The mold is then coated with a wax and release agent before the first carbon fiber cloth layer is applied. An epoxy hardener is applied to each custom cut sheet before it is placed on the foam skeleton. After all the layers are applied, a release sheet and breather sheet is then placed over the body, and the whole thing is placed in a vacuum bag and a vacuum applied. The mold sits for 24 hours to cure and then the hardened carbon fiber is popped from the mold for assembly.

The entire milling of molds and carbon fiber process took the students approximately three months to complete and then it was on to the actual build. If you've ever built your own race car, hot rod or restoration, then you have some idea of what these kids had in store for them. They had to design and build the chassis components, manufacturing what they couldn't outsource. The vehicle's electrical and propulsion system had to be designed. And the entire thing had to be assembled by hand.

With the goal of energy efficiency, every aspect of the design had to be weighed against its impact on overall weight and aerodynamic impact. Even the selection of the driver had to be carefully considered, with those duties eventually falling on the shoulders of Nicole Ortega, currently a senior at Wheat Ridge and member of the team for their 2016 run. How did she become the driver? "Girls' weights don't tend to fluctuate as much as guys do in their high school years," Ortega told me. That makes sense, and just shows how much thought and energy these young students were putting into their project.

The entire project took roughly eight months to complete. Eight months of late nights, long weekends, lots of fundraisers, corporate presentations and overcoming one challenge after another. Unfortunately, there would be additional obstacles placed in their way.

One week to go

With the car built and one week left to go before the competition in Detroit, test runs began. The team was limited to testing in the school parking lots and they weren't sure how that would relate to the hills and turns they would face on the downtown Detroit streets. But Sprague shares the story of the last major challenge his team had to overcome.

"We tested the car out front (of the school) between 10-11 p.m. with only the parking lot lights to light our oval course about three days before the competition. We were checking the speed and we weren't going to be able to finish the track in Detroit in enough time (seven laps of the 0.9 mile course had to be completed within 25 minutes). So the next morning I started calling around to see if I could locate additional fuel cells, maybe even buy one if needed. The kids put so much into it, the car was ready, but we weren't getting enough power."

"These cells aren't something you can buy off the shelf. It normally takes a few months to get one to you, let alone two days. I called the folks at Horizon (Horizon Fuel Cell Technologies) in Chicago, told them what we're doing, to see if we could get more power from our fuel cell. They had their tech team talk about it, but said he didn't think he could get us a new one. About 15 hours before we were scheduled to fly out to Detroit, the Horizon rep called me back and said, 'You're not going to believe this. I found you a fuel cell – in the Czech Republic.' If we could pay for the fuel cell in the next two hours, they would drop ship it direct to Detroit and it would arrive the second day we would be there."

"It took a little doing, but we came up with about $10,000 with help from the University of Colorado-Denver, and ordered the fuel cell. Later I got an email saying it was held up in Customs because it didn't have the right number

on it. Several late night calls to Customs finally got the fuel cell released and it began the trip to Detroit, via Atlanta. Severe weather over the flight route between Atlanta and Detroit delayed the shipment even more."

"To this point, the students didn't even know a new fuel cell was coming, let alone all the obstacles that had to be overcome to get to this point. The students' reactions when it arrived ranged from disbelief to shock that we all of a sudden had a new fuel cell, and finally great big smiles and fist pumps as they began changing out the power source. It showed up the next morning, and we spent half a day installing the new fuel cell in the car."

Well, the team came in knowing that they may not complete the required course in time with the old cell. Would the new one do better? No time left to test and find out.

TIme to run

Consider that, of the more than 100 teams that originally entered, only 89 of them passed inspections and were allowed on the track. Consider that the Wheat Ridge team was composed of high school students with no experience in designing and building anything, let alone a hydrogen fuel cell-powered car. Consider that the team had just spent hours on a last minute fuel cell change that they had not had a chance to test and had no idea of what performance to expect from it.

This was the stress load on the shoulders of these young men and women as the #218 Wheat Ridge High School entry made it's way to the start line. But that stress would soon be relieved as the entry that started as a dream posted a best run efficiency of 151.5 miles per kilowatt-hour, nearly 40 m/kwh better than their second place competitor. That's right! The young team from a small town in Colorado placed first in the Prototype Hydrogen category and went home with a $2,000 check, a huge trophy and bragging rights of having come to Detroit and taking it all their first time out.

