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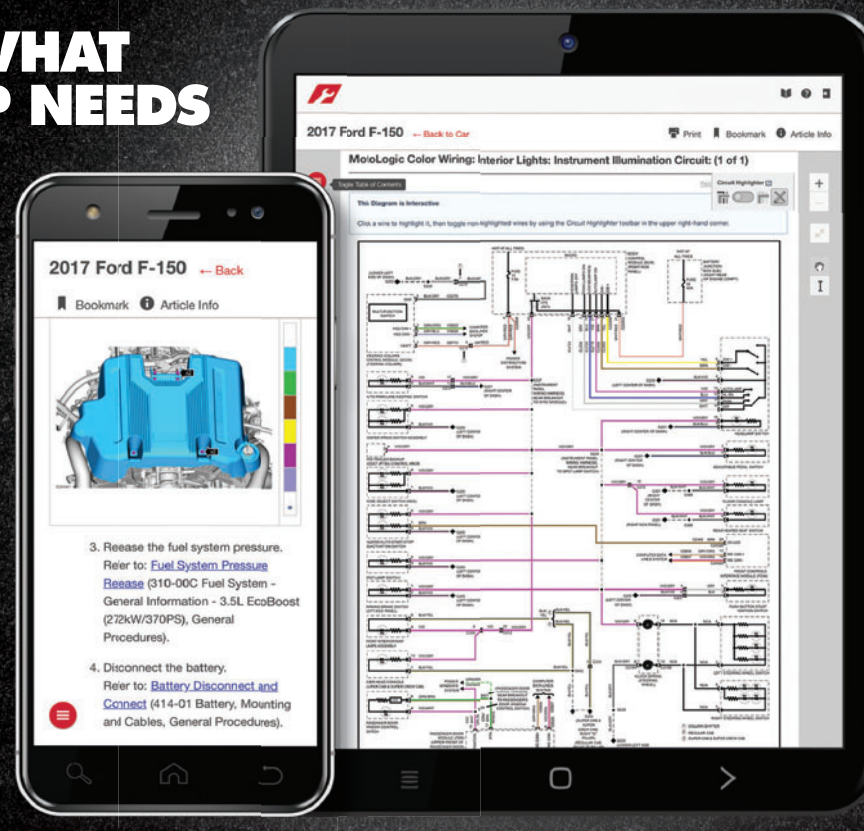

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OPERATIONS

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INSIDE LOOK

Get an inside look at Hydroboosters and Power Brake Boosters from MPA. Watch now! *MotorAge.com/MPAlook*

WEB EXCLUSIVES // MOTORAGE.COM

GET EASY-TO-FOLLOW WIRING DIAGRAMS

Gary Hixson, marketing manager for ProDemand with Mitchell 1, walks you through how the update can help you find the exact wiring diagram you need, which can then make you a more efficient and accurate diagnostician. Using real wiring diagrams, Gary shows how the update takes seemingly simple ideas and brings them to life. No more flipping through 16 pages of wiring diagrams to find one small section. Jump to the area you need. Interactive diagrams allow you to click on components to highlight wires. Highlight the entire length of the wiring to keep your place from page to page. Bringing together a variety of information into a wiring diagram, Mitchell 1 illustrates how the new features can improve your skills. Watch and learn how to utilize the update for yourself.

MOTORAGE.COM/WIRINGLOOK

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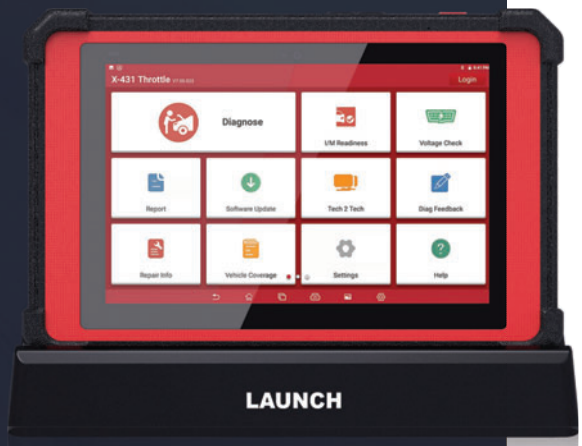

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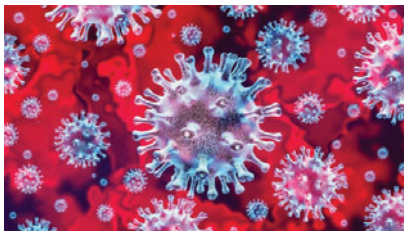
SANITIZERS CAN HELP MITIGATE CORONAVIRUS EXPOSURE

JAMES E. GUYETTE // Contributing Editor



With President Donald Trump's public coronavirus characterizations rapidly evolving from hoax to national emergency, cancellations, quarantines and lockdowns have become a fact of life.

Americans are now being advised to stay home and avoid interpersonal contact. Yet motor vehicle traffic remains instrumental for the nation's functioning, which means a lot of people are still driving — which in-turn results in continuing demand for automotive maintenance, repairs and parts-purchases that can't be accomplished while your hunkered down at home on the couch behind closed doors.

Technicians and counterpeople working with the public are thus on the front lines for possible coronavirus exposure. Contamination can come from vehicle surfaces to a limited extent; harmful germs on people are able to survive for a longer period.

"We as an industry need to be flexible and agile," says Paul McCarthy, president of the Automotive Aftermarket Suppliers Association (AASA), explaining that maintaining adequate supply lines and ensuring personal safety amid this crisis are ongoing challenges likely to carry on for the foreseeable future.

Richard "Rick" Williams, owner of the

>> CONTINUES ON PAGE 6

BREAKING NEWS

NEW RESOURCES

WIRING DIAGRAMS IMPROVE REPAIR PROCESS

Vehicles are changing so much. That's nothing new. But what is new are tools that make it easier for you to repair them.

Gone are the days of following a printed wiring diagram from page to page. But really, gone also are more "old school" digital wiring diagrams. Rather than follow along a scanned or digitized version of a wiring diagram, working with an interactive diagram can save time, headaches and backup on vehicle repairs.

Mitchell 1's exclusive interactive wiring diagrams have evolved since its initial debut last year, bringing more convenience to technicians of all levels. The new interactive wiring diagrams let technicians navigate from the diagram directly to component information without a secondary lookup. Component names

>> WIRE CONTINUES ON PAGE 6

TRENDING

AUTO VALUE, BUMPER TO BUMPER NAME TECH OF THE YEAR

Auto Value and Bumper to Bumper have named Mark Calzia of M.C. Tire & Automotive in Moline, Ill. as the 2020 Technician of the Year after his score on a custom ASE exam.

MOTORAGE.COM/CALZIA

ZF AFTERMARKET POSTPONES EDUCATION PROGRAM

ZF Aftermarket and Jeff Buckley, owner of My Father's Shop, are postponing the Installation Education campaign, which has been open to education institutions.

MOTORAGE.COM/ZF

AUTOCARE 2020 RESCHEDULED

Autocare 2020 in Brisbane, Australia has been rescheduled from its June 19-20 dates to October 30-31. The location will remain at the Brisbane Convention & Exhibition Center.

MOTORAGE.COM/BRISBANE

AUTOMOTIVE PARTS ASSOCIATES NAME SUPPLIERS OF THE YEAR

Automotive Parts Associates has recognized the APA Suppliers of the Year for their outstanding service and support of shareholders and organization initiatives.

MOTORAGE.COM/APA

YATES SERVICE RESPONDS TO COVID-19 CONCERNS

Yates Automotive announced the launch of Complimentary White Glove Vehicle Pickup & Delivery Service and full-service gas pump attendants.

MOTORAGE.COM/YATES

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>> CONTINUED FROM PAGE 4

Springfield, Mo.-based SafeSpace Co., has been emphasizing the effectiveness of his line of sanitizing products as applied to combating the risks presented by coming in contact with coronavirus pathogens.

How can a vehicle be disinfected and deodorized?

Tackle car clutter: Toss out any obvious sources of odor like food wrappers, napkins, musty magazines and other trash. Once you've cleared out the clutter, search the car's nooks and crannies — under seats, inside cup holders, and inside the trunk — for spills or food scraps. Then, vacuum any soft surfaces in the car including floors and seats.

Disinfect surfaces: Use disinfecting wipes to clean any non-carpeted car surfaces like the dashboard, cup holders and interior handles. Then employ a misting agent to destroy hard-to-reach bacteria.

The SafeSpace Auto Odor & Germ Eliminator generates an ultra-fine, contact disinfectant mist, killing germs and leaving the car's interior smelling fresh and clean. Mists like this one are a more effective way to disinfect interior spaces because they kill germs that you might miss during a simple once-over.

The Auto Odor & Germ Eliminator can disinfect all the hard-to-reach spots in your car, like the nooks and crannies around the seats and center console that you can't reach with disinfecting wipes.

Spray vents: Over time, every car's vents develop a layer of dirt and debris. Plus, germs love to hide in small, hard-to-reach spaces like car vents. The dark, warm, and moist environment within the ventilation system is a prime breeding ground for germs and bacteria.

To tackle these issues, treat the car's vents with a misting agent like the SafeSpace Auto Odor & Germ Eliminator. Shake the can well, press the valve and direct a two-second burst of the mist directly into the vents so that it can drift inside the plenums and attack germs where they thrive.

What is coronavirus?

According to the World Health Organization (WHO), coronaviruses (CoV) are "a large family of viruses that cause illness ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV)."

Any coronavirus that has not previously been identified in humans is known as a novel coronavirus. An example of this is the most recent coronavirus outbreak, which is known as 2019 Novel Coronavirus (COVID-2019). COVID-2019 was first identified in December 2019 in Wuhan, Hubei Province, China.

According to public health officials, COVID-2019 is less deadly than SARS. Although it's difficult to quantify due to the likelihood of unreported infections — especially early in the outbreak — currently about 2 percent of reported cases have proved fatal.

Two of the primary reasons that health officials are concerned about this outbreak is that COVID-2019 spreads fairly easily and it's difficult to know who is infectious.

>> WIRE CONTINUED FROM PAGE 4

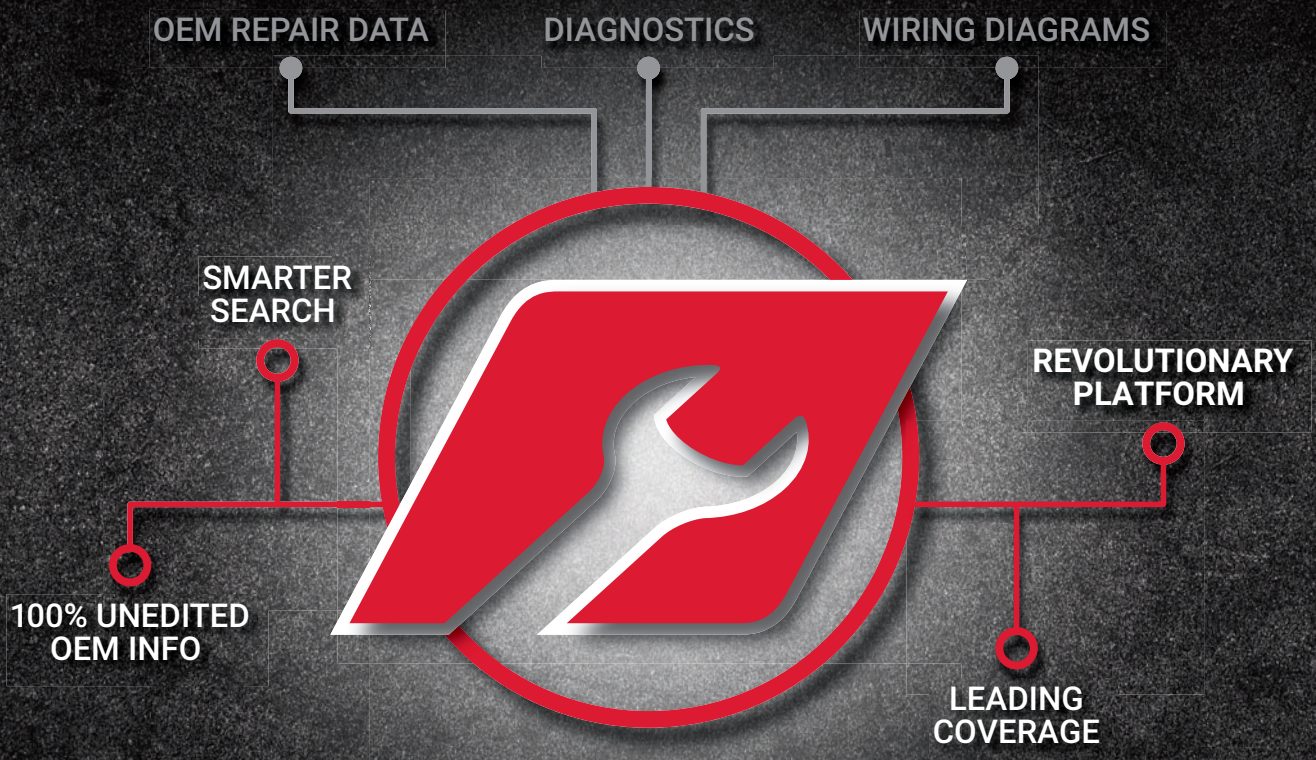
shown in the wiring diagrams are active links that take you straight to information like component location, connector views, replacement procedures and more.

New interactive diagrams like this are a game-changer for technicians, says Gary Hixson, marketing manager for ProDemand with Mitchell 1.

About 20 years ago, Mitchell 1 was first to bring full-color, system-level wiring diagrams to the automotive aftermarket. Through the years, the company has continually enhanced the diagrams, but with last year's update and now the new interactive features, this is an even bigger game-changer. What does it mean for techs?

- Now component names in the diagrams are active links that connect directly to complete component information.
- Perform a 1Search and ProDemand will take you right to the specific page of a wiring diagram associated with your search, and all wires for that component will be highlighted.
- Toggle highlighting of associated wires for each component and instantly see all wires relevant to the component — no need to click each wire separately.
- See a simplified view of complex diagrams with wires highlighted across all pages to a termination point.
- Zoom and orientation are maintained across multiple pages, streamlining navigation.
- Hidden wires are only faded, providing detail while preserving the big picture view.

Hixon led an informative video recently about the company's initial update to its wiring diagrams, and said these overall are an important function. You can watch the entire video at MotorAge.com/Mitchell1wiringdiagrams.



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A game-winning strategy to hit your sales goals

Don't underestimate the power of effort in all you do

Have you ever felt like no matter how hard you try to hit your sales goals, it never seems to work out? Let's listen this month to veteran ATI Coach Rick Johnson explain how he helps shop owners accomplish their sales goals. You have a great shop and state-of-the-art tools, you went to self-help classes and seminars and sought management consulting help. You even sent your staff to classes, bought a cabinet full of top-notch tools and invested in software that was supposed to put your business on auto-pilot while you "rake in the dough" and take it to the bank. But somehow your processes fell apart, business got slow, and you found yourself wondering — is there another way? Is there something I am missing? And there begins your journey for the next shiny penny.

Trust me, there are plenty of shiny pennies out there — plenty of products promising all kinds of wonderful results. But sadly, I'm here to tell you that's not the answer. More than likely, you have all you need to be successful. You already have the tools, equipment, training and marketing in place. So, what could be keeping you from achieving success, keeping your business from running like a well-oiled machine, whether you are there or not? I have an idea, and the good news is that you don't have to buy anything!

MORE THAN LIKELY, YOU HAVE ALL YOU NEED TO BE SUCCESSFUL. SO WHAT COULD BE KEEPING YOU FROM ACHIEVING SUCCESS? WHEN YOU HAVE EVERYTHING YOU NEED AND YOU CONTINUE TO END UP BACK AT SQUARE ONE, CHANCES ARE, YOU'RE MISSING EFFORT.

"Almost" doesn't count

That's right, the only thing you must buy into is what I am about to tell you. When you have everything you need, and you continue to end up back at square one, chances are, you're missing effort. Is your staff giving less than 100 percent on the job? Does it bother you when you ALMOST hit your sales goals, or your team ALMOST hits their hours-billed goals? What's worse is when you ask them why or what happened and their answer is: "We tried." If you're like me, you get frustrated. Tried? Come on! — what does that even mean? Winners don't just try; they make things happen. They overcome objections and bring their A-game every time. When they miss their goals, they know why and how to adjust so that they win next time.

I see this mindset and strategy in football. In fact, the other day I heard that in the average football game there are only six plays on offense that are successful. Imagine that, in a game that has typically 120 or more plays, only six on offense are successful! But the team that wins comes to the line each time, confident they will score. They block and tackle with all their might; the receivers run the best route they can; the backs run as hard as they can — every play, every time, knowing full well that they are only going to be successful six times! But they do it play after play, week after week, for those six plays of glory.

They, too, have the best of everything — equipment, facilities, coaches. But they also have the desire and attitude to win. There is no "trying" on their team. So, how does this apply to your auto shop? You must cultivate this winning attitude in your shop by sharing

knowledge. You must tell your staff how to be the best and why it's important.

Unlike winning football teams, we shop owners often forget the fundamentals. We stop doing the simple things like handing out business cards and asking for referrals. We stop exit scheduling and setting the next appointment when we get busy, don't we? And how about follow-up calls? We tend to let those slide too, don't we? Posting on Google My Business or Facebook business are also forgotten. And how about looking into your customers' vehicle history to find out what service milestones are approaching and other forms of customer relationship building? Today, more than ever, customers want to know that they're more than a number. If you're struggling with remembering to do these fundamentals, use ATI's Back to Basics Checklist.

Winning is never easy

Educating the customer as to why they need to invest $800 for maintenance on a car that runs well takes a lot of effort and needs to be done repeatedly. Just like the lineman on a football team, blocking each play, making sure his stance and foot position are absolutely perfect. Just like the receiver running route after route, making sure his turns are exactly on time with perfect body position. He doesn't know if this will be the time he scores, but he sure knows he won't ever score (or in your case make the sale) without 100 percent effort.