What did the team do to celebrate? If you would believe now Junior Nate Rockenfeller, they hit the Hard Rock Café and flirted with the waitresses. But I think Sprague tells a more accurate tale when he told me that "The competition was stressful. Right after we won there was a sense of relief; everyone was quiet and walked back to the paddock. We were all pretty well spent, went back to the hotel and then out to eat. Once we were cleaned up and out eating, their energy returned. The students started laughing, telling stories and having a great time, once again as a team."

Will the team be back to defend its title in 2016?

Sophomore Casey Kramer, who dreams of designing cars one day with a goal of earning a degree in mechanical engineering at Colorado State University, filled me in on the goals for the 2016 competition. "We are building two cars. One will be almost the exact same as the 2015 car and competing in the same category. The second entry is for the Urban Concept category, a street legal car (miniaturized) complete with windshield wipers, headlights and taillights. Both will be powered by hydrogen fuel cells."

To say this is yet another ambitious project would be an understatement. Fielding an Urban Concept hydrogen powered entry and getting past inspection would be a victory for these young engineers all on its own, considering that last year no fuel cell powered entry made it past this point. But having had a chance to speak to these young competitors, I have a feeling that their entries will do a lot more than just pass inspection. I have a feeling they'll be coming home with two more trophies for the school's display case. We at *Motor Age* wish them the best!

Want more information on the school's success, how you can support their efforts or how to start a similar effort at your local school? Contact Sprague at clspragu@jeffco.k12.co.us.

PETE MEIER
DIRECTOR OF TRAINING

Pete Meier is an ASE certified Master Technician and sponsoring member of iATN. He has over 35 years practical experience as a technician and educator, covering a wide variety of makes and models. His primary goal is to bring working techs the information they need.

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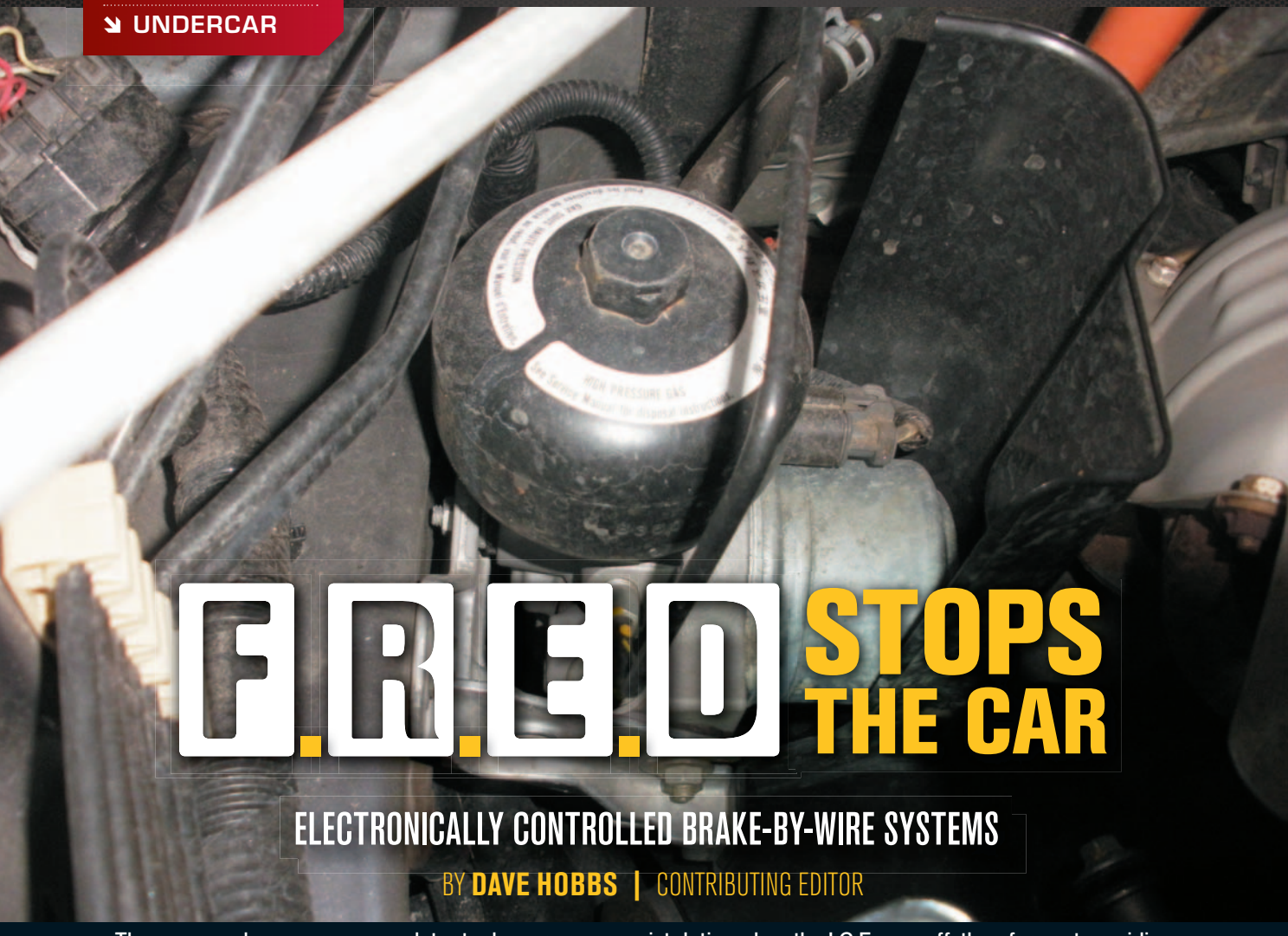