So many times I'm asked, "What is the one thing I need to do that will make me successful?" There is no "one thing" or a shortcut to success. It is no different than the championship football team. Winning the game starts days before game day. It's all those hot summer workouts, endless hours in the weight room, hours of film study and running the same play repeatedly, and that 100 percent effort each time they're in the game and at the line.

What's your game day strategy?

Think about your shop. What does your summer workout "onboarding" look like? How does your weight room "on the floor training" look? How many times do you run the play over and over, "role-playing" with your associates? So, what I am telling you is simple: There is no one big thing; it is 100 little things that add up to the score or sale! And the willingness to give it your all every time. No matter how many times you don't score or make the sale, are you willing to give it 100 percent effort the next time you are on the line?

So, talk to your staff and explain the importance and impact of giving 100 percent effort and surround yourself with staff that will do all those little things each time. If you do, you will surely find success and the business you have always wanted.

At ATI we have compiled a Back to Basics Checklist. These are the simple fundamentals that combined with all your shiny pennies and training will help you reach the success that you desire. Simply go to *www.ationlinetraining.com/2020-04* for a limited time.

CHRIS "CHUBBY" FREDERICK is the CEO and founder of the Automotive Training Institute. ATI's 130 full-time associates train and coach more than 1,700 shop owners every week across North America to drive profits and dreams home to their families. Our 32 full-time Certified Performance coaches have helped our members earn over ONE BILLION DOLLARS in return on their coaching investment since ATI was founded. This month's article was written with the help of Coach Rick Johnson.
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THE IMPORTANCE OF COACHING

When you're up by 2 in the last 10 seconds of the game, who do you look to for guidance? Your coach.

CAROLYN GRAY // Contributing Editor

As a kid were you in Little League? Or maybe on your high school football team? Or even the debate team? You probably remember the coach you had and the impact that person had on you and your team's success.

It's the same for a business owner. You need a coach to guide you when things are great — and possibly more importantly — when things aren't so great. "Coaching is the reason I have the successful business I have today," says Donny Yeoman, owner of Yeoman Service Center in Fort Wayne, Ind.

Having that impartial support and expert guidance is key to owning a successful shop that builds each year. The most successful business owners have a coach.

A new client first needs to recognize the need they have, but also recognize the value in a coach. Like any good investment, good coaching will pay for itself many times over. A business owner can easily be so entrenched in the day-to-day running of a shop that they can lose sight of short- and long-term goals. They can put aside the importance of looking at their numbers with a rigorous eye. They can put important initiatives like marketing or hiring issues off to the side.

Their coach has the knowledge and experience to ensure that a business owner is sticking to the plan they developed together. Sticking to that plan is what the client and coach do together. Each has their role. This business plan for success needs to be achievable. It needs to be realistic. The plan needs to lay out a path to success that the owner can grasp. And the plan needs to be a working document that the coach and owner can continually refer to as the overall blueprint of the business.

"My coach at DRIVE is always encouraging me to reach new levels of success. Sometimes you just need that push," Yeoman says.

The coach must be cognizant of when and how to push the shop owner. No business is exactly like the other. Each owner has their own strengths and weaknesses. To be able to structure the guidance given is a skill the coach must have in their toolbox.

It's the responsibility of the coach to inspire, encourage and develop the owner's skill set. They need to change the mindset of the owner to realize they are a business owner and not a tech. But in the process of developing the skills of the owner, the coach needs to be aware of not thwarting the progress of the client. They need to know the right balance of complimenting but still pushing the owner to the next level of knowledge and success.

The shop owner needs to be ready to accept input and guidance. They need to respect the recommendations of the coach. Being the boss has many hats — marketing, productivity, recruitment and HR, customer service, sales —

PHOTO: TODD WARNOCK / GETTYIMAGES.COM

and more. The successful shop owner will come to learn, with the help of their coach, that as a business owner their focus needs to be on running the shop and not fixing a car or truck.

"My coach is my accountability partner — Andrea keeps me on the right path to reach the goals we established together," Yeoman days.

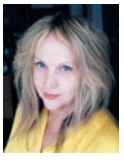
The vital importance of a shop having a qualified coach onboard will ensure that each area of the business is being considered and addressed.

Unfortunately, a professional coach is often brought on when the shop doesn't have anywhere else to turn. Their debt is piling up. They are losing key team members. Their production numbers are way down. And often they are reverting to working on cars in the back because it's what they know rather than looking at the business as a business — a business they are solely responsible for — and also the future of their team members and their families.

Frequently, the shop owner initially has the "I can figure it out" attitude. After all, that's what they know. They know how to fix stuff — mechanically, at least. The coach will work with them to shift their mindset to that of owner.

Often, a coach can act as simply a sounding board. How many shop owners have someone in their life whom they can honestly say has solutions, someone they can trust and not feel like they're bothering a friend or loved one with their business issues. Sometimes working with a coach is like going to confession — the solution comes out of the person's mouth; the solution was within them the whole time.

But it wouldn't have been discovered without the partnership between a trained coach and their client. This relationship, and the respect they have for one another, is the building block of a profitable business. There may be disagreements — maybe a voice raised over time or even a well-intentioned squabble — but each knows the shared goals at hand. This partnership needs to be open and honest and one that propels the shop owner's business to a level of success that wasn't conceivable when the business opened. Making a profit, taking care of your family and employees is the goal. And the coach makes it all attainable.



CAROLYN GRAY has an extensive background in Marketing, Creative, Media Strategy and Branding including Vice President of Digital at FOX Broadcasting and Co-President of Filmaka Studios. She brings that wealth of knowledge to DRIVE.

Has our industry lost focus on one important point?

Is your shop able to recruit and retain the talent it needs to survive?

Shop operators within the independent sector realize that their labor rates must move higher if they are going to retain competent technicians. The client must be educated on the realities of this issue through communication from the shop.

Before anyone can command higher labor rates, however, management must clearly acknowledge — and understand — one very important point: that your shop must be set up to attract and retain competent technicians and support staff. No one, anywhere within our industry, has the right to demand higher rates if their staff are not properly trained to execute all services thoroughly, accurately, professionally and efficiently for the price being demanded by the shop from their client.

A comment that does come up frequently now, however, is "Where can I get competent technical training?"

Everyone in this industry must take some of the responsibility for making our current bed that we are lying in, as now the complaining has begun. Everyone has been running their training based on price. Everyone wanted the very best quality training, but the greater majority were not willing to pay for it. This industry has now lost some fantastic trainers because of this attitude. The best trainers that I have had the privilege of meeting were exceptional people, highly skilled, had taken the time to learn all the detail the right way, kept on top of their skill level, were always a step ahead of their students and were prepared to travel around to share their knowledge. They loved this industry and had a high regard for its true potential. Way too many within the industry did not appreciate this. The independent sector was not willing to pay these skilled professionals a fair fee to ensure they were retained within our industry.

Consider that there is a parallel comparison that can be made here. As the public does not seemingly appreciate the skill level required today to become and remain a competent licensed technician, the independent sector of our industry does not appreciate the skill level and commitment required to be a competent technical trainer. If you are not happy with the current availability and level of technical training today, you are now witnessing the results of your past attitudes towards the financial support of this subject. There is an acute shortage of competent trainers left in this industry. This is well on its way to becoming a travesty for our sector of the industry. A few years back, I was aware of one competent technician whom I had a very high regard for, who had the ability to become a dynamic trainer, and even hinted to me the personal desire that he would have liked to become one, but found a substantially better income level by becoming an equipment salesman. Go figure. Our industry is providing zero incentive to retain the best of the current ones who are still around, or attract new ones to take over their role. We are continuing to chase them away.

WE MUST GET OFF THIS ISSUE OF PRICE, PRICE, PRICE ON EVERYTHING WE DO IN THIS INDUSTRY, AND EVERY LEVEL MUST GET BEHIND THIS.

We must get off this issue of price, price, price on everything we do in this industry, and every level of our industry must get behind this. We are in the knowledge business, and knowledge is the key to survival today and tomorrow. To receive and experience the knowledge disseminated from highly skilled technical trainers is truly an investment into the business, not an expense. Whenever you pay a highly skilled trainer a professional fee to execute the service of delivering his/her high level of knowledge to yourself and your people, you have always recouped that investment back within 30 to 45 working days, at the latest. Why do we then complain about putting out the money they ask for? If they are the best, pay them, or you will lose them. The choice is yours.

Answer this question honestly: Would you take the time to become a competent trainer for this industry today? Would you take the time to learn the skills they have, including develop the ability and skill required to deliver their knowledge in a public forum called the classroom, in a format where the student actually enjoys the whole experience and looks forward to the next course with the trainer? The ability to be able to do that is a skill. Would you be prepared to take the time required to stay on top of your technical skill level considering the fast-paced technology changes taking place within the vehicle, to ensure you are always one step ahead of everyone who attends your class? Would

you be willing to work all those nights the industry wants you to, away from your family, because the independent sector of the industry cannot organize their business so that training can be done during the day? Would you do all that at the current industry's pay level? I didn't think so. Now you see what the problem is, and it is getting worse every year. We seem to treat these people like second-class citizens in that even we don't think they deserve a professional income. Everyone must wake up and treat and pay the technical trainers left in this industry a professional income to keep them around and provide the financial incentive to attract new ones. I have said many times that a competent technician in our industry is worth easily $100,000 to $130,000 per year. So a competent trainer, when you think about it, who is capable of staying ahead of these competent technicians is easily worth $125,000 to $150,000 a year, but, in both cases, this sector of the industry is nowhere close at paying these levels because we say we can't afford to. I must disagree.

The real problem is that we are always trying to pay for training out of current cash on hand, and now the receivables in the business are out of control. Cash is tight because of mismanagement, so the shop perceives that they cannot afford a course. The second problem is that management is not willing to educate the client on the real costs of this business today, and in turn, they never have charged the correct labor rates in the past to recover these costs. This has compounded itself over the past five years. Consider getting your receivables in so you have the cash to take all the necessary training required to be the best.

It is time to get off the price issue when it comes to competent training and realize the fantastic return on this investment when you implement the knowledge taught. Everyone must work hard to retain the competent technical trainers left within our industry. Get your financial house in order; write the check; attend their classes; become a sponge and absorb the knowledge they share with you; and become competent and the very best that you can be. Move your labor rates to the level of your competency. Make the investment; reap the rewards.

BOB GREENWOOD, AMAM, is president and CEO of Automotive Aftermarket E-Learning Centre Ltd. (AAEC), which provides business management resources for the automotive aftermarket. Bob has more than 36 years of business management experience and is one of 150 worldwide AMi-approved instructors.
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CREATING AN ETHICAL CULTURE

Ethical behavior should be part of everyday life in the shop, but it starts at the top

BRYCE HOLT // Contributing Editor

Perception is everything when it comes to business, and the good news for the automotive industry is that its reputation has improved greatly over the years. A generation of business owners has worked hard to improve the image of this industry. Yet, there are still some businesses that perpetuate the negative stereotypes of shops by making customers feel they have been taken advantage of. Much work has been done, but there is always room for growth.

The most proactive way to change a negative perception is to bring the ethics discussion to the forefront and address it head on. Then, you'll have a framework to develop a code of ethics for your shop or strengthen your existing one.

Areas of concern

Shops and the technicians within those shops are faced with ethical dilemmas every day. Some decisions are made without a second thought, but all decisions have long-term consequences. Just a few of the common ethical issues in this industry include:

- **Shop practices**. The way a shop is run is a reflection of the management. Your shop practices can be a major ethical stumbling block. Price gouging, recommending unnecessary services and repairing with substandard parts, unprofessional conduct and workplace bullying are just some of the ethical concerns that will affect your customer base. What is the perception of your shop in your neighborhood and community? When a customer walks in the door, do they get a good feeling about your business?
- **Poaching.** Stealing technicians from other shops is one way to get a quality technician with the right experience. Yes, it's a common and often accepted practice in this industry, and the technician shortage doesn't help. Poaching employees may seem inevitable, but is it ethical to steal from your competitors? There are other ways to find technicians, including entry-level. Grow your own!
- **Workplace safety.** Is workplace safety a No.1 priority in your shop? If it isn't, it should be. Ethical shops put an emphasis on maintaining a healthful environment for workers and educate their employees about ways to improve. Are you training your employees annually on the hazards of the workplace? Not only is it the law, but also it's the right thing to do. An accident-free workplace should be the topmost goal, and that starts with training everyone, not just upper management.
- **Use of company resources.** Occasional personal use of time and equipment is generally accepted in most industries as long as it doesn't affect job performance or disrupt the workplace. But the misuse or abuse of time, materials, equipment or information can be an ethical challenge. Shop manag-

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ers should pay careful attention to the habits of their employees, and this starts with modeling good judgment and behavior regarding company resources. Managers should also feel empowered to resolve issues related to time and resource management.

The reasons behind ethics

It probably goes without saying that you should run an ethical shop. Doing the right thing is the right thing to do. But does it really affect your business' bottom line? In a word, yes.

What are the advantages of running an ethical shop? Most important to your bottom line, your business will retain its customers. A customer who has had an experience where they were treated honestly, where someone went above and beyond, and where they received a quality repair will be a repeat customer. They'll tell others about their good experience, and you'll have additional customers.

On the other hand, if they have a bad experience, many will immediately post on social media and tag your shop about what transpired. Bad publicity can ruin a business in the short-term, but that review lives on years later and can be hard to overcome. One technician's dishonest behavior or bad attitude can affect your shop for years.

Establishing trust is key to keeping your customer base. Thinking about ethics ahead of time will help you and your employees prepare for instances that test decision making and ethical boundaries. When everyone understands the benefits of making the right choices, they can consciously work to make better choices, act appropriately and avoid problems.

Establishing a code of ethics

A code of conduct, or ethics, is a document outlining professional standards expected of all company employees and representatives.

Public companies are legally mandated to have a code of conduct and required to make it public. Most industry associations have a code of ethics and publish it for their employees or members. Does your shop have a code of ethics?

Establishing a code of ethics can be as simple as writing down what is important to your shop and getting feedback from others, including employees in all areas of the business. This code should clarify your business' mission, values and principles, linking them with standards of professional conduct. An added benefit of having a written code of conduct is that it becomes a benchmark against which an individual's and the overall shop's performance can be measured.

You should include items important to your business, such as complying with federal, state and local laws; treating customers fairly, openly and honestly, without discrimination; advertising in a straightforward manner; explaining vehicle issues clearly to customers, distinguishing between existing problems and preventive maintenance; using only high-quality merchandise and allowing inspection where necessary; taking care with customer vehicles; communicating with customers and informing them of the status of their vehicle repair; and resolving problems promptly and standing behind warranties.

Ideally, your code of ethics will be a guide for the everyday ethical decisions everyone working in the shop faces. It should be written clearly and in simple language, and respond to real-life questions and situations. There are plenty of free resources on the internet for creating a code of conduct, including templates that provide a framework. Just fill in the blanks and your shop's particular details, and you are on your way. When you have your code of ethics completed, post it on your website so customers can see what you are all about.

If your shop already has a code of ethics, is it sitting on a shelf somewhere collecting dust? A new year is a good time to update it to reflect what's happening today. Make sure every employee has a copy and acknowledges they have read it.

Next steps

Once your business has a code of ethics in place, management is responsible for cultivating an environment where everyone can feel comfortable to speak their mind, particularly with respect to ethical concerns. Work to create an open and supportive environment where employees feel empowered to open a dialogue and don't feel like they are "tattling" on a co-worker.

Follow up is key. If an employee reports a concern, investigate the issue and take appropriate and swift action. This should include not only personnel issues, but also safety hazards that need to be addressed. Your employees should know they won't be retaliated against if they raise concerns in good faith.

Ethical behavior starts at the top. Managers need to demonstrate the importance of your code of conduct. Changing behavior or creating an ethical culture does not simply happen; it is the result of clear and direct communication of expectations and is shown by example.

But just because ethical behavior starts at the top doesn't mean that employees are exempt from upholding the code. Ethics should be a part of daily work for each person in the shop. Everyone is responsible: if they see something, they should say something.

BRYCE HOLT is COO of S/P2. Each year, S/P2 provides online training to more than 175,000 workers and students nationwide on industry-specific safety and pollution prevention, ethics, soft skills and human resources topics, as well as an online workplace mentoring program for the automotive industry. *info@sp2.org*

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Coronavirus relief for small businesses being considered

ASA signs coalition letter supporting small business provisions

As of this writing, the U.S. Congress has passed an Emergency Supplemental Appropriations disaster assistance bill entitled the Coronavirus Preparedness and Response Supplemental Appropriations Act of 2020, H.R. 6074. This new law allows for $1 billion in loan subsidies to be made available to assist small businesses impacted by financial losses as a result of the coronavirus. The Small Business Administration (SBA) is now enabled to provide an estimated $7 billion in loans to these same impacted businesses. An additional $20 million is available to administer these new funds.

Congress is currently debating H.R. 6201, the Families First Coronavirus Response Act, which is designed to "bolster the federal government's response to the coronavirus outbreak and address the severe impacts of the coronavirus on Americans' personal safety and financial security" according to the U.S. House Appropriations Committee. Important provisions in the Families First legislation include Emergency Paid Sick Leave Act and tax credits for paid sick and paid family and medical leave.