F.R.E.D STOPS THE CAR

ELECTRONICALLY CONTROLLED BRAKE-BY-WIRE SYSTEMS

BY **DAVE HOBBS** | CONTRIBUTING EDITOR

The pump and pressure accumulator took over power assist duties when the I.C.E. was off, therefore not providing vacuum. The ABS worked in cooperation with a device called "creep assist" to prevent the vehicle from rolling when stopped in traffic during idle stop mode.

Any tech who works on modern vehicles knows that butterflies-in-the-stomach feeling when we raise the hood of a vehicle and see some components that look so foreign and bizarre to us we shake our head and think, "I hope I never have to work on that!" Inevitably there is a "F.R.E.D." (Frustrating Ridiculous Electronic Device) controlling the overly complex system making everything even more intimidating. With throttle-by-wire being a standard system for several years, we've gotten over the butterflies on that system, but the feeling still exists for many techs when it comes to brake-by-wire systems. This article will help you move past your butterflies as the industry moves forward with making yet another 'drive-by-wire' subsystem commonplace.

Why brake-by-wire?

Electronically-controlled brake-by-wire is a means to stop the vehicle for:

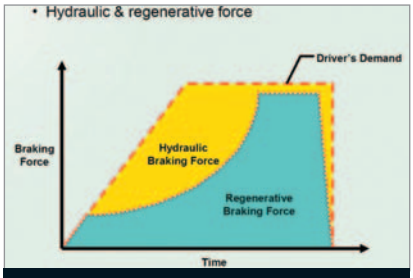
- Adaptive cruise control
- Self-parking systems
- Autonomous vehicles (self-driving)

Adaptive cruise control systems have been around for about a decade, and the self-parkers are approaching out-of-warranty times. Early experimentation with autonomous vehicles has shown to be very promising to help avoid collisions and increase customer convenience. It's even speculated that unless your planned retirement from auto repair is in the next decade, you might very well see customers' cars show up at your shop for preventative maintenance services at 2 a.m. (when the vehicle is not being used) via an autonomous trip scheduled by you and your customer. Good luck getting good lube techs to work the graveyard shift!

Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs) were some of the first to sport this new form of brake hydraulic system. Brake-by-wire can take into consideration:

- The need for regenerative (regen) braking requires that conventional friction brakes on the drive wheels be limited in order to maximize the effectiveness of regen braking.
- HEVs extend fuel economy in several ways including Internal Combustion Engine (ICE) auto stop when the ICE shuts off to save fuel when the vehicle stops and on some models while driving. Without the ICE running, there is no source of vacuum for conventional vacuum power-assisted braking. EVs do not have an

Photo: Dave Hobbs



When a driver leaves his/her foot on the brake pedal of a HEV / EV too long or presses with a great deal of force (panic / ABS type stop), the Hybrid ECU and Skid Control ECU shift the responsibility of increased field current into the stator windings inside the MG (Motor Generator) to provide regenerative braking to the vehicle's brake-by-wire friction braking system. The transition is transparent to drivers.

Photo: Toyota

ICE to begin with, so vacuum-assisted anything is out unless you wish to reduce the EV's range further by using valuable electrical energy to run an electric vacuum pump.

Base brake system mechanical friction components – nothing new!

No matter how much complexity there seems to be in any of the HEV braking systems, the mechanical components that actually stop the vehicle are fairly standard and the ABS/TSC/Stability control sensors and hydraulic controls (solenoids and low pressure pump) are also fairly straightforward.