The Automotive Service Association joined other aftermarket associations, including the Automotive Oil Change Association, Auto Care Association, Tire Industry Association, Independent Lubricant Manufacturers Association, Service Station Dealers of America, California Autobody Association, California Automotive Business Coalition and the International Carwash Association, in a letter to House Speaker Nancy Pelosi (D-CA) and Minority Leader Kevin McCarthy (R-CA) requesting that Congress and the Administration consider additional small business assistance including:

- Lawful declaration that COVID-19 is a "DISASTER" for the purposes of allowing small businesses to obtain funding directly through the Small Business Administration and to obtain access to any other state, federal, and/or private relief dependent on a federal "disaster" declaration;

- Allow 100 percent deduction of business losses for non-remote-function-capable small businesses (NRFCSB) for the 2020 tax year applicable to all business formation types (e.g., S Corporations, Sole Proprietors, Partnerships, etc.). A NRFCSB is defined as a small business according to Small Business Administration standards that requires onsite employee activity and consumer interaction in order to engage in its core functions;
- Allow NRFCSB employees to qualify for Federal-State Unemployment Insurance Program benefits including payroll assistance for reduced hours and without impacting the employer's insurance rate;
- Provide a federal Child Care Subsidy for NRFCSB employers and employees.
- Provide Mortgage Assistance plans for NRFCSB employers and employees.
- Provide federal assistance for health care costs and/or a mandate to private health insurers that they must cover for free or at most the actual cost of necessary health care related to the COVID- 19 pandemic; and
- Include Tax-Exempt Entities in temporary aid to address the harm they're experiencing from event cancellations and reduced meeting attendance as a result of COVID-19. Specifically, we urge you to include associations, nonprofits and other tax-exempt organizations within any federal aid packages or supplemental appropriations measures.

The Trump Administration is also considering relief in the form of tax deferments and business loans. The House of Representatives and the Administration are still working on the details of the package and negotiations with the Senate are ongoing for this latest, related legislation. Guidance for businesses impacted by coronavirus is already available at www.sba.gov.

ROBERT REDDING is the Automotive Service Association's Washington, D.C. representative. He has served as a member of several federal and state advisory committees involved in the automotive industry. *rlredding@reddingfirm.com*

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THE FIGHT FOR OUR INDUSTRY'S LIVELIHOOD

Securing vehicle data access and its importance to the industry

BILL HANVEY AND PAUL MCCARTHY // Contributing Editors

It's important to pause and recognize the changing dynamics afoot in the auto industry. Digitalization and connectivity, AVs and EVs, increased consumer expectations and a shifting competitive environment could greatly affect the future of the independent auto care industry. However, digitalization and connectivity represent the biggest and most immediate threat and could have significant impact on the aftermarket's ability to remain competitive and enduring.

Vehicles today are more than just vehicles. They are data collection resources. There are nearly 69 million connected vehicles on the road today; by 2022, 87 percent of new vehicles in the U.S. will be equipped with wireless technology that transmits vehicle data (i.e., telematics) in real time, according to IHS Markit forecasts.

Starting with the 2015 models, all new vehicles come with wireless technology that generates 25GB of data per hour, according to McKinsey estimates. This includes data on driving behavior, GPS location and important diagnostics such as maintenance and repair information, among others.

Wireless technology has given vehicle manufacturers more opportunities than ever to monopolize data. Under the guise of safety and security, manufacturers are wirelessly collecting maintenance and repair data, making them the gatekeepers of information tied directly to jobs of auto care industry technicians.

Vehicle manufacturers could obtain exclusive access to and control of vehicle data, manage the value chain throughout the industry and wall off independent technicians from vehicle data entirely. This potential monopolization of vehicle data positions vehicle manufacturers to alter the auto care industry landscape and threaten the independent aftermarket that makes up more than 70 percent of vehicle repair and maintenance.

The impact on the auto care industry is substantial. Though it generates $392 billion in revenue each year and supports 4.6 million American jobs, those figures could dip significantly, as independent repair shops starve from lack of data access and are rendered noncompetitive. If independent technicians are unable to directly access maintenance and repair data, it means lost revenue and a smaller customer base, and fewer opportunities to innovate products, technology and services.

Simply put, our industry's livelihood is at stake.

Your Car. Your Data. Your Choice.

The idea of locking the auto care industry out of work, the loss of consumer choice and reduced competition for repair and maintenance services, and potentially losing good-paying jobs sparked the formation of the Your Car. Your Data. Your Choice.™ education and advocacy campaign. This effort is aimed at increasing industry and consumer awareness on the realities of modern vehicle data and the implications of not having access or control of vehicle data.

According to McKinsey estimates, vehicle data could be worth as much as $750 billion by 2030. As digitalization and automotive IoT continues to disrupt the auto industry, vehicle manufacturers looking for new revenue sources, would love to exploit vehicle data. Nevertheless, the independent aftermarket certainly will fight hard for consumers.

But we can't do it alone: you and your customers play a critical role. The problem Your Car. Your Data. aims to solve is straightforward: three quarters of American consumers — your customers — do not know about vehicle data or why it's important they control who has access to their information. These consumers are largely ignorant to the enormous quantity of information their vehicles produce — let alone who owns this data and can access it. Aside from losing their relationship with their trusted independent mechanic, mandatory trips to manufacturer-controlled shops would mean more money spent to service their vehicle. Having to go to dealerships will mean longer wait times and traveling to inconvenient locations. As a result, customers may delay or ignore safety-critical repairs or services.

Our argument is simple: consumers should be able to choose the price, person and place they want to perform repair and maintenance services.

A concerted effort to spread awareness is underway. Your Car. Your Data. has momentum and more supporters joining the movement each day. The future of our industry relies on each of us sounding the alarm with customers and articulating why it matters.

Your role in the fight to preserve our industry

The most meaningful progress achieved is in personal, one-on-one conversations between shop owners, point-of-sales representatives or technicians and their customers.

Personal relationships are the lifeblood of our industry—and your customers trust you. A few conversations with a handful of loyal customers could produce additional allies in our fight for data access and control.

Your Car. Your Data. provides, free of charge, a variety of materials for technicians and other industry employees to share with customers or use when engaging with them about the data access and control issue. In addition, following are two quick and easy actions you can take today to demonstrate support.

1. Encourage your customers to sign the consumer data access and control petition at yourcaryourdata.org.

2. Use the materials available to you at autocare.org/telematics and aftermaketsuppliers.org/CarData, like the Vehicle Data fact sheet or the Technician one-pager, to learn more about the issue and provide you with the materials necessary to engage with your customers.

It ain't over till it's over

Americans can take heart in the fact that a thriving movement is already underway. By signing the consumer data access and control petition, contacting their government representatives and spreading the message by word of mouth, drivers and industry advocates can continue to fuel this growing movement. Vehicle manufacturers are relying on consumer ignorance, silence and apathy as they look to control drivers' vehicle data; the Your Car. Your Data. campaign represents a countervailing force.

Fight for the livelihood of your industry. Join our movement and sign the petition today. Then, spread the word by engaging your customers. We welcome your support.

BILL HANVEY is the President and CEO, Auto Care Association. Prior to becoming president and CEO of the Auto Care Association, Hanvey served as SVP of the Automotive Aftermarket Suppliers Association (AASA).

PAUL MCCARTHY is the President and Chief Operating Officer of the Automotive Aftermarket Suppliers Association, the light vehicle aftermarket division of the Motor & Equipment Manufacturers Association.

Emergency repair

Fire trucks and ambulances are regular clients at this Tennessee shop

ROBERT BRAVENDER // Contributing Editor

There are all sorts of niche markets in the auto repair trade — diesel, small engines, European imports — but the one with the highest visibility is perhaps the most overlooked: emergency vehicles. A particularly high level of service is required for fire engines and ambulances, and as it turns out, not everyone can do it.

"They had this at a regular repair shop," said Paul Moss, gesturing at a medium-sized fire truck from a regional department. Along with his wife Lisa, Paul is co-owner of Alpha & Omega Repair Service. Opening an access panel behind the cab, he revealed the heart of the unit, the powerful water pump for the fire hoses.

"(That shop) left the truck outside overnight. The water in the pump froze and cracked the fittings. You just can't do that with these trucks," he said.

"You have to know how the pump works, know about hydraulics, about aerial devices like ladders and buckets," Moss remarked. "With emergency vehicles we do a lot of PMI, Preventative Maintenance Inspection. That's a yearly thing on fire trucks, but ambulances we do about every 3,000-5,000 miles according to how the customer wants to do it. Ambulances are run a lot; fire trucks may not have 5,000 miles on them in a year."

Besides the PMI and DOTs, Alpha & Omega does annual water pump tests on fire trucks with a towable tank they built themselves. "The pumps are tested for volume and pressure when they're manufactured, and they have to maintain those numbers throughout the life of the truck," Moss explained.

"We hook a 6-inch intake to my tank, which can hold 3000 gallons of water," he continued. "The fire truck pulls its prime so gravity pushes the water into the pump. Once we get that started, I shoot the water out of the fire truck through the hose into the deck gun right back into the tank, and it keeps circulating back and forth. We monitor certain pressures at gallons per minute."

Bottom line: in this particular niche market it really helps to have a background in firefighting. Starting as a volunteer firefighter at age 15, Moss got into diesel repair around the same time and pursued it into trade school. He eventually got a job servicing heavy equipment for a strip mining company near his hometown of Clintwood, Va., doing ambulances on the side.

"[The local departments] had them to several places and couldn't get them fixed, and we fixed them," said Moss. "That's how it started, working on air conditioners and electrical, two biggies on ambulances."

Unlike automotive repair, nearly all fixes have priority for the companies, counties and municipalities that run these emergency vehicles. "Of course, everybody's got a budget that they have to live by, but for the most part these are emergency vehicles so they want them right," he observed. "There are a few that might get into a bind every now and then, and they may have to prioritize, but for the most part our customers want their stuff fixed right. You know when the bell rings and these trucks go out, people's lives depend on them."

The Clintwood branch of Alpha & Omega officially opened in 2010, where Moss concentrated on servicing industrial fleets. "We actually go up on mine property and work on support ve-

PHOTO: ALPHA & OMEGA REPAIR SERVICE

ALPHA & OMEGA REPAIR SERVICE

Bristol, Tenn. // emergencyvehiclerepairs.com

Paul & Lisa Moss Owners	**3,000** Total square footage of shops
2 No. of shops	**70** No. of customer vehicles per week
10 Years in business	**$1.1 million** Annual gross revenue
12 No. of employees	

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hicles: lube trucks, performance trucks, powder trucks. We also do work for a tree company. And we do all of the vehicles and equipment maintenance for the town of Clintwood."

But then in 2013 Moss got a dream offer — full time firefighter in Bristol, Va. A city about an hour and half away on the Virginia/Tennessee border, Moss figured he could still run the Clintwood shop during his off days. But once in Bristol, his reputation for work on emergency vehicles quickly caught up with him.

"I loaded up a trailer with tools and started going around working at different fire departments and rescue squads in this area," laughed Moss. Soon he leased a location in Bristol, Tenn., and opened his second Alpha & Omega shop; this one focused more on emergency equipment. But he kept the concept of the trailer — it eventually evolved into a mobile unit.

"The rural areas have volunteer fire departments, and they don't have time to transport units back to us, so a lot of people would prefer to pay us to come to them," Moss explained. "They don't have to worry about transport, about the equipment, knowing everything is safe at their place. If we've got time we also do some roadside assistance; we get all kinds of calls from people; 18-wheelers, bigger trucks, some RVs."

Between them, the two locations cover about 200 miles along the Interstate 81 corridor, going from Sevierville, Tenn., north and east to Pulaski, Va., as well as west into Kentucky.

Other than the mobile tank tester, Alpha and Omega has diagnostic tools for the engines, transmissions, ABS — "even the wiring since they went to Multiplex," he added. "They've got nodes all over the truck. It's less wire, but you've got to have a special computer to do diagnostics on that."

While the Clintwood store is smaller at about 1,200 square feet, most of the work is mobile, although Moss has plans on doubling that facility's size. It has three mechanics and one secretary, with one technician dedicated to the strip mining job. The Bristol location is bigger at 4,500 square feet, and currently has two secretaries, his wife as the office manager and three technicians.

To enhance his position in the emergency vehicle market, Moss also made sure his staff is not just ASE-certified, but certified as Emergency Vehicle Technicians (EVT), a recommendation from the National Fire Protection Association (NTPA), a trade organization for the fire prevention and fighting industry.

"The EVTs mostly test your knowledge of rules and laws suggested by the NFPA, like what class of a leak will cause a vehicle to be taken out of service," he explained. "We require all of our technicians to get some sort of certification. Not everybody is a master tech, but according to what their main job performance is we require them to get certifications in that area," said Moss. "We have the jobs somewhat broken down into specialties; everybody's got their niche."

However, that makes this market quite challenging. "It opens up a whole new world of training," acknowledged Moss, "because when you're talking pumps, that's a whole other certification process. You've got three main manufacturers of fire engine water pumps and they all have their own schools to go to. Add to that the different fire truck manufacturers, which have their own schools."

Despite this training regimen, or perhaps because of it, Moss has diversified over the years. As a diesel expert it was only natural that he became a Jasper engine dealer, with all that involves. They're also an authorized Spartan RV service center, since Spartan manufactures chassis for both motorhome coaches and fire trucks.

"Spartan didn't have anyone in the area committed to doing their RV work," Moss said, "so they had us go ahead and get certified. Now we do their warranty work, and just because we're on their website we get a lot of RV work coming in here."

They also have a dealership license to sell ambulances for Excellance, fire trucks for Spencer, and Warner truck bodies. "Most of time people come in and spec out the truck they want," he said of the process. "I send the specs to the manufacturer, who makes sure they meet all the NFPA requirements, send back drawing to be proofed, and then they'll start making the truck. Finally we pick it up and deliver it to the customer."

Of course the pressure of maintaining two shops an hour and half apart can be a bit of a topographical challenge for Moss. However, also being a fireman with the city of Bristol was proving to be too much for this arrangement.

"The seven or eight days a month when I (was) doing a 24-hour shift put a strain on things," he admitted. "If issues arose it was hard for me to deal with them while there."

So in May 2019, Moss reluctantly gave up his professional firefighting career. "This business has grown to the point where I can't manage both shops and work at the fire department. I've been blessed to be a fireman; it's the best job in the world. But after a lot of prayers, we're going to go with this business fulltime."

ROBERT BRAVENDER graduated from the University of Memphis with a bachelor's degree in film and video production. He has edited magazines and produced shows for numerous channels, including "Motorhead Garage" with longtime how-to guys Sam Memmolo and Dave Bowman.
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ASA training, business event postponed until late summer

ASE INSTRUCTOR TRAINING CONFERENCE STILL ON SCHEDULE

MOTOR AGE WIRE REPORTS //

Noting the seriousness of the Coronavirus, ASA's Board of Directors decided to postpone the association's joint CARS (Congress of Automotive Repair & Service), TTF (Technology & Telematics Forum) and annual business meeting until August 24-25, 2020.

Plans are for the event to remain at the same location.

The board made the decision after some key business partners indicated they might not be able to attend because of company travel bans resulting from the COVID-19 pandemic.

The event had originally been scheduled for May 4-5, 2020 in the Dallas-Fort Worth community of Hurst.

"While we're disappointed to have to postpone the event because we have such an excellent venue, we understand the need for the delay because of health concerns," Fisher said.

Fisher said ASA leaders realize the seriousness of the Coronavirus (COVID19) and are, as a result, doing everything possible to keep its employees and members safe while continuing to provide top-notch member experiences.

ASA's decision comes in the wake of numerous groups postponing — and sometimes canceling — events.

In addition to NAPA Expo being postponed, CIC canceling its April 8-9 meeting and ASA Northwest postponing its upcoming meeting, major league baseball, professional hockey and golf and pro and college basketball are among other groups to take action.

"Like everyone else, we're following CDC guidelines and keeping the health of our members at the forefront," Fisher said, adding ASA's commitment to top-notch member services will not wane.

When the event occurs later this year, it will still feature co-located options such as CARS and TTF in addition to the ASA's Annual Business Meeting and Live Podcasts.

TST Big Event gets a new date

The annual TST Big Event — now in its 17th year — is a one-day intensive training event for service repair technicians and is a must attend.

Originally slated for late March, the event has been rescheduled to August 15 at the Westchester Marriott in Tarrytown, NY.

For 16 years, the TST community of automotive technicians have come together for this annual event of knowledge sharing that is truly special. Think: what's now, what's new, what's next and how to fill the gap — learning what actually matters (while sitting elbow to elbow with your peers).

Three industry-known trainers will be presenting: Scot Manna, Bobby "G" Gruszczynski and John Anello.

Registration includes a free Android tablet loaded with three full color manuals and newsletter. Also included is food, vendors and tool raffles — last year the event gave away more than $50,000 in tools and hosted more than 35 vendors! You must be present to win.

The cost is $125 for members and $200 for non-members and includes the new model Android Tablet, three training seminars, a hot breakfast, lunch, snacks through the day and many chances to win.

ASE educator's conference on schedule

The ASE Education Foundation will hold its seventh annual Instructor Training Conference on July 14-17, 2020, at the Embassy Suites Hotel, in Frisco, Texas.

The conference will offer more than 60 technical sessions with over 100 hours of training to choose from over three days. Session presenters representing more than 35 organizations will deliver training to hundreds of high school and college instructors from auto, truck and collision repair programs nationwide.

"We aim to provide the very best mix of technical training possible," said Mike Coley, ASE Education Foundation president. "Thanks to our ASE Education Foundation partners, our conference sponsors and our technical presenters, participating instructors will benefit from a great week of networking and learning."

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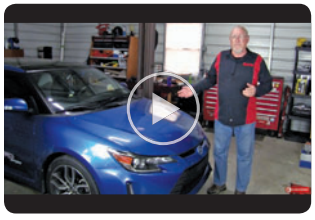

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BUG CAUSES DTC P0171 ON MITSUBISHI

VEHICLE: 2011 Mitsubishi Outlander, 2WD, L4-2.4L (4B12), Automatic Transmission

MILEAGE: 88,396

DETAILS: First, the tech connected a scan tool and checked the long and short fuel trims. The sum of both equaled +30 percent at idle. The reading did not improve or change at any RPM. He checked for vacuum leaks and found none. Because the fuel trims were not worse at heavy load, he suspected that the fuel pressure and volume was correct but checked it anyway. The fuel pressure and volume was at specification at all engine speeds. Next, the tech checked the Mass Air Flow meter (MAF) PID and found it to be low (2.6 g/s at idle).

CONFIRMED REPAIR: When he removed the MAF to inspect it, he found a large bug inside it. He removed the bug, cleaned the MAF and fuel trims returned to normal. After clearing the DTC, the vehicle was fixed!

This tech tip and others come from ALLDATA Tech-Assist, a diagnostic hotline of ASE-certified Master Technicians.

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GDI — HIGH PRESSURE DIAGNOSTICS?

LIKE ANY OTHER TECHNICAL CHALLENGE, KNOWING HOW THE SYSTEM OPERATES IS HALF THE BATTLE!

ERIC ZIEGLER // Contributing Editor

Gasoline Direct Injection, or GDI, is the latest in advancement in fuel injection and fuel control in modern engines. GDI was born out of OEMs having to deal with tighter government-mandated regulations to increase fuel economy while reducing greenhouse gases. Per Wikipedia, early GDI designs date back to 1925 to a simple low compression truck engine. Mitsubishi was the first OEM to mass produce in 2006. In 2008, GDI made up less than 3 percent of U.S. production vehicles. By 2016 that number had grown to over half! This technology is here to stay.

Applying an old idea to meet new challenges

Engineers had to go back to the drawing board and make some important changes to fuel injection as we know it. Port Fuel Injection (PFI) had become the industry standard, but had reached the limits of being able to maximize fuel economy and meet the tighter EPA tailpipe emissions requirements. The paradigm shift in design would require the advent of a higher-pressure fuel injector that would directly inject fuel into the cylinder.

GDI would require several changes to the engine design. The GDI injectors work on hundreds or even thousands of pounds of fuel pressure. First, we would require a pump capable of generating

PHOTO: BOSCH

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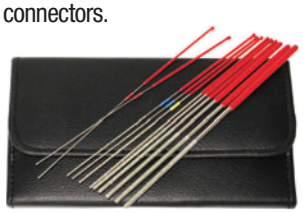

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this higher pressure. The electrical fuel pump in the tank certainly would not be capable of this, so a mechanical pump would be required to generate this higher pressure and would need to be precisely controlled by the PCM. The pump is driven off the engine's camshaft and is connected to a housing, which is usually incorporated into the camshaft's bearing cap. The housing utilizes a roller-style solid follower that drives the spring-loaded plunger. The fuel volume regulator is used by the PCM to control how much pressure the high-pressure pump generates.

The internal design of the engine also would have to change. Newly improved piston designs like swirl-based and tumble-based models would work in conjunction with the advancements of Variable Camshaft Timing (VCT) to raise the effective compression ratio to help make a more ideal environment for a leaner, more efficient fuel combustion by injecting the fuel charge directly into the combustion chamber, akin to a modern common rail diesel but with a spark plug.

These improvements help increase fuel economy by reducing pumping losses and providing an overall leaner mixture. The stratified charge also helps in reducing heat losses in the combustion chamber and the cylinder walls. The cooler fuel charge is due to the nature of being directly injected into the cylinder.

PHOTO: BOSCH

THE HEART OF THE FUEL DELIVERY SYSTEM is the high-pressure mechanical pump. These pumps are capable of creating thousands of pounds of pressure, so exercise caution when servicing or repairing any of the high-pressure components.

New system, new diagnostic processes

Our modern engine has become more complex and higher-tech and so have our scan tools. We now have more data at our fingertips than ever before. The advent of bidirectional controls, buffers for scanner movie/snapshots as well as built-in systems tests, let us leverage technology to benefit our diagnosis. GDI systems are no exception to this. The scanner plugged into the DLC is often the best place to start our diagnostic by garnering the most information with the least amount of effort. Let's look at some of the systems that GDI incorporates and how we could use the power of the modern scan tool to investigate.

First and foremost, the GDI system starts with the fuel in the tank. We must get the fuel from the fuel tank to the GDI high-pressure fuel pump. To do this we have an electric fuel pump in the tank. Often, the fuel system is a returnless design, meaning that any excess fuel delivered to the rail is not returned to the tank, unlike in the days when we used a two-line system. The old return-style system generated almost full pump output and returned to the tank the fuel that it didn't use. Nowadays, most vehicles have eliminated the return line and must precisely control fuel delivery based upon the engine's demands. To do so, the in-tank fuel pump's speed is controlled electrically by a fuel pump driver module, which increases the duty cycle feed to change the delivery of the pump. The PCM can control the duty cycle command of the fuel pump driver module. So where does a tech start the diagnosis with a scan tool?

Are there any GDI control circuit codes for the GDI injectors or the HP (High Pressure) pump? Are there other engine performance codes? How do the fuel trims (STFT and LTFT) behave? Are there misfire codes or has the PCM detected misfire activity? Is there any sort of supply system pressure or GDI injector balance test offered by the scan tool? All of this will help to guide the diagnostic process. Also, like any suspected drivability issue involving the fuel system, or any drivability issue for that matter, the vehicle's fuel trims need to be closely examined. Make sure the system is in

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closed loop and examine the FTs at idle, 2000 rpm no load and 2500 rpm loaded. I would suggest graphing both short term fuel trim and long term fuel trim on both banks in addition to both upstream and downstream oxygen sensors, if applicable. This gives the tech a window into the engine's ability to "fuel" the engine and the PCM's control of its fueling.

Few, but common, problems to look for

There has been lots of information put out there about the most common failure with the GDI engine: the carboning of the intake valves. There are as many remedies as there are OEMs, all with different degrees of success. We are going to examine some of the failures techs have encountered and the process by which they came to accurately diagnose them and the thought process that went along with it.

The GDI injection system requires significant high fuel pressure to be generated by the HP fuel pump, which is driven by a camshaft lobe via a roller follower "bucket" that sits in a housing atop the camshaft (oftentimes the housing doubles as a cam bearing cap). The PCM controls the stroke of the HP pump via the FVR (Ford term) or the fuel volume regulator. Pressure is output to a solid steel line that is a "one use" application — if it is loosened or removed it must be discarded and replaced. It has a style of fitting that crushes and seals when the line is torqued. Remember this system can produce hundreds to thousands of pounds of pressure — a definite safety concern! NEVER attempt to access the high-pressure side of the system until you've followed the OEM process for relieving the pressure in the lines.

There is a pressure sensor on the GDI high-pressure fuel rail that the PCM uses to monitor the pressure and

PHOTO: BOSCH

THE INJECTORS USED IN GDI SYSTEMS can be conventionally operated or use piezoelectric crystals to open the pintle.

to look for validation when it asks the FVR to ramp up the HP pump to generate more HP fuel pressure.

So, what if the pump fails? How would you expect it to behave? How would it manifest itself in the scan data? If it fails to generate enough HP fuel pressure, the desired and actual PIDs will not be close to equal. The actual will be less than the desired if the pump is weak and the fuel trims should show the PCM's compensation by adding fuel for a leaner than normal condition.

But what happens if the pump fails in a more common yet less conventional way? What happens if the pump leaks? Where will the fuel that leaks from it go? The HP failures that I know of caused by the HP pump tend to leak into the crankcase! How will this failure manifest itself in scan data? The desired fuel pressure and actual fuel pressure PIDs (Parameter Identifiers) are not going to match. The tech may see the corresponding drop in pressure when the pump loses pressure when it is shut off. Moreover, how will we expect our FTs to behave in this scenario? The leaking fuel into the crankcase is diluting the oil with what? Answer — hydrocarbons! Now think about the PCV system pulling a vacuum on the crankcase and picking up the HC-laden oil fumes and reconstituting them in the air-fuel mix via the intake manifold. If your answer was exhaust gases exhausting the engine will be richer than a normal running engine, you are correct! Subsequently, the PCM will see this and try to restore the engine to stoichiometry by pulling away fuel or shortening the base pulse width of the injectors. This change manifests itself in negative FTs. But let's say for the sake of argument that a leaking GDI injector could similarly tip its hand. How could a tech use a scan tool to differentiate between the two? The tech could use the GDI fuel system balance test for one. But let's say the tech did not have that ability on their scan tool. Can you think a simple way to check and see if the negative FTs are a result of the GDI injector leaking or a leaking HP pump to CC? How about noting the FTs and then take the PCV system out of the loop, if the negative trims trend back toward positive with the PCV is removed the HCs (rich condition) is most likely coming from a leaking HP pump. The oil level should be

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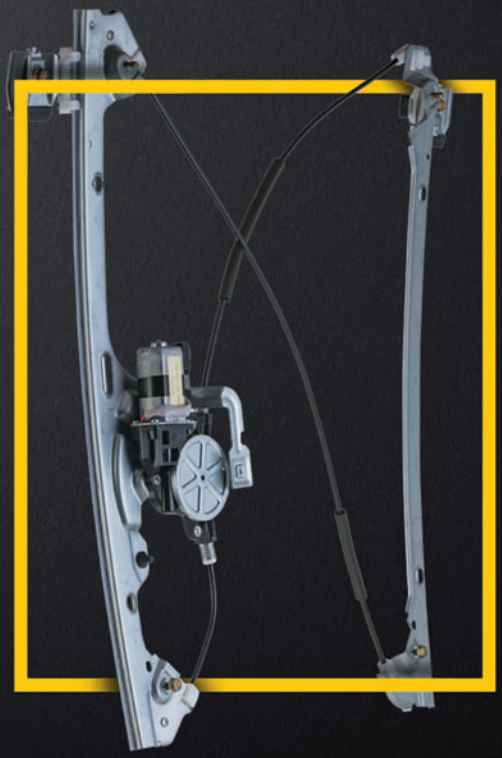

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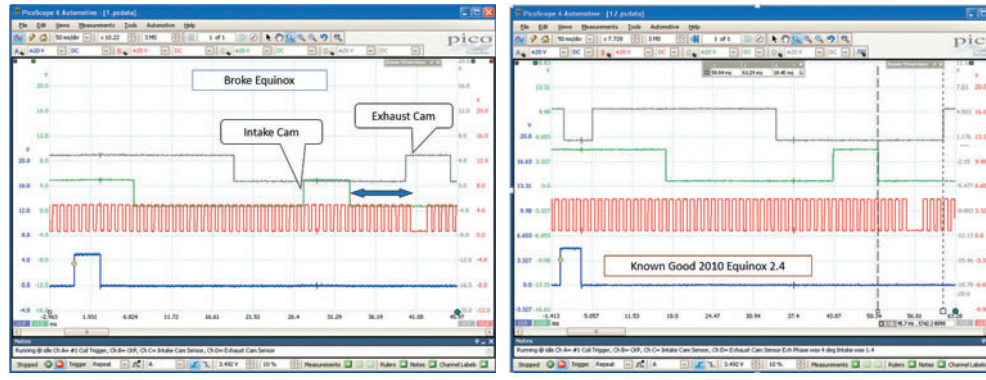
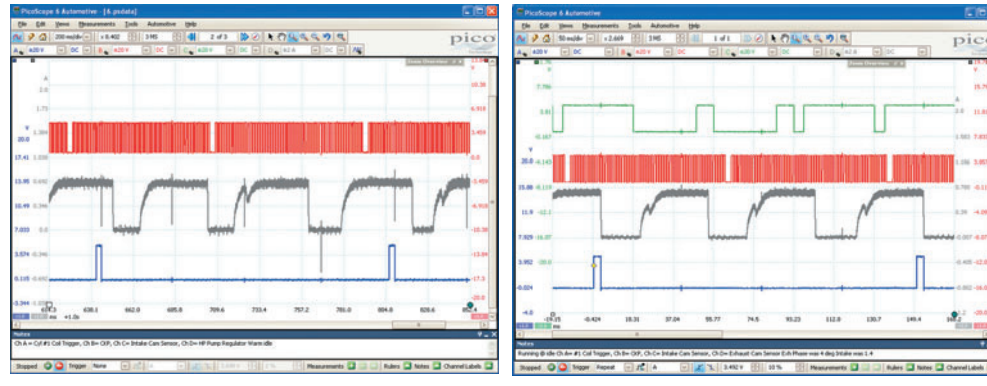
checked for being higher than normal and see if it smells of fuel.

An interesting case

We have investigated a couple of the more common "pattern failures." How about looking into some more off the beaten path? The following case study was shared by former *Motor Age* contributor, trainer and diagnostician Scot Manna. The vehicle in question was a 2010 Chevrolet Equinox with 2.4 liter inline 4 cylinder with GDI. The history of this vehicle was that it arrived at the shop a couple of quarts low on oil and had the MIL on with cam phaser codes.The codes were believed to be a result of the obvious lack of oil.



THE BROKEN EQUINOX SYNCH PATTERN (left) shows that base timing is off when compared to a "known-good" Equinox (right).



LOOKING AT THE CURRENT RAMPS of the failed vehicle and the known good sheds light on the issue. Note the missing pintle humps on the first capture versus the consistent humps on the "known-good."

PHOTOS: SCOT MANNA

An oil change was performed and new oil filter installed, the cam phaser operation was confirmed and codes cleared and the vehicle was returned to the customer.

Three or four months later the vehicle returned with an MIL complaint. A scan was performed and the following codes pulled: P0016 (CKP/Intake CMP not plausible), P0017 (CKP/Exhaust CMP not plausible), P0089 (Fuel Pressure Regulator Performance), P0172 (Rich Exhaust) and P228D (FPR 1 Control Performance — High Pressure).

So is the CKP/CMP issue causing the Fuel Pressure Regulator Performance and Rich codes or is it the other way around? GMSI is accessed and the codes and some research is done. It would seem logical that a fuel pressure regulator and a rich condition could be correlated. The service information referenced seems to agree. The code diagnostic for P0089 also lists P228D as well.

Part of the enable criteria for setting the above codes is that P0016 or P0017 are not set. Scrolling down and reading on listed in the "diagnostic aids" section is a note that any problem with the camshaft timing can cause high pressure codes to set due to the proximity of the HP to the camshaft and the fact that it is camshaft driven. This seems more logical, but the two statements seem to contradict one another. A logistical plan of attack is needed indeed! The OE scan tool GDS 2 and a scope will be used.

The plan was straightforward — the intake and exhaust camshaft position codes must be diagnosed first before looking into high-pressure pump control. A CKP\CMP synch test is performed with a lab scope. The scan tool graphing the high pressure shows that currently high pressure cannot be controlled properly by the PCM. The graph also shows that the PCM is trying to get it under control.

The lab scope is hooked up to the CKP (Crankshaft Position Sensor), both Intake and Exhaust CMPs (Camshaft Position Sensors) and an ignition sync was included. A known-good waveform is acquired for comparison. A quick comparison shows the base timing of the engine is indeed out. But what is the correlation between the CKP/CMP correlation and PCM's inability to control the HP pump? Could the timing of the camshaft that drives the HP pump be off enough for the stroke of the HP pump to be causing it to work against itself? Wouldn't this cause the pump not to work properly? This vehicle does start and run. Moreover, how could a tech prove this theory?

Perhaps doing the "extra test," which I refer to as the Manna Mantra, will shed some light on this. The scope is now going to be used to examine the HP current. The scope captures show the HP pump regulator current while running at idle with very high rail pressure. Note there are missing pintle bumps seen in the waveforms!

It appears the actuator may not be able to move the pintle due to too much pressure in the pump chamber. A known-good HP pump current waveform obtained from a good running vehicle tells the rest of the story. The pintle bumps are indicative of the pump chamber opening and closing.

There is a definitive difference between the broke vehicle captures and the known good vehicle waveforms. The base engine timing was out of time. The engine repair was performed and codes are cleared. The codes did not return.

Another head scratcher!

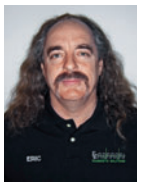
But how about a failure of another sensor that manifests itself as a GDI issue. This case comes to us courtesy of our friends at Gladney Automotive Solutions in College Station, Texas. The vehicle is a 2015 GMC Canyon with a 2.5 L 16V GDI engine. The vehicle was involved in a significant frontal collision and was repaired by a body shop. Afterward, the vehicle is reported to misfire occasionally, have idle issues and a P0506 code. The technician starts by looking into the scan data and notices that the fuel trims are negative for a rich exhaust condition. The total FT (long term + short term FT) is nearly -35 percent at times.

A quick search for TSBs is done and the P0506 turns up in a PI #PIP5529B. The PIP doesn't seem to apply the PI deals with stalls due to the intake bolts working loose. The vehicle intermittently has a misfire reporting on cylinder number 2. The plug was removed and is carboned. The vehicle is clearly running rich. The GDI injectors were scoped with a Pico scope. The PCM is driving the injector and if the injector was causing the misfiring cylinder one would think the FTs would be lean, not rich. But what about a leaking injector? What if the HP fuel pump was leaking to the crankcase like the earlier case study? The injector balance test is performed with GDS2 and the injectors all have relatively the same pressure drop. The vehicle seems to pass the GDI pressure test. The PCM is driving all the injectors per the Pico scope. The vehicle is no longer misfiring on cylinder 2 now and the FTs have dropped to -15 percent. The tech removes the spark plug on cylinder 1 and notices that it too is carboned up.

The vehicle's owner was contacted and is insistent that the problem was not there, pre-collision.

A little diagnostic detective work reveals that the front impact damaged the AFS (Air Fuel Sensor) in the front exhaust manifold. A closer inspection reveals a shiny sensor installed in the manifold. What if the incorrect part had been installed? The technician believes that a closer look is in order and removes the sensor. The problem has been located — the incorrect sensor had been installed in the vehicle -a regular Zirconia-style O_2 was installed in place of a wideband Air Fuel Sensor! The correct sensor is installed and the problem is corrected.

Most of us have become accustomed to diagnosing PFI systems. GDI injection diagnosis may seem a little more challenging but it is basically no more complex. The pressures are considerably higher and there is a mechanical element involved — the HP pump is cam driving. But when a technician uses the resources available to them in a systematic way, the diagnosis of HP GDI systems is not any more complex than its low-pressure cousin, PFI.