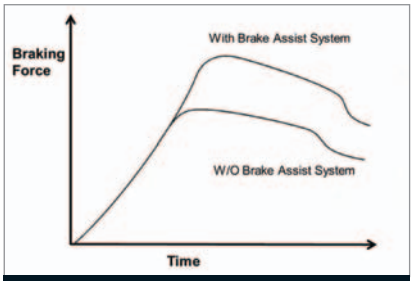
Regenerative braking

Regenerative braking (regen) uses the inertia of the vehicle to generate electricity to recharge high voltage batteries. This is accomplished by using the kinetic energy of the vehicle. Kinetic energy is energy of motion; the kinetic energy of a vehicle is what it possesses because it is moving. In a conventional vehicle, the kinetic energy is transferred into heat, through the mechanical braking process into the brake pads and rotors. This heat, which is also energy, is dissipated into the atmosphere and is lost. Regenerative braking captures the kinetic energy to use later in the form of electricity to power various motors. This energy is stored in the high voltage battery pack.

The regenerative braking action starts as soon as you take your foot off the accelerator pedal. Regenerative braking will only start when the computer or electronic control unit (ECU) detects the throttle is not depressed. However, the mechanical brakes do not engage fully during normal braking. This is controlled by a computer system or electronic brake controller (EBC) on most hybrids. This process is called series regeneration. The computer will determine how much the mechanical brakes should engage until a pre-determined speed is attained (typically around 4 to 10 MPH). At this point, the mechanical brakes will be the primary brake. This minimizes the amount of energy lost due to heat/friction in the mechanical braking system and maximizes the amount of energy recaptured and stored in the HV battery in the form of electricity.

Honda — simplicity (kind of)

Honda HEV braking systems are not as 'brake-by-wire' as most other HEVs. Going for simplicity, they still utilize a connection between the foot on the brake pedal and the hydraulic brakes. One noticeable variation on a Honda HEV braking system is the presence of a pressurized accumulator similar to those used on conventional non brake-by-wire ABS-equipped vehicles a few years ago. In the late 80s/early 90s, the trend for many OEMs was to scrap the vacuum-power brake booster and conventional master cylinder and throw the function of the hydraulic base brakes into a combination master cylinder and ABS modulator. An electric pump ran to provide power-assisted braking pressure increases from what the driver's foot could manually muster and a nitrogen-filled pressurized accumulator provided assistance to the power braking functions in case the electric pump could no longer provide power-assisted braking functions. These types of systems were call integral ABS systems. Most HEV/EV braking systems borrow some of these components, and Honda is no exception. However, the business of completely switching from hydraulics brakes to electric regen brakes is not used. In order to get more of a Honda HEV's braking turned into fuel saving regen braking, the ICE on most Honda HEVs uses a cylinder deactivation system to reduce the effect of engine braking on the vehicle. This provides more stopping opportunity to the regenerative braking system on Hondas, which spells increased fuel economy.



Brake Assist Systems are popping up on new vehicles all over and not just the true full blown brake-by-wire vehicles. You might consider them a little taste of 'brake-by-wire' for the rest of us. OEMs have studied drivers of all ages and discovered something alarming about their braking habits in emergency stopping situations; close to ½ of all drivers can't / won't do hard braking right! Either they don't have the strength or they don't have the reflex reaction ability to apply the brake pedal hard enough / apply the brake pedal long enough to get the vehicle stopped as fast as it has the capability to stop. So with the ABS module acting as 'big brother' when it sees the brake pedal stroke sensor applied with a very initial quick and hard apply that module concludes that conditions are present for a maximum braking scenario / emergency stop. Now if you let up slightly on the pedal a form of brake--by--wire kicks in to continue with a very hard and more prolonged braking occurrence. BAS has proven to get vehicles stopped faster and therefore prevent accidents!

Photo: General Motors

Toyota Prius brake-by-wire operation

Toyota makes up the overwhelming majority of HEVs out there, with the Prius being the most popular model in the corporate line. The Prius has classic sophisticated brake-by-wire with an electronic brake system in combination with hydraulics. It uses a pressure transducer and stroke simulator to determine brake pressure. The stroke simulator also gives the driver a normal tactile feel. This system also has traction control and anti-lock

brakes. Gen II (2004-2009) and Gen III (2010-current) both have stability controls and BAS, neither of which are unique to HEVs or EVs.

Each wheel is applied the correct amount of braking individually. This is controlled by a brake actuator. It does not have a vacuum power booster.