ERIC ZIEGLER is an ASE Certified Master Tech who specializes in module programming, drivability, electrical and network systems diagnostics. He owns and operates EZ Diagnostic Solutions Inc. and is a trainer for Automotive Seminars and The Driveability Guys.
eric@diagnosticsolutions.com

ELECTRICAL 101

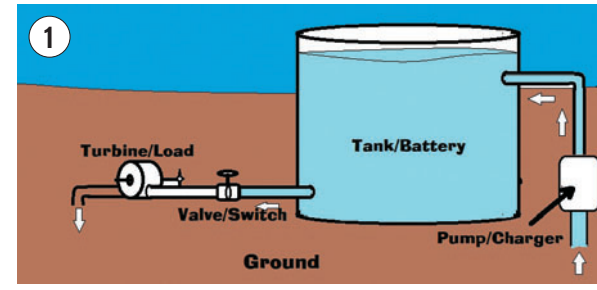
ANY SOLID ELECTRICAL FOUNDATION MUST BE GROUNDED IN BEDROCK PRINCIPLES

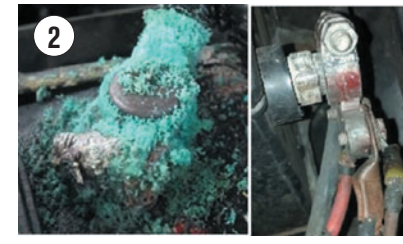
RICHARD MCCUISTIAN //
Contributing Editor

During my career as an instructor, I taught basic electrical theory several different ways, but one of the more successful ways I've used is that of a water tank (the battery) and how the water in the tank will flow out wherever there is a pipe connected to the tank (**Figure 1**). The more water there is in the tank, the more pressure there is on the pipe (more voltage, more electrical pressure). If the water tank is empty or almost empty (dead or weak battery), that needs to be fixed first. Conventional theory says flow goes to ground after passing through the load.

Put a valve in that pipe and you have a switch. Opening the valve in the pipe would be like closing a switch; opening the valve releases water pressure and closing a switch allows current to flow to a load (think water wheel or turbine). If the pipe is clogged where it leaves the tank (dirty cable connection), there won't be enough flow even if the switch is open and the tank is full. Resistance can be illustrated using the size of the outlet connected to the pipe — a small outlet would represent more resistance and a large outlet less resistance.

It doesn't matter which side of the load the switch (valve) is on, the load won't operate unless the switch is closed (valve is open). Color that ground-side versus power-side switching. Partially closing the valve is like adding resistance to a circuit, which reduces the flow of current. Of course, you can't partially close an electrical switch, but switch contacts can develop resistance over time, which would work the same way. With resistance in the switch contacts, the load in that circuit can't receive as much current and can't do as much work, but resistance coupled with current produces heat, oxidizes terminals and melts connectors.





The water model breaks down somewhat at this point because, unless you're using thousands of pounds of pressure, adding resistance by partially closing a valve doesn't produce heat the way resistance does in an electrical circuit. And while the size of a water tank doesn't change, the inevitable loss of cold cranking amps in a battery basically means the battery keeps losing capacity until it is too small and weak to spin the starter.

Refilling the water tank is like recharging the battery. In a charged battery, the electrons (negatively charged) have been forced to the positive side of the plates and they desperately want to travel back to the negative side of the plates in that battery. Think of that as electrical "gravity." Whenever there is an available path back to the negative side of the plates in the battery, the electrons will travel as quickly as they can in that direction like water running downhill. Without resistance (like a dead short), the circuit becomes the load, and the weakest part of it can get hot enough to melt, and the battery will be drained at a very high rate until melting breaks the circuit. Fuses and circuit breakers are used as weak links in the circuit to protect the rest of the circuit from damage. Anybody who has had to replace a bunch of melted wires understands this.

Some people use the army men principle to illustrate electricity, and that works too, but the point is that those of us who teach want our students to understand why electricity does what it does, and while Ohms Law is something I always made my students memorize, we don't often use it when we're working on electrical circuits.

But once we learn to understand how and why current flows, we need to learn how to measure volts, amps and resistance, and we definitely need to understand (and cover) voltage drop (**Figure 4**), which has received thousands of pages of print over the last 20

PHOTOS: RICHARD MCCUISTIAN

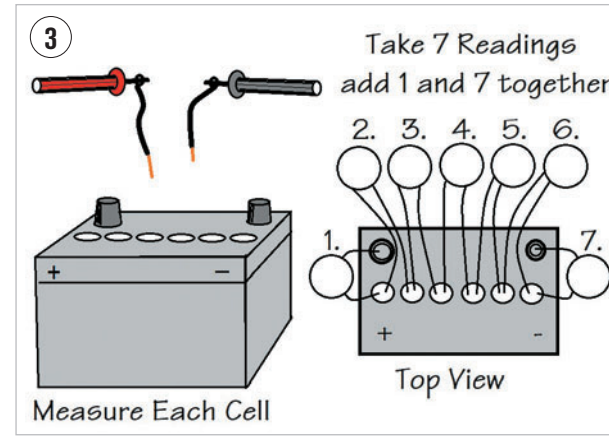
years in this magazine and others, so we'll touch on that just a bit too. And then there's the tremendous need to understand schematics, but that's for another article and another time.

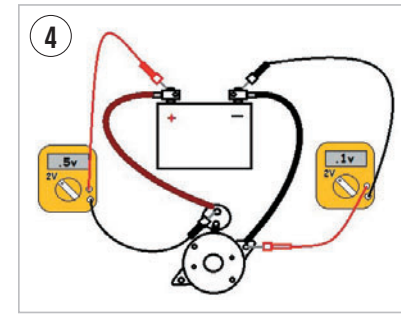
This article isn't just about batteries, but before we go on, it bears mention that any and all electrical troubleshooting of a circuit that is operating poorly or not at all should begin with a reliable test of battery health and a comprehensive inspection and cleaning of the battery terminals (**Figure 2**), even if they don't look like they need it. One of my graduates who works at a Ford dealer once fixed a puzzling transmission problem on a Power Stroke diesel by just cleaning the battery terminals. As for older GM vehicles, most seasoned mechanics know how those side-post battery terminals are so dreadfully good at concealing voltage-dropping corrosion.

For a quick and reliable battery test, I favor using tools like the MidTronics PBT 300 to measure battery CCA because it's quick. If you do a quick test of the battery without removing the terminals and then do another test of the battery with battery terminals removed, you can compare the readings and get a bit of data regarding resistance between the terminals and the battery posts.

Specific gravity testing with a refractometer is a good test too, but for years I also taught all my students to perform the age-old Sun Battery test (**Figure 3**), which is seldom used in the real world around here.

To perform that test, I like to wrap a piece of copper wire around the tip of my voltmeter and probe the fluid in each battery cell on batteries with removable caps, comparing the voltage among cells. The battery charger needs to be connected and turned on briefly while each reading is taken but turned off between measurements. According to the ancient Sun specs, any deviance between cells of more than 0.1 volt during this test is grounds for battery replacement. Sun also calls for a repeat of the test with each cell loaded at half the battery's CCA, but I usually just taught the charging element of the test. I condemned a few batteries this way when I was working at the dealer — it's a good data set.





Putting a battery on high charge and checking the voltage after 3 minutes, the charging voltage should be less than 15.6 volts — if it's higher than that, the battery is sulphated and needs replacing. That's a go-no-go test.

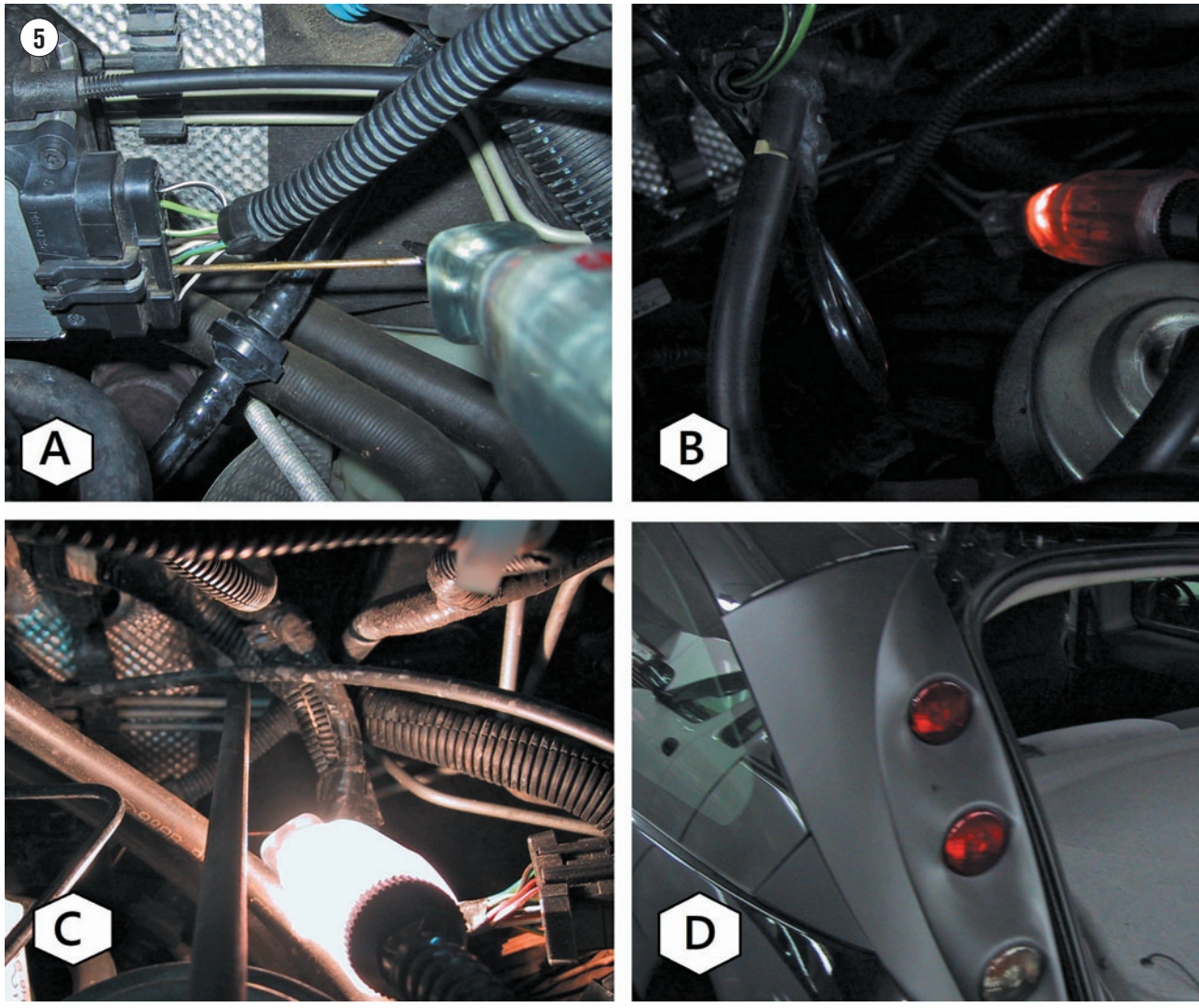
Tools

For just about any job we do on a vehicle, we need to have tools we can trust, and first off, we need to know which tools and methods will deliver viable results. Just about any kind of troubleshooting requires the gathering of reliable data, and bad data is almost as bad as no data.

For the first 10 years of my professional career (early '70s to early '80s), I used a test light for just about everything and almost never picked up a voltmeter except to check available battery voltage. Then when I started doing electronic engine control work, I splurged on a $50 DVOM from Radio Shack — I realized I needed a meter to know how much voltage was present rather than just knowing there was voltage there, since sensor signals are primarily voltage, with practically no amps.

It was about this time that just about all the OEM automotive and heavy truck instructors began to tell mechanics to throw their test light away and ONLY use a meter to work on modern vehicle systems. The first time I heard this I mentally discarded it — and while I owned a meter and a logic probe, I never stopped using my low impedance test light, because using a meter on everything can be troublesome and misleading for a person who doesn't understand voltage drop, resistance and current flow. Logic probes are good for quick power-and-ground verification, such as in power window and door lock testing, but beyond that, I haven't found them to be particularly useful. My test light can tell me things a meter can't sometimes (**Figure 5**).

Ford's early shop manuals sometimes had us measuring voltages in their pinpoint tests when we actually needed to know a lot more than how many volts were present. One day I got smacked around by an ABS problem on a Taurus because I was told to check the voltage at a particular relay



output terminal and that it should be higher than 10.5 volts. If it was, I was to move on to the next step. It was 11 volts, so I moved on when I shouldn't have. At the end of that shop manual test procedure, the concern was still there. When I got my test light out, I found that the relay had dirty contacts and, while it showed 11 volts unloaded, that 11 volts dropped to zero as soon as the ABS controller put any kind of load on that circuit. When I saw that the current leaving the relay wouldn't illuminate the 0.25-amp test light bulb I realized I had a bad relay and in that case, testing with ONLY a meter had cost me a lot of time. As a digression at this juncture, I'm not going to say much about relays in general in this article other than to state that it is dreadfully important to understand how a relay works, and everybody should know how to properly test one. Just because a relay "clicks" doesn't mean it can carry a load.

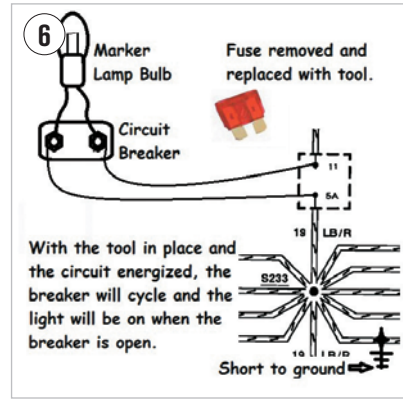
This voltage drop concern can obviously also happen on a ground circuit as well. One of our trainer vehicles, a 1998 Ranger, developed a no-start bug that I didn't plant. There was no fuel pump operation. With the fuel pump disconnected at the tank and my test light installed, I got bulb illumination between the fuel pump power pin and the connector ground pin, but since an electric fuel pump pulls about 5 amps when it's moving fuel, I removed the test light and wired up a 5 amp load — a halogen headlight bulb, which, by the way, didn't illuminate when the fuel relay closed, just like the pump didn't run. The problem turned out to be on the ground side of that circuit, but rather than tracking it down, we ran another ground to the frame and the pump went back to work.

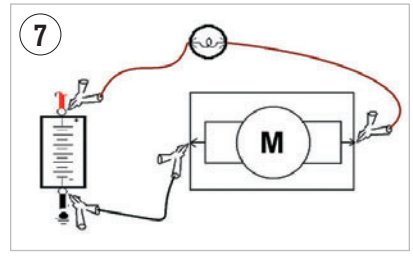
Imagine how confusing it would have been to disconnect the fuel pump and use a meter to measure voltage at that connector. Backprobing the

connector with the pump connected would have shown no voltage.

In this case, though, a low impedance test light wasn't even sufficient at 0.25 amps of load. With that in mind I always try to use a test load that matches the load the circuit normally carries.

Searching for short circuits can be made simpler with a self-resetting 8- or 10-amp circuit breaker wired parallel with a small light bulb and connected in place of the fuse. The circuit breaker will keep resetting every couple of seconds until you find and remove the short by disconnecting or manipulating harnesses, etc. (**Figure 6**).





Methods

Okay, so we need to know how to use (and read) a meter, a test light and a logic probe. Auto-ranging meters are only good if you're in tune with the symbols and decimal points, so be careful. One of the most needful uses for our DVOM is the voltage drop test where we check just one side of a circuit from point to point to see how much is being lost along the way. This is most regularly done with starter circuits, but this will work on dim headlights or any other poorly performing load. For just one easy example, by connecting one meter probe to the positive battery terminal and the other one to the headlight connector where power is flowing and then from the ground side of the battery to the ground terminal at the headlight. Of course, current must be flowing to take this measurement, and if you find voltage drop on either side of the circuit you have to find out where it's being lost by narrowing your measurement points. Checking voltage drop across fuses to find parasitic drains is a good practice if you set your meter on the lowest voltage setting, and we've seen lots of articles on that. FLIR cameras are also good for finding the hot relay or whatever when searching for a parasitic drain.

Another indispensable function is the meter's "amps" function. With the positive lead moved to the amps measurement port on the meter and the selector switch set accordingly, the meter becomes a jumper wire (literally) that can report how much current is flowing, and that's tremendously helpful when chasing parasitic drains (although an inductive probe with a scope is better for this). Also, you can remove a fuel pump relay and feed power to the fuel pump through the meter to measure fuel pump current. If the pump is spinning dry it'll only pull a little more than 1 amp unless the pump motor has overheated and has partially melted windings. If it is moving fuel it'll be pulling between 4 and 9 amps. If, however, the vehicle has a fuel pump module instead of a simple relay circuit, you'll need to perform that test at the pump module connector instead. Oh, and when you're done with an amp test, always remember to move your meter's test probe back to the Volts port on your meter if you don't want to have to buy a $10 fuse for your Fluke when you go back to measuring volts.

One of the more useful tests I came up with for a test light is the fan test, where you remove the fan relay and connect a test light from the hot side of the battery to the terminal leading out to the fan (**Figure 7**). The light will illuminate and then when you slowly turn the fan through, if it goes out at any point, you have a bad fan motor. That's a go-no-go test I developed when I was at the Ford dealer. I had never seen anybody else do that, but I started doing it on Tempos that would sometimes trigger the popoff valve on the A/C compressor when sitting at a traffic light.

You can also check A/C clutch circuit for continuity this way. Any current bearing load circuit can be checked using this same method. I used it to test for fuel pump circuit continuity when checking no-starts 'way back in the 80s.

The basic tenets of what I'm saying here is that a solid understanding of volts, amps and ohms and how they interact in vehicle electrical systems is one of the key elements of vehicle electrical work. The other key element in electrical work on vehicles is knowing which tools to use, when to use them and knowing how to interpret the data. Without those basic skills, it's easy to get lost.

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HORSEPOWER AND TORQUE

UNDERSTANDING THE TWO TERMS IS DEPENDENT ON UNDERSTANDING THE HISTORY BEHIND THEM

TRACY MARTIN // Contributing Editor

How much power an engine produces has been a subject surrounded by controversy since the advent of the steam engine in the late 18th century. Defining the illusive horsepower number has always come down to who you ask and what machine (dynamometer) was used to measure it. To understand horsepower, the concept needs to be put into historical perspective.

"Show me the money!" A great line from the movie *Jerry Maguire* is one way to look at why horsepower measurement from its inception has been a moving target. The dollars and cents of measuring an engine's power is easy to understand. For example, if an engine made by Ford makes 300 horsepower and Chevrolet makes an engine that produces 310 horsepower, and both engines sell for the same price, which is more desirable? This logic applies not only to engines but anything that can be bolted on to an engine, like an aftermarket exhaust system, for example. Many aftermarket exhaust manufacturers advertise that their systems will increase the power output of an engine by some amount. If two similar systems claim different power increases, one will have an advantage in the marketplace.

Chevrolet, Ford, Chrysler, Mercedes-Benz, Porsche, Audi, Nissan, Toyota and other manufactures all are trying to sell products, and if horsepower is a factor in the equation, more can only be better. Read the latest review of any high-performance automobile in an enthusiasts' magazine and more than likely horsepower will be listed as a means of comparison between similar cars. It's only logical that if horsepower sells, then measuring a higher vs. a lower number is going to take place. Horsepower is measured using a device called a dynamometer and while these machines don't produce power like an internal combustion engine does, they have something else in common. When it comes to advertising horsepower numbers, more is always better.

Every company that manufactures dynamometers has a practical reason to steer potential customers away from their competition by pointing out why the other guy's dyno produces inflated horsepower numbers. This practice is just "business," and screwing around with the numbers that calculate horsepower has been going on for a while — since the early 1800s. In 1712, Thomas Newcomen designed the first commercially successful steam engine, but it was not very efficient and had limited uses, mostly pumping water out of deep mines. Scottish inventor and mechanical engineer James Watt came up with a vastly improved version of the steam engine in 1764 that used 75 percent less coal than the Newcomen engines. Watt's business plan was to collect royalties from his customers based on one third the savings in coal that a similar sized, older steam engine consumed. This payment plan worked for customers who had existing steam engines and could track their use of coal, but mine operators who still used horses needed a differ-

PHOTO: FROUDE HOFMANN

THIS FROUDE HOFMANN HYDRAULIC DYNAMOMETER measures power for marine engines and can absorb 39,440,000 (million) foot pounds of torque and 650,000 horsepower. It's more than 9 feet in diameter (see worker on scaffold for scale). If you think it's big, you should see the engine that it connects to! Its cost — a mere $5 million. Despite its size, it operates in the same general way as all water brake dynamometers.

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ent way to calculate what they would pay for this cutting-edge technology, Watt's steam engine.

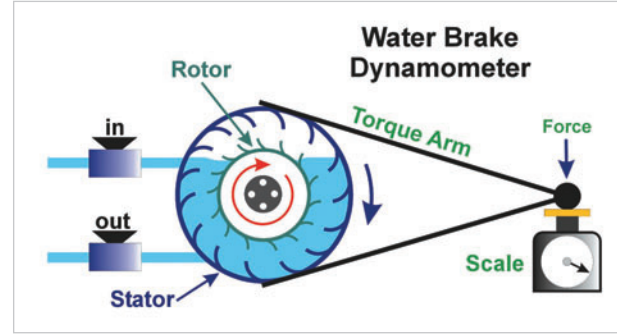
Watt's plan to entice mine owners to purchase one of his steam engines was based on how many horses the owners could replace, and that depended on knowing how much work a single horse could perform over a period of time. If a horse could raise a bucket of coal weighing 366 pounds up a mine shaft at the rate of one foot per second, in one minute the horse could raise the bucket 60 feet.

With this information, Watt calculated that the horse could raise 21,960 lbs. one foot in one minute. Watt experimented further and in 1782 found that a brewery horse (a large breed) was able to produce 32,400 foot-pounds of work per minute. Watt rounded that number up to 33,000 foot-pounds per minute and that became the standard that is still used today. Other engineers at the time place that number far lower at 22,916 ft. lbs/min. Few horses of even the largest breeds can pull that much weight for any length of time and speculation started that Watt had exaggerated the number to his advantage for the purpose of over valuing his steam engine's capabilities. Another view is that Watt was just applying good marketing techniques by comparing horses (a familiar form of power and effort at the time) to new technology — the steam engine.

Dynamometers

It took almost 50 years before a practical way was invented to measure the power produced by a steam engine. The first dynamometer was invented in 1821 by Gaspard de Prony. The de Prony brake, as it was called, was used to measure the performance of engines and other types of machines. This type of dynamometer, or power absorption unit, is called a water brake and is still in use today. It can measure anything from a Briggs and Stratton lawn mower engine that makes 2 horsepower to marine diesel engines that make considerably more — the Froude Hofmann model RLS295 dynamometer can absorb 39,440,000 million foot-pounds of torque and 650,000 horsepower.

A water brake, or hydraulic dynamometer, basically consists of two half couplings — a rotor and stator. The stator is stationary and the rotor is connected to the engine's flywheel. The rotor and stator have semi-circular shaped vanes that direct the flow of water as the engine turns the stator. Water or hydraulic fluid flowing around the vanes create a torque reaction through the dynamometer casing, or stator, which is free floating so that a slight rotational movement takes place when under load. The outer housing doesn't rotate because a torque arm holds it in place. The arm is called a torque arm because it "feels" 100 percent of the engine's torque trying to rotate the outer housing as the engine tries to twist or load it. Before electronics, a scale was used to measure the load from the torque arm.



THE WATER BRAKE DYNAMOMETER is basically an inefficient pump and uses the engine's power to make hot water. This design has been around since 1821 and is still in use today.

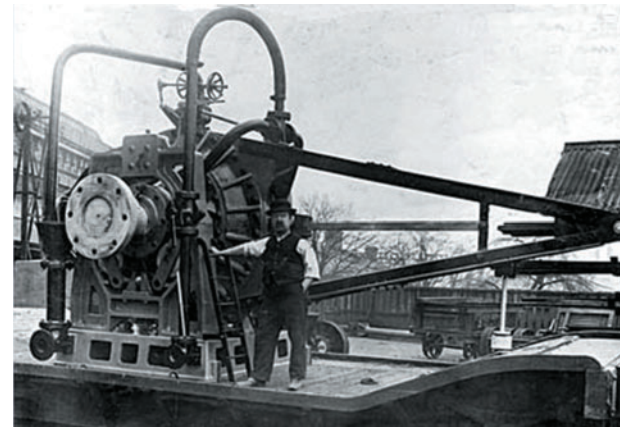


PHOTO: FROUDE HOFMANN

IN 1877 WILLIAM FROUDE INVENTED the hydraulic dynamometer or water brake. Pictured is a large version of an early water brake circa 1900 — a model FA7, Froude Hofmann. The torque arm is easily visible to the right and looks to be almost 15 feet in length. The company was established in 1881 and is still in business providing design and manufacturing of high-technology, specialized test equipment. They produce power measurement products for engines used on ships, automobiles, aircraft and even motorcycles.

Today a load cell transducer or strain gauge converts the force applied to the torque arm to a digital signal that is sent to data acquisition software on a laptop or PC. Engine loading, or how much the stator is resisting the engine's torque, is controlled by varying the level of water in the rotor housing using inlet and/or outlet valves. Raising the water level increases the rotational drag of the water brake's rotor, applying more resistance or load to the engine. By design, the water brake is an inefficient pump and uses the engine's power to make hot water. Large water brake dynos use a cooling tower that could be as large as a building to dissipate the heat from the water; smaller versions can use a garden hose.

DC generator – AC motor dynamometers

An alternative to the water brake is the electric DC, or AC motor that provides power absorption as well as serving to drive

an engine to measure frictional torque or produce real-world road conditions. An engine coupled to a DC motor can use its power to drive it, essentially turning it into a DC generator. The electrical output of the DC generator can be calculated and converted into torque measurements. The electric motor dynamometer can work in reverse in that it can drive an engine to determine its frictional horsepower losses. Large AC electric motors are also used to provide load absorption. They provide the same functions as the DC motor/generator. These types of dynamometers are very accurate and can regulate engine speed within a couple of RPM and have the ability to adjust engine loading from zero to 100 percent in microseconds. Because of their high cost, these types of dynamometers are used for laboratory-grade engine development by OEMs.

Eddy durrent dynamometer

Similar to a DC generator power absorption unit, the eddy current brake type dynamometer also uses electricity to place a load on an engine. The difference between the two is the eddy current brake does not generate electrical current. The engine being tested is connected to the dyno's input shaft spinning a metallic rotor that creates a magnetic field. When current is increased to the dyno's internal electromagnetic coils, the rotor shaft becomes harder to rotate and thus loads the engine. Torque load is measured using a strain gauge similar to those used on a water brake dynamometer. The rotor gets hot as the dyno resists the engine's power and must be cooled usually by the use of a fan.

Inertia dynamometer

There are basically two types of dynamometers in use for testing automobiles: load and inertia types. Load dynamometers require a direct connection to the engine and are not practical for use outside of an engine laboratory. The inertia dynamometer (aka chassis dynamometer) is far more commonly used as the vehicle's drive wheels are placed on steel rollers to measure power output. Unlike a load type of dynamometer, the inertia type doesn't measure torque, but instead calculates it by measuring acceleration. An inertia dyno calculates engine power output by measuring the time it takes for the car's drive wheels to accelerate a heavy steel drum. Force at the surface of the drum is measured indirectly by measuring its acceleration from one revolution to the next. Force is calculated using Newton's 2nd law, Force = Mass x Acceleration. Because the mass, or weight, of the drum is known, force (horsepower) can be calculated. A typical dyno run begins with the engine running just over idle with the rear tire turning drum. When the throttle is opened the engine accelerates the dynamometer's drum as engine speed increases to redline. Computer software used with inertia dynos can accurately measure acceleration of the drum over small increments of time and calculate a value for torque. Using torque and engine RPM, rear wheel horsepower can be calculated.

The reason that inertia types of dynos are not used by OEMs is that there is a significant loss of power due to the vehicle's drive train. The dyno industry figure for this loss is typically set at -15 percent, but this is far from accurate, as each vehicle uses a variety of components/designs to get power from the engine's flywheel to the drive wheels. Real-world drivetrain losses may be as high as 40 percent or more. However, despite drivetrain losses, an inertia dyno is an effective, cost-friendly way to measure the effects of vehicle tuning and modifications. With a skilled operator, dyno runs can be repeated with the accuracy needed to determine the effects of aftermarket performance engine components.

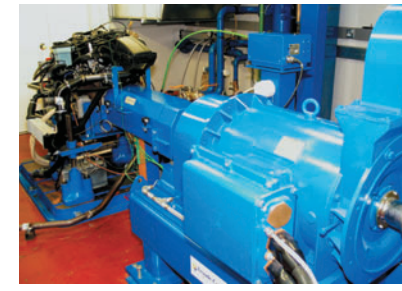


PHOTO: FROUDE HOFMANN

THIS AC MOTOR DYNAMOMETER is manufactured by Froude Hofmann — the RSL130. It's used in the automotive industry for engine development. It can absorb power as well as drive (power) an engine to simulate real-world road conditions. The RSL130 can absorb 130kw or 174 horsepower.

PHOTO: DYNOJET RESEARCH

IN 1877, WILLIAM FROUDE INVENTED this Dynojet eddy current load absorption unit, which is ideal for testing automobile engines because of its quick response and loading capabilities. The electromagnetic coils are located next to the heat absorption rotor. The rotor looks like a disc brake and has large cooling fins and passages to dissipate heat created by loading an engine during a dyno run.

Measuring torque

Before we discuss how a dynamometer measures horsepower, torque must be understood. Torque is the "twisting" energy that an engine produces at its crankshaft or flywheel. Torque is measured in "foot-pounds" (ft-lbs.), which is also the common terminology used in the United States to specify the tightness of a bolt. Torque can also be expressed in "pound-feet" and the difference, or confusion created by the two terms, is in what they technically measure. The "pound-foot" is technically used to measure the

twisting force applied to a bolt or fastener. This type of torque is static torque, because it's measured when a bolt stops turning and reaches a predetermined torque value. A torque wrench is used to measure how much twisting force is applied to a fastener. The torque wrench indicates to the user how much torque is being applied. This type of torque is called static torque because there is no acceleration involved when a fastener reaches its final torque value as measured by a torque wrench. To add confusion, torque wrench measurements are expressed in foot-pounds or inch-pounds even though this is not technically correct.

"Foot-pounds" is a measurement of work defined as force over a given distance. Foot-pounds is used to measure the dynamic torque of a turning shaft. Dynamic torque is different than static torque because it involves acceleration. An engine can produce both static and dynamic torque. For example, if a car is being driven at a steady throttle opening on a flat surface, the type of torque produced by the engine is static because there is no acceleration of the engine. When the throttle is opened and the car accelerates, the torque produced is dynamic. Dynamic torque is determined using a dynamometer and can be measured at the engine's crankshaft, transmission output shaft or at the drive wheels. The two terms are often used interchangeably even though they measure different types of torque. Foot-pounds will be used in this article to refer to torque as it is the common American terminology.

Calculating horsepower

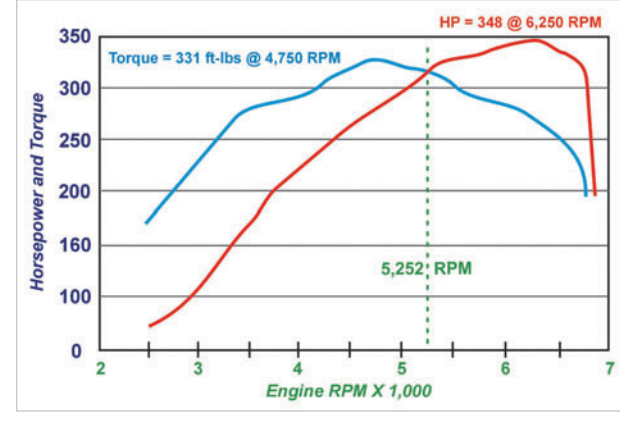
An engine's horsepower output can't be measured directly but is a calculation of torque multiplied by the engine's speed. The formula for horsepower is: Torque x Engine Speed, divided by 5,252 equals horsepower. The number 5,252 is the result of lumping several different conversion factors together into one number. A quick internet search for "horsepower 5252 constant" will provide a detailed explanation of how the number is derived. On most dynamometer graphs (see **Figure 1**) that show horsepower and torque curves, the two curves always cross at 5,252 RPM because at that RPM the two will always be equal. Dyno charts that don't show this are questionable at best.

Horsepower vs. torque

One activity that many enthusiasts participate in is benching racing using horsepower and torque numbers. Often the statement "Torque causes acceleration, not horsepower" is made and while it may make some kind of intuitive sense, it is incorrect. Horsepower and torque are linked by the fact that horsepower is calculated from torque in foot-pounds and engine RPM (HP = T x RPM / 5252). Because of this formula, horsepower and torque are not independent from one another in relation to engine power. For an engine, torque is always listed at specific

PHOTO: DYNOJET RESEARCH

THIS CORVETTE IS STRAPPED DOWN to a Dynojet inertia dynamometer. The steel roller weighs several hundred pounds and has an abrasive surface to keep rear tires from slipping during a dyno run. The rate of acceleration of the roller is measured and used to calculate horsepower. More information about various types of dynamometers can be found at www.dynojet.com.



ALL HORSEPOWER/TORQUE GRAPHS PRODUCED BY DYNAMOMETER SOFTWARE should show horsepower and torque crossing at 5,252 RPM. This happens because at that RPM, torque and horsepower are equal to each other. In fact, below 5,252 RPM the torque will always be higher than horsepower and above 5,252 RPM the horsepower will always be higher than torque. A chart that doesn't show these characteristics has a math problem and is questionable.

RPMs, because no work or power is produced unless the engine is turning. Once an engine is turning fast enough, the force exerted against a load (like accelerating the drum on an inertia dynamometer) and speed at which its work is being accomplished can be measured.

Keep in mind that the connection between torque and horsepower is the rotational speed of the engine. In **Figure 2**, a Corvette 6.2L, LT4 engine generates 658 HP at 5,750 RPM with torque peaking at 651 ft-lbs. at 4,800 RPM. By comparison, a Lotus Formula 1, 3.0L engine makes 932 HP at 12,000 RPM and 508 ft-lbs. at 7,000 RPM. The Corvette's torque is 148 ft-lbs. greater than the Lotus and one might think that in an all our race the Vette's massive 6.2L engine would dominate the much smaller 3.0L Formula 1 engine. However, the

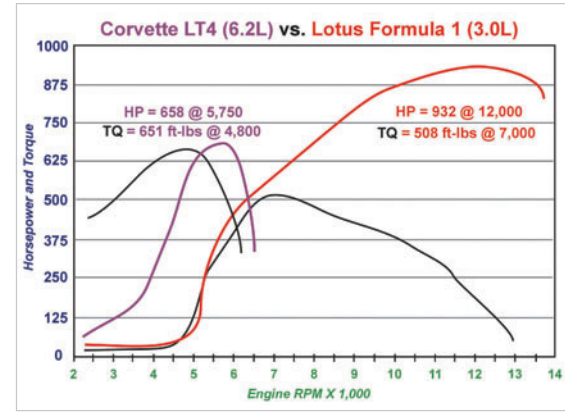
Lotus engine makes up for its smaller toque number and displacement with more engine speed (6,250 RPM more) that translates into 932 horsepower at 12,000 RPM, 247 more than the LT4.

The dyno chart shows that each engine's torque drops after a certain RPM. This is due to the fact that as RPM increases, the cylinders don't fill with air as well as at lower engine RPMs. Cylinder filling is directly proportional to torque production. Horsepower increases on both engines after torque decreases because horsepower is a product of RPM and torque. After reaching its maximum value, the decrease in torque at a given RPM is small, and not enough to offset the increasing RPM of the engine. Overall horsepower increases until the drop in torque becomes large enough that it outweighs the increase in RPM. This takes place at maximum horsepower output and can be seen on both engines at different RPMs — higher for the Lotus and lower for the Corvette.