The brakes are also operated by hydraulics when the vehicle is moving at less than 4 MPH and the ABS system is activated. Although the main hydraulic unit (called a brake actuator, and it is mounted behind the inverter) has a great deal of wiring going to it, it is NOT the module with the primary logic for braking. Containing the usual electric pump motor, solenoids and a pressure accumulator, it carries out hydraulic work for ABS/TSC/VSC as well as brake-by-wire brake apply. The Hybrid ECU, which controls HV battery charging and motor operation, monitors the battery control/monitor module and communicates with the skid control ECU.

Toyota skid control ECU – the real 'brains'

The skid control ECU module contains the inputs for wheel speed sensors, steering angle sensors and lateral/yaw inputs and then determines the correct amount of hydraulic friction brake application based on vehicle speed, ABS status, the pedal stroke sensor and HV battery pack state of charge. The skid control ECU module then commands the ABS hydraulic unit (brake actuator) to activate the pump and solenoids in order to apply a traction control like apply of the mechanical friction brakes. The Hybrid ECU, being part of this communications network (CAN), provides a command to the inverter/electric motor control module in order to provide a progressive apply of field current into the motor generator's stator windings. The more the current is applied to the stator windings, the more regen braking occurs. Because the friction braking system is so dependent on 12 volt power to the various modules and the brake hydraulic unit, a back-up 12-volt power supply (power supply containing 22 capacitors) is located in the rear compartment next to the 12-volt auxiliary battery to short-term supply power in the event there is a loss of power from the 12-volt auxiliary battery.

Preventive brake maintenance for hybrids

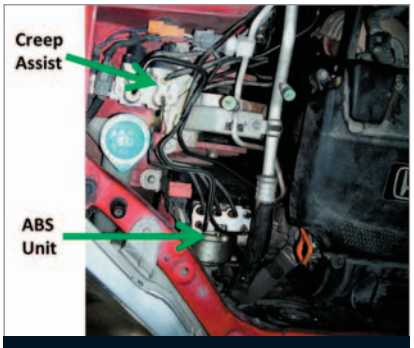
On any older vehicle, who hasn't applied a parking brake only to find that you're most likely the first one to operate it in several years? It sticks because of rust and corrosion in the cable, and you end up spending time getting it freed up and lubricated. With hybrid brake-by-wire, the regeneration function is so effective you'll likely see the brake pads last well over 150,000 miles. So what is there to do? Remember the parking brake that's seldom used and sticks? Think of HEV/EV service brakes that way. Instead of brake pad/shoe R&R along with rotor machining/replacement, you have the sticky/rusty component syndrome. The piston can stick in the caliper, the caliper's bushings/O rings get dry, etc. So everything you would do on a thorough brake job (lube bushings, push back caliper piston) would be a good idea to limber up the seldom-used service brake components on an HEV/EV. Ensure free movement of the caliper pistons and other hardware at least yearly. This is especially true in areas where road salt is commonly used. This is a very common problem with some Toyota Prius models because of the steel pistons used in early models.

Brake rotors are prone to become rusty as well and should have the rust/glaze removed with some Scotch Brite or equivalent to prevent brake noise.

It is not recommended to use vacuum bleeding on a hybrid vehicle. Pressure bleeding, however, is recommended with most manufacturers.

Safety tip: Keeping the hands clear!

Whether the pads are finally worn out or you are just doing a little PM on the front calipers, on many brake-by-wire vehicles, including Ford HEVs, you'll want to remember to deactivate the control of the system when working around the calipers. On some HEVs such as the Ford Escape, when the driver's door is opened, the self-check system is activated. On a normal ABS system, we've heard this self-check occur with a pump motor activation/solenoid cycling. OEMs have managed to quiet this function down from when we used to hear it at about 15 MPH years ago. On HEVs with brake-by-wire, OEMs don't want to wait until the vehicle is going 15 MPH before checking to see if the brake-by-wire system is working. As the door opens, chimes go off and other distracting noises to cover the sound of the pump turning on and solenoids being activated along with the front calipers being pressurized with a couple of thousand PSI. This self-test feature works great unless you are in the process of removing a brake bad from a dismounted caliper and the service advisor opens the door to get the odometer reading. In that case, your hand will be in a brake-by-wire vice and you'll be spending the rest of your day having hand surgery for the bones that were broken. As with any new system, read all you can, get all the training you can and practice all the safety procedures published by the manufacturer, because 'F.R.E.D.' is still taking more ground as we move closer and closer to the total drive-by-wire vehicle!