Putting horsepower in perspective

All automobile manufactures use horsepower and torque numbers to sell performance, image and technology of their products. They test their engines unencumbered by alternators, AC compressors, power steering and water pumps and transmissions. Power measurements are taken directly from the crankshaft under ideal environmental conditions — cool ambient temperatures and sea-level barometric pressure. They can't "adjust" numbers too drastically because of legal issues with advertising claims and most use S.A.E. correction factors to level the playing field.

Most cars and light trucks that are reviewed in magazines have horsepower and torque numbers listed as well. Magazines seldom go to the trouble of removing an engine to have it tested on a dynamometer, but instead use a chassis dyno to measure drive-wheel horsepower and torque. Magazines are a mixed bag regarding how they get their performance numbers. The better magazines will use the same dyno and operator to get all the horsepower numbers for the cars they test. With the correction factors applied, their results are usually consistent. Comparing one magazine's numbers to another is pointless because of the variables in just about everything related to testing.



DESPITE ITS SMALLER SIZE OF 3.0L, compared to the Corvette LT4 engine at 6.2L, the Formula 1 engines produces 932 horsepower, 274 more than the Corvette engine. The difference is the RPM where each engine reaches maximum power. Note that both engines' torque and horsepower are equal 5,252 RPM.

Whether you work in a dealership or independent shop it's a good idea to have a business relationship with a shop that has a dynamometer and does performance tuning. You never know when one of your customers will ask you, "I'm thinking about installing a high-performance exhaust system. How much more horsepower will it make over stock?" If you have worked with a shop that has a dyno you can sublet the dyno work and do the installation of the part in your shop. You can provide the customer with the dyno charts that show before and after horsepower and torque numbers.

Find a local dynamometer service and interview the operator keeping in mind that the performance numbers are only as good as the operator who conducts testing. Ask how long they have operated a dynamometer, what types of cars or trucks they have experience testing, what correction factors are used, what brand of dyno they have and what charts and graphs will be provided when testing is completed. An experienced dyno operator will check rear tire air pressure (a fairly large factor in power output on a chassis dynamometer) and check to see if any emission-related components need to be removed or disconnected before testing. Most importantly, will they take the time to explain the results of testing so you can speak to your customer with confidence regarding power increases (or the lack thereof in some cases). If you have read this article and the dyno operator knows less than you do, look for another testing facility.

Know what your customer's goals are regarding performance modifications they are thinking of making. Are they looking for all-out performance, better acceleration on the highway or simply better fuel economy? One unwritten task of any repair shop is to educate customers so they have confidence in your knowledge and abilities. If they ask engine performance-related questions and you have nothing to say, or worse give them bad information, they'll find another shop for all their repair work.

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SEEK THE SQUEAK AND REVEAL THE SQUEAL

THE NOISY BELT MAY BE A SYMPTOM OF A LARGER PROBLEM THAT, IF LEFT ALONE, COULD LEAD TO A MUCH MORE EXPENSIVE REPAIR!

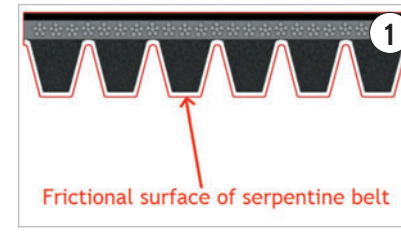
BRANDON STECKLER //
Technical Editor

We have all been here quite a few times. A 1997 model year vehicle is in the shop for routine service, along with the complaint of belt noise after a recently replaced alternator. A dry-rotted, shiny serpentine belt glistens beneath the glow of your inspection lamp. You reach down to manipulate the belt to confirm your suspicions. Upon twisting the belt, the surface area resembles more of the Grand Canyon then it does a drive belt. You replace it due to its terrible condition and then it happens. The new belt is squeaking like a hungry church mouse and we are quick to blame the parts house or the belt manufacturer because of the defective component they've supplied us with. We then decide it is just good sport to replace the tensioner because, after all, what else could allow this brand-new belt to be so audible? Forty minutes into attempt number two and the noise is still present! Realizing only late into the process that the new belt is exhibiting wear marks on the external edge, it becomes obvious that the new alternator pulley is distorted and appears to have been dropped or hammered into place.

Attack the problem professionally

This scenario is all too familiar and I've seen it play out many times in years past. According to Bobby Bassett of GATES Corporation, 99.8 percent of all belts returned as "defects" are indeed the victims of a root-cause failure, and not the belt itself. This poses a big problem for the entire automotive service industry and parts industry as well. If the shop making the claim is not acknowledged, it wouldn't be surprising if that shop sought parts supply elsewhere. So, the parts houses step up to the plate and perform the exchange. But who pays for all of this? In the end, no one is in business to lose money. At what point does the cost of the parts increase significantly to offset this loss? Times are changing, and this practice of returning parts that have not failed will not be as easy moving forward. There is much more to a simple serpentine belt inspection/replacement then hanging a new belt. Stick with me and you'll discover why approaching the accessory drive belt system (ADBS) as a true "system" is just what is necessary to fix the vehicle right the first time.

The ADBS is in place to serve a simple purpose — to transfer torque from the engine to the accessory systems like the alternator, air conditioning compressor, water pump and power steering pump for example. As elementary as that goal may seem, the ADBS has to endure a relatively heavy load for a very long time. It carries out this task in two



different ways. The first and primary job is to remove the slack in the belt that develops over time and maintain adequate tension as the belt wears. The second is to absorb torsional vibrations as each cylinder achieves combustion and as accessory demand changes. The ADBS accomplishes this task through friction and is comprised of only a few components, common to all vehicles. The torsional vibration dampener is the pulley affixed to the crankshaft and serves as the driving member of the system. The crankshaft is coupled to the pulley with a rubber dampening element that absorbs vibrations from the accessories and combustion events. The idler pulley is a free-spinning pulley on which the belt travels to optimize belt routing and suppress flutter. It does this by reducing the distance between other accessories. Newer vehicles have alternator decoupler pulleys that serve as one-way roller clutches. By allowing the alternator to freewheel, it increases the lifespan of not only the alternator but the entire ADBS as well. The tension provided by the tensioner wedges

PHOTOS: BRANDON STECKLER

the ribs of the belt into the grooves of the pulley to create the friction necessary to overcome the load demands of the accessories combined. A tensioner lives a hard life and averages over one billion oscillations in a 100k mile period! It's amazing how much load the accessories place on the ADBS. An ADBS operating a supercharged vehicle under full load can rob an engine of over 50HP! For a belt to maintain the kind of friction necessary to prevent slippage under those loads is no easy feat. It's also imperative that the ADBS is functioning correctly to maintain longevity and keep the entire system operating trouble-free.

What is belt noise?

For the ADBS to operate properly, friction has to be maintained, meaning no slippage is desired. The noise we hear from time to time is the noise from the rubber of the belt rubbing on a component (like a pulley) rather than rolling across and driving it. Belt noise is exhibited by either a squeal (sustained) or a chirp (rhythmic) and either clue points to a different issue. Belt noise is a symptom and typically occurs due to loss of tension, as the real fault is an issue somewhere else in the ADBS system. This can occur for numerous reasons, and it's our job as technicians to determine the root cause of the noise. This can be carried out systematically and the analysis of belt wear can always lead us to a root-cause failure.

To adequately evaluate an ADBS system, we first have to realize that things are not as they used to be. Before the advent of the serpentine belt, we relied on V-belts to drive the accessory components. These belts required periodic adjustment and the systems took up a lot of space longitudinally within the engine compartments. Relative to their surface area, the V-belts provided little friction and at times were a nuisance, because they tended to roll or flip. The upside is that if a belt failed or became displaced, the other accessories (that weren't operated by that belt) still functioned. As the industry transitioned from V-belts to the neoprene serpentine belts, we realized a lot of benefits. The new systems took up less space and provided better friction because the ribs of the belt/pulleys allowed for more surface-area frictional contact (**Fig. 1**). The belts were more fuel efficient and lived a much longer life. Inspection was relatively easy as the belt would exhibit visible indicators of pending failure and reduced efficiency. The main failure characteristics of these serpentine belts include (**Fig. 2**):

Glazing = The shiny, glossy look to the rubber surface of the belt. This is caused by excessive heat build-up and is always the cause of a loss of tension

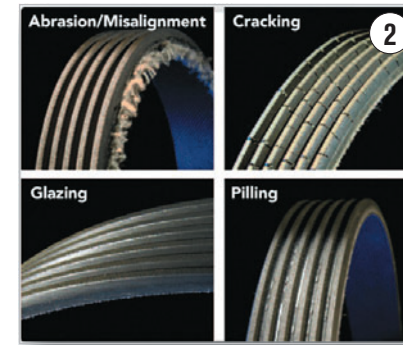
Pilling = This occurs when the rubber drive-surface of the belt becomes disassociate and rolls up into little tar-like balls that collect on the surface of the belt and transfer to the pulleys. It's typically caused by a source of contamination like engine oil, A/C compressor oil or antifreeze.

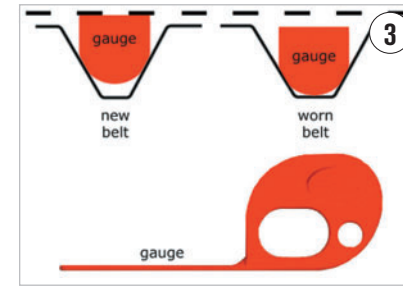
Cracking = Due to heat and age, the rubber begins to dry-rot, get brittle and separate. It's common for this to occur around 50-60k miles with most neoprene serpentine belts.

Rib-Shear = As time goes by, cracking can lead to rib-shear — when the frictional-surface of the belt begins to fall off of the backing. This can also occur due to heavy wear on a particular spot on the belt, caused by a pulley alignment issue.

In with the new

Today's belts are highly engineered and no longer comprised of neoprene like their ancestors. The serpentine belts of today are made of a technologically





advanced material known as Ethylene Propylene Diene Monomer-Class rubber (or EPDM) and it is formulated to withstand heat and prevent dry-rotting, giving the belts a significantly more serviceable life. Where a neoprene belt typically lasts 50-60k miles before showing signs of wear, a belt made with EPDM can go 100,000 miles and still exhibit no visible evidence indicating a need for replacement. With that being said, our evaluation of the belts must change as well. A simple visual inspection will not suffice. These newer belts don't fail or age like the neoprene belts and lose only small amounts of material over time. But even a 5 percent loss of material can cause marginal operation of the accessories leading to complaints like poor A/C performance, for example. Careful inspection must be carried out to prevent these complaints from occurring.

Although this article is focused on the serpentine belt, it's worth briefly mentioning the stretch-to-fit belts as yet another technological advancement. It's a one-time installation belt made with a compound called Polyamide, which gives the belt an elastic charac-

teristic. It's known as a stretch-belt (as the nickname implies), because it is stretched to fit over the pulleys it is intended to drive. It requires a special tool to install the belt properly. The tool also has provisions to remove the belt or the belt can simply be cut with a blade. Either way, the belt is not designed to be used more than once. You've been warned!

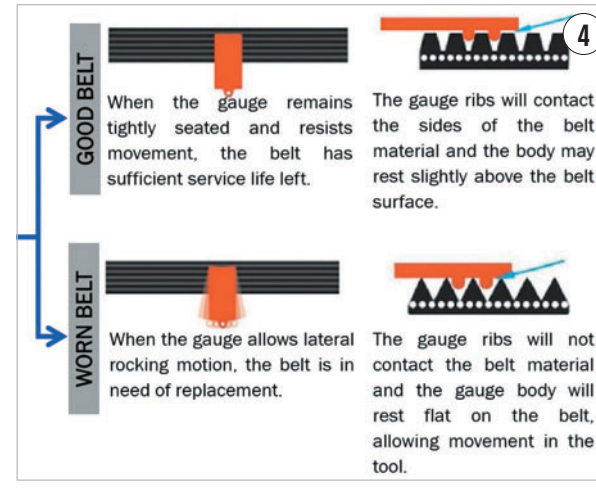
The systematic approach

Addressing normal wear first, I'll state again that only a small loss of material is occurring even at 100k miles of life. As the belts wear slowly, the surface of the belt disappears, and the ribs of the belt begin to sink deeper into the pulley. At about 5 percent to 10 percent wear, the surface of the belt can bottom out in the pulley, and a loss in friction can occur. There are tools available to detect this invisible wear and they serve as a simple-to-use "Go/No-Go" gauge. The tool is available in two different designs, one of which is easy to use with the belt removed from the vehicle. It's placed within the ribs of the belt and if the tool drops below the surface of the belt, it indicates belt replacement is required (**Fig. 3**).

The other version of the tool is just as simple to use but with the belt still installed (**Fig. 4**). The ribs of the tool engage the ribs of the belt. An attempt to "wiggle" the tool in a rotating fashion is then carried out. If this can be accomplished, too much wear is present and the belt must be replaced. If the tool cannot be "wiggled," there is still service life available for the serpentine belt.

Gaining diagnostic direction easily

Discussed earlier was the fact that noise occurs from a fault in the ADBS. Eliminating the noise permanently means fixing the actual problem, not the noise (the result of the problem). A simple first step for resolving noise issues is to use the spray bottle test. Applying water to a noisy belt can reveal a lot about the nature of the fault. When the belt is sprayed and the noise is then increased, it's indicative of a tension-related issue. The water allows the friction to diminish further and intensifies the noise. If the noise is intermittently eliminated or reduced, it indicates an alignment related issue. In this scenario, the water serves as a lubricant between the noisy components. This will allow us as technicians to focus our efforts in the appropriate areas, rather than wasting time and/or money, emptying the parts-cannon.



Tension-related issues can be due to an incorrectly sized belt, a worn belt or malfunctioning tensioner (or a combination of the two). Monitoring the wear markers on the tensioner is possible on some vehicles. It's always worth a look to see if the extension of the tensioner still falls within limits (**Fig. 5**). Observing the tensioner can reveal excessive oscillations and would suggest the tensioner and belt be replaced as a pair. They are designed with approximately the same lifespan.

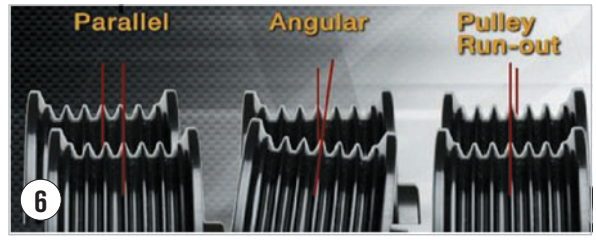
Alignment-related noise faults fall into three different categories (**Fig. 6**):

Angular = Angular faults occur when bearings/bushings start to wear, either in an accessory pulley, idler pulley or tensioner pulley. Many times, as tensioners begin to fail and come apart, they allow for enough movement to cause angularly related noises and extreme belt wear. Bent mounting brackets will do the same.

Runout = Runout occurs when a pulley is improperly mounted or bent/distorted. These issues typically cause a rhythmic chirp, rather than a constant squeal.

Parallel (Offset) = Parallel faults occur when pulleys and/or components that the pulleys mount to are not aligned with the other pulleys. This places an additional load on the side of the belt and causes premature wear/belt failure. An offset of only 1 degree will cause an increase in belt temperature of over 30 degrees-F. This noise tends to be the loudest at the shortest pulley spans.

Knowing that these issues cause noise and premature failure is one thing, but detecting it can be quite a challenge, depending on the location/accessibility of the components in question. Thankfully, there are helpful tools available to eliminate the guesswork (**Fig. 7**). The DriveAlign by GATES is a laser-emitting device designed to easily indicate both parallel and angular misalignment. Here is how it works:



The DriveAlign is first indexed within the ribs of an accessory component's pulley, as a point of reference. The pulley is then rotated while the casted laser beam is monitored for where it strikes another pulley in the system. If the offset from the point of reference is not the same, parallel misalignment exists and must be corrected. If parallel misalignment is not present, the tool is then referenced to that other pulley and the process is reversed. If the laser then falls at a point dissimilar to the point on the referenced pulley, the first component is not offset but crooked in its mounting, causing angular misalignment, and must be corrected for.

Some things never change

The multi-groove serpentine belts of today are still prone to the same root cause failure as the belts of years past. It's no secret that a foreign substance like engine oil, transmission fluid, A/C compressor oil, antifreeze and power steering fluid will cause a loss of friction and a belt to slip. The contaminants can degrade the belt's integrity and cause an undesirable noise, loss of A/C performance, battery charging issues, MILs and even potentially dangerous situations like loss of power steering assist. It's imperative that the source of the leak as well as the reason why the leak occurred, is located and rectified during belt replacement. What some techs fail to realize is improper service procedures will cause the same repercussions. For instance, a leaking camshaft seal is a common failure on many engines. Replacement of the seal will likely stop the leak, but if the reason the seal failed to begin with was due to excessive crankcase pressure or even a scored camshaft sealing surface, a comeback is sure to follow. A simple leaking water pump is also a common occurrence and can be easily replaced or not-so-easy in many engines. Technicians have been doing so for years. The issue is that the service procedures have not remained the same. There are steps of the process added to ensure component longevity, and must be followed. The procedure requires the installer to rotate the water pump impeller by hand, before installation. This distributes the lubricant from the seal, around the pump shaft evenly, before the pump comes in contact with any coolant. Not carrying this procedure will result in premature failure of the pump seal and coolant leakage is sure to follow.