Not pictured are solenoids to prevent compression on the engine during coasting. If you eliminate the effects of engine braking you can put more stator field current into the MG (Motor Generator) to get more regenerative effect (saving fuel) whether coasting or pressing the brake pedal.

Photo: Dave Hobbs

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Dave Hobbs is a field trainer and training product developer for Delphi Product & Service Solutions. He holds ASE CMAT/L1 and EPA 609 certifications and is an experienced hybrid instructor. Dave has been featured as an instructor in more than 15 automotive training videos.

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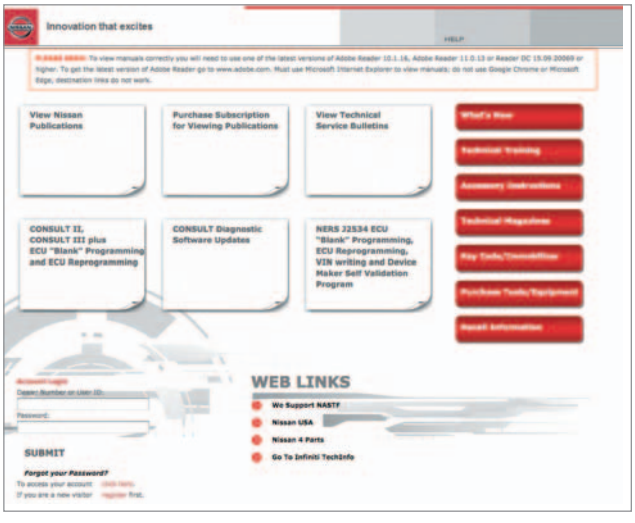

the CONSULT scan tool hardware or the software for the CONSULT. This is useful for shops that do not have CONSULT, but wish to purchase ECM files for their compatible J-5234 device.

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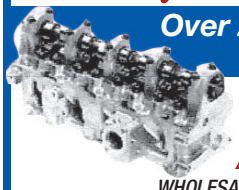

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LET THE TOOLS TAKE OVER

MAKE YOUR WORK EASIER AND LET THE TOOLS DO THEIR JOB

BY **PETE MEIER**
Director of Training

In our November edition of The Trainer, we investigated why it was possible to read voltage on your Digital Multimeter when one lead was on the negative battery post and the other lead was on a body ground. If that idea still throws you, take a moment to watch the video at MotorAge.com/nov15trainer.

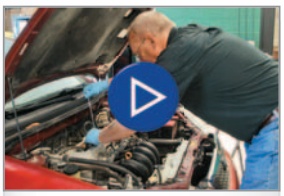
Now, if you watched the video already you hopefully had a few "light bulb" moments as the concept of voltage drop on the ground side of an electrical circuit was demonstrated. Here's the short version:

All voltage will be used to overcome all sources of resistance in the circuit. Normally, the load is the one real source of resistance and, therefore, will use the most. If I put one meter lead on the battery ground terminal and the other lead on the ground side of the load I'm testing (with the circuit closed and operating), I should read nearly 0.0 volts if all is well. If I read more than that, the amount of voltage I'm reading on my meter is telling me there is an additional source of resistance between my second meter lead and the first lead at the battery.

But what happens on the positive side of the circuit? If I leave the one lead at the negative battery post and move the second to the positive side of the load, I'll read close to system voltage but not quite. I have to take a second measurement directly at the battery and then subtract the two to see how much voltage drop exists on this side of the circuit. That can be confusing, especially if the source voltage is varying while you're attempting to test.

In this edition of The Trainer, I'll show you what I mean and demonstrate how moving just one lead will remove the confusion. Understand this, and you'll be tracking down electrical gremlins with the best of them!

[VIDEOS]



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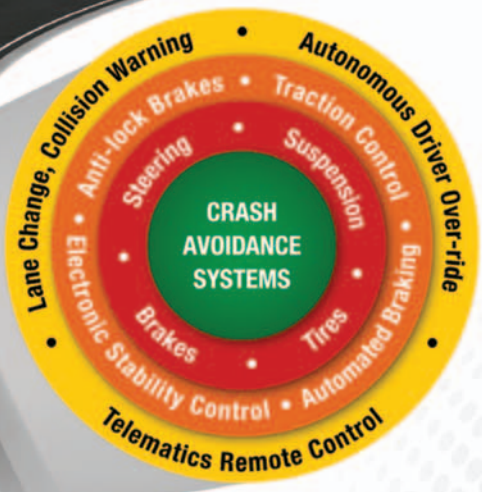

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