I never wish to discount the importance of proper research either. The one thing many technicians fail to do (early in the process) is to research applicable TSBs (Technical Service Bulletins). Considering the millions of alike vehicles on the road, chances are someone has encountered the evident noise issue before, and there is a countermeasure for the concern. Not only is this a time saver but also an insurance policy to ensure the job is done properly the first time. Consider this example — a 2007 Toyota Corolla exhibited a noise after alternator replacement. After the visual inspection was carried out, a simple search of service information, using the keyword "belt" left us with the information we desired. A potential clue from a TSB to the root cause of the noise (without getting our hands dirty). It outlined an inspection procedure that would determine the need to replace not only the tensioner

but the belt as well. Furthermore, it indicated in the replacement procedure, a need to fully stroke the tensioner a few times to bleed air from the tensioner assembly and prime the tensioner to do its job and remove slack from the belt. How bad could this have gone if the procedure wasn't followed properly? How many tensioners and/or belts would potentially be returned as "defective?"

Have a game plan and follow it

So, as you can see, regarding the visual inspection and proper replacement of the serpentine belt is a concept of the past. A level of complexity was added that simply can't be ignored. We have to stop thinking of "belt noise" as a belt issue and always consider the entire Accessory Belt Drive System for the root cause of the noise fault. The takeaway? Have a systematic approach for ADBS evaluation, consider the root cause of the fault, research TSBs early in the evaluation and always follow proper service procedures. Those components that we're so quick to call "defects" will be diminished significantly, while your confidence in the quality of the parts and your customer's confidence in the quality of your repair will increase many times over.

BRANDON STECKLER is a working technician at Lykon Automotive in Bristol, Pa. He has worked in the field for over 18 years and holds ASE certifications A1-A9, X1, L1, L2 and L3 and C1.
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NAILING DOWN AN INTERMITTENT

CUSTOMER CONCERNS THAT ARE HERE TODAY AND GONE TOMORROW ARE OFTEN CALLED INTERMITTENT COMPLAINTS. HERE'S HOW ONE TECH TOOK ON THE CHALLENGE!

EDWIN HAZZARD // Contributing Editor

In all my years of automotive experience, I still find to this day the repair process of nailing down an intermittent drivability complaint to be one of the toughest tasks there is. When the customer arrives at your shop with an issue that they are experiencing, it is your job to rectify the issue and to satisfy their expectations. When the technician verifies the customer's issue, a solid diagnostic game plan can be put together, leading to a successful conclusion.

But what if the customer states that the problem only happens every once in a while and there's no rhyme or reason when it happens? How do you approach an issue like that as a working technician who probably gets paid on flat rate?

2015 CHEVROLET COLORADO

Tackling intermittents

To start my preparation into this diagnosis, I try to gather as much information as I can from both the customer and the shop. There's no limit on the information that you gather. It's picking and choosing what bits of that information you use that's important. Once I obtain all that I can get I always like to check service information, technical bulletins and repair hotline fixes for anything that can remotely point to the problem that the customer is experiencing. I am not looking for the quick fix here, just a possible route I can take to pick a correct diagnostic path.

The vehicle I'm faced with is a 2015 Chevrolet Colorado four-door with a 3.6L V6 and a 6-speed transmission with rear wheel drive. (**Fig.1**) The odometer is showing 98,000 miles and other than routine maintenance, there haven't been any major repairs done. Also as an aside, there are no engine codes stored in the PCM to give us any clues.

When verifying an intermittent drivability problem, naturally you want to verify the issue that your customer is experiencing. Everyone must be on the same page. But as fate usually rears its ugly head, I was not able to get what the customer was feeling. The complaint is

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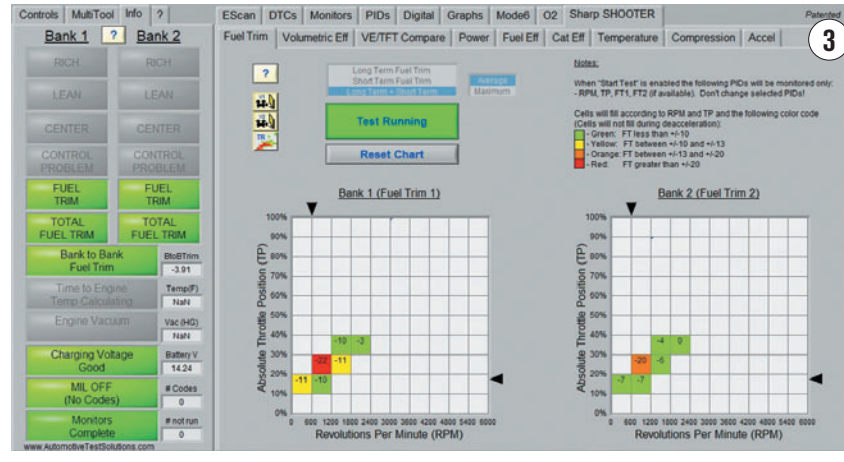
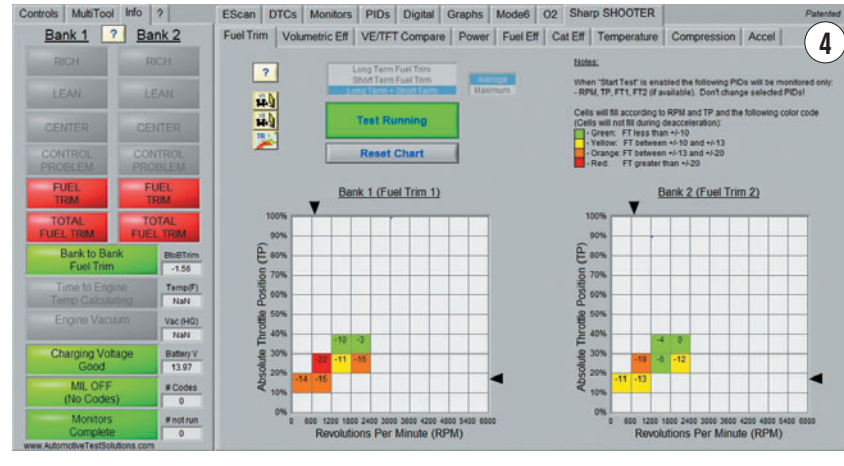
an intermittent hesitation on acceleration. Since this could be one of many different things, I thought it would be best if I started my diagnosis with a Global OBD-II scan tool and chose my Automotive Test Solutions (ATS) Escan. I selected this tool because it will allow me to look at air-fuel mixture control along with volumetric efficiency, exhaust flow dynamics, enhanced OBD-II scan data as well as a super simplistic use of Mode $06 data too.

I set my tool up on the passenger's seat so I would have access to saving screenshots and running the multiple tests available in the "SharpSHOOTER" section of the tool. I chose to start my diagnosis using the fuel trim test. This test will show what the fuel delivery system is doing while you are driving the vehicle and going through all of the rpm and load ranges of the engine starting from an idle, through acceleration, to wide-open throttle. As you can see in **Figure 2**, the scan tool is measuring the throttle percent as well as engine RPMs and showing both banks of the engine. Looking closely at each colored box you will see a number and a smaller plus or minus sign in each frame. Those signs are showing you what percentage the vehicle is controlling the fuel mixture at that particular time. As with any tool that ATS produces, anything in green is good, yellow is just out of spec, orange is failing and out of spec and when it's in red that means it has failed and gone completely out of spec and at the bottom of the scale. This is a screenshot of a normal acceleration with 0 percent to 40 percent throttle and an rpm reading from 600 at idle to 3600 RPMs.

ATS ESCAN



FIRST ROADTEST using escan fuel trim test.



SECOND ROADTEST using escan fuel trim test captured problem.

Felt it THAT time!

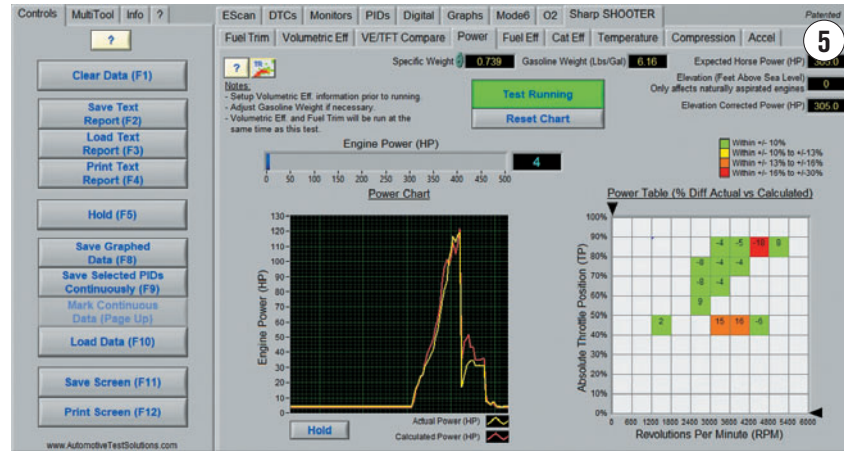
With this screenshot, my fuel delivery was good going from positive three to negative five. I didn't feel any hesitation on this road test. On my return trip back to the shop I was lucky in that I actually felt the same concern the customer has been experiencing. Look at **Figure 3**, the screenshot I obtained on my return trip, and compare it to the first one. Notice a difference? At 30 percent throttle and over 600 RPMs, the scan tool captured the hesitation. It's showing a negative fuel trim in both the orange and red boxes. A negative number indicates that the PCM is cor-

recting for a detected "rich" condition. Essentially, the PCM is making a correction to its base fuel calculation. That means that at that particular point the engine was getting too much fuel and our hesitation was experienced.

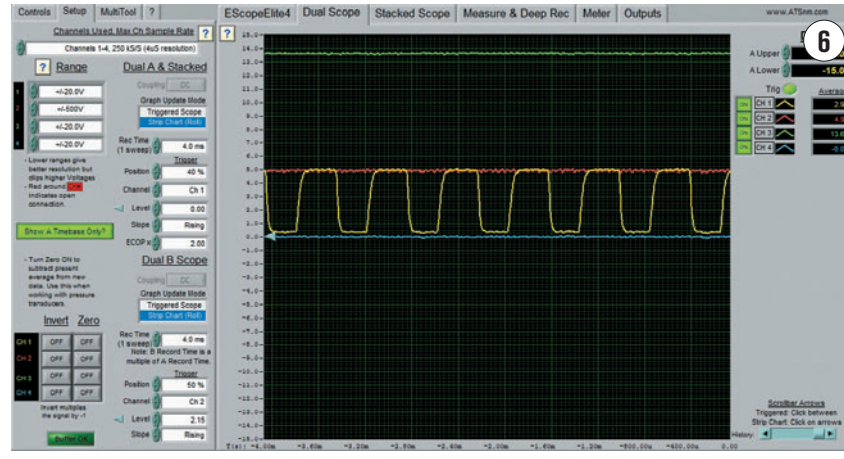
So what did I learn from this screenshot? I know that since it was shown on both banks that it is not a bank-specific problem. I did one more road test and as you can see in **Figure 4**, the problem is getting worse. Look at the left side that's showing both bank fuel trim and total fuel trim in red along with our fuel trim boxes showing more yellow and orange. So I know it's a fuel delivery problem or at least I think it is. I could have broken out the fuel pressure tester and the pressure transducer tools and tested further but since I'm still in the vehicle road testing it, I want to perform some other tests before I get my hands dirty.

I want to make sure that I am getting the correct airflow into the engine along with the correct use of that airflow. I want to make sure that the engine is breathing right and that there aren't any restrictions like exhaust flow, intake plenum obstructions or any air metering measurement concerns. This tool will allow me to measure the correct airflow going into the engine by measuring what is commanded and what is expected.

The test I did next is the volumetric efficiency and fuel trim comparison test. This test measures the amount of air that the engine takes in and compares it to the fuel trim calculations. It takes the volumetric efficiency and shows it as estimated horsepower. Look at the graph on the left side. The line in red is showing calculated horsepower and the line in yellow is showing actual horsepower. The scale is measuring engine power over time. The graph on the right side is showing what is considered a power table. It is showing percent throttle and RPMs.



THIRD ROADTEST using escan fuel trim test problem worse.



SCREEN SHOT of the escan VE/TFT comparison test.

Gotta catch it in the act

Just as with the VE test, the actual and the calculated results should mimic each other and if they do, then the correct VE is obtained. In this test, it is showing a little stumble in the higher rpm range, but I didn't notice any hesitation while capturing this screenshot during my road test. Being the ever curious person that I am, I was thinking that if the MAF (Mass Airflow) sensor had an intermittent glitch in it, that may be the cause of my complaint. I think I should do some component testing just to give myself some peace of mind.

I hooked my Escope up to the MAF sensor (which on this vehicle is called a Multifunction Intake Air sensor). It's an 8-pin sensor that measures Mass Air Flow (MAF), Humidity, Barometer (BARO) and Intake Air Temperature (IAT). I hooked up to the following pins — Channel 1 in yellow is my sensor signal wire, Channel 2 in red is my 5-volt reference wire, Channel 3 in green is my 12-volt battery feed, and Channel 4 in blue is my sensor ground.

As you can see in **Figure 6**, all of my signals look good. Even though I have that glitch that was caught by the Escan, I wanted to check out the air measuring sensor going into the engine for any circuit issues that could contribute to a hesitation issue. Besides, I didn't suspect any issues with the sensor, but I wanted to check it just the same. So after inspecting the Multifunction Intake Air sensor, the intake duct from

the sensor to the upper plenum all the while looking for cracks that might allow unwanted, unmeasured air to enter along, with any loose clamps, I was unable to find any component issues with the air intake system. The air filter itself was clean and free of debris.

Is it fuel delivery?

Now with the intake airflow part of the engine out of the way from my diagnostic thought process, I'm going to take a closer look at the fuel delivery system. The fuel system on this vehicle is an electronic returnless-type system. It has a high pressure fuel pump that has a range of 290 to 2100 psi depending on the engine speed and load requirements of the engine. The low side of the fuel system has a pressure of around 45 psi at idle.

Now I know I can monitor the fuel pressure data PID using my scan tool, but sometimes due to the PCM update rate the data might not read as fast as you want and you can miss that elusive glitch. Since I want to capture my fuel pressure in real-time, I decided to hook up my lab scope using a pressure transducer. I'm not usually a big fan of using a transducer on a gasoline source, as the gasoline getting inside the transducer could create havoc on the internal parts of the transducer. I happened to have an older transducer laying around so I decided to use that one instead of my better ones.

I proceeded to hook up the scope to my pressure transducer and then attached it to the fuel rail. I made all the necessary routings needed for a safe road test and took the vehicle for a drive. During my test drive, I wasn't able to duplicate the customer's concern. Sometimes that's how it goes. Unfortunately, I couldn't get a screenshot of the fuel pump acting up. I road-tested the truck a few more times with my pressure transducer still hooked up along with monitoring the fuel pump with an inductive amp clamp at the fuel pump relay. I was trying to also catch a glitch of a possibly failing fuel pump electronically. As fate would have it, I came up short on these test procedures. So now I have a couple of hours into this vehicle trying to come to a concrete solution so I can report my findings to the shop manager.

Where to now?

Remember I stated that I had a pretty big ego when it comes to diagnosing the tough ones? Since I don't have a solid conclusion but I did gather some pretty good evidence, I decided I would give the shop manager a choice. I recommended two routes that I could take with this. The first one being that I continue to keep testing and hopefully, I can catch the ever elusive Houdini-like problem, or I recommended a low-pressure fuel pump replacement based on the mileage and the service history of the vehicle. This vehicle does not have an external fuel filter as its part of the fuel pump tank module in the fuel tank. My ego is hoping that the shop manager will get the customer to authorize more diag time so I can catch Houdini. My gut feeling is that the fuel pump might be starting to go and/or there is some type of debris inside the tank that is restricting the flow on an intermittent basis. For that to be inspected, the fuel tank would have to be dropped and a good visual inspection will need to be done looking at the inside of the tank.

As fate would have it, the customer went ahead with the fuel pump replacement. After a few weeks had passed, the shop owner contacted me to let me know that Houdini never came back. Well, that's good news, right? It is for the customer's sake but not for my ego. It's still bruised from not correctly and positively identifying the cause of the problem.

One of the lessons that I've learned a few times is that sometimes you won't get that home run. The only thing you can do is put together a solid game plan, understand the system that you're working on and perform as many tests as you can think of to try and pinpoint that elusive problem. Remember, Houdini is always out there — it's just that sometimes he has disappeared and is waiting to be found.

APPROACHING INTERMITTENTS

The nature of an intermittent fault implies that a considerable amount of time may be spent waiting for — or trying to recreate — the conditions in which the fault is present. To an impatient technician, they may cause that person to jump to conclusions or misdiagnose. I approach these situations as logically as possible.

I can't recite an exact number, but I can say a majority of intermittent faults I've dealt with were related to a previous repair. If the customer is in your shop for the first time, do you ask questions about what may have been done previously? When you can verify which services and previous repairs had been done using your service history, it is one of the most powerful tools a shop has when it comes to diagnosing problems.

Keeping reading at **MotorAge.com/intermittent**.

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AD INDEX

AD INDEX

PRODUCTS

TRAINING

IS THAT COMPRESSOR COMPRESSING?

IMPROPER OPERATION OF A VARIABLE COMPRESSOR MAY NOT BE THE FAULT OF THE COMPRESSOR

PETE MEIER // Director of Training

Diagnosing the cause of low system pressures or the lack of pressure differential between the low side and high side of the air conditioning circuit was easy in the days of fixed displacement compressors. If the refrigerant charge was correct and the clutch was functioning properly, odds were good that the compressor was the culprit.

Variable compressors, though, changed all that. These compressors run continuously, whether the A/C is on or not, with an electronic valve controlling the stroke of the compressor pistons.

These compressors use an axial piston design, with the pistons driven by a wobble ("swash") plate. Since the angle of that plate determines the length of the piston stroke, changing that angle changes the length of the stroke and that changes the amount of refrigerant pumped on each stroke.

The valve can be mechanical or electronic and if electronic, it's controlled by the ECM based on a variety of inputs. And like any other computer-controlled component, the correct operation of the compressor is dependent on the ECM receiving accurate information and then correctly implementing its programming.

So how do we verify that the system is working properly, and the compressor is compressing when it should? In this edition of The Trainer, I'll share a few different ways of testing today's variable air conditioning compressors along with a few notes on other symptoms that may incorrectly steer you toward a compressor replacement.

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