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MAY 2023
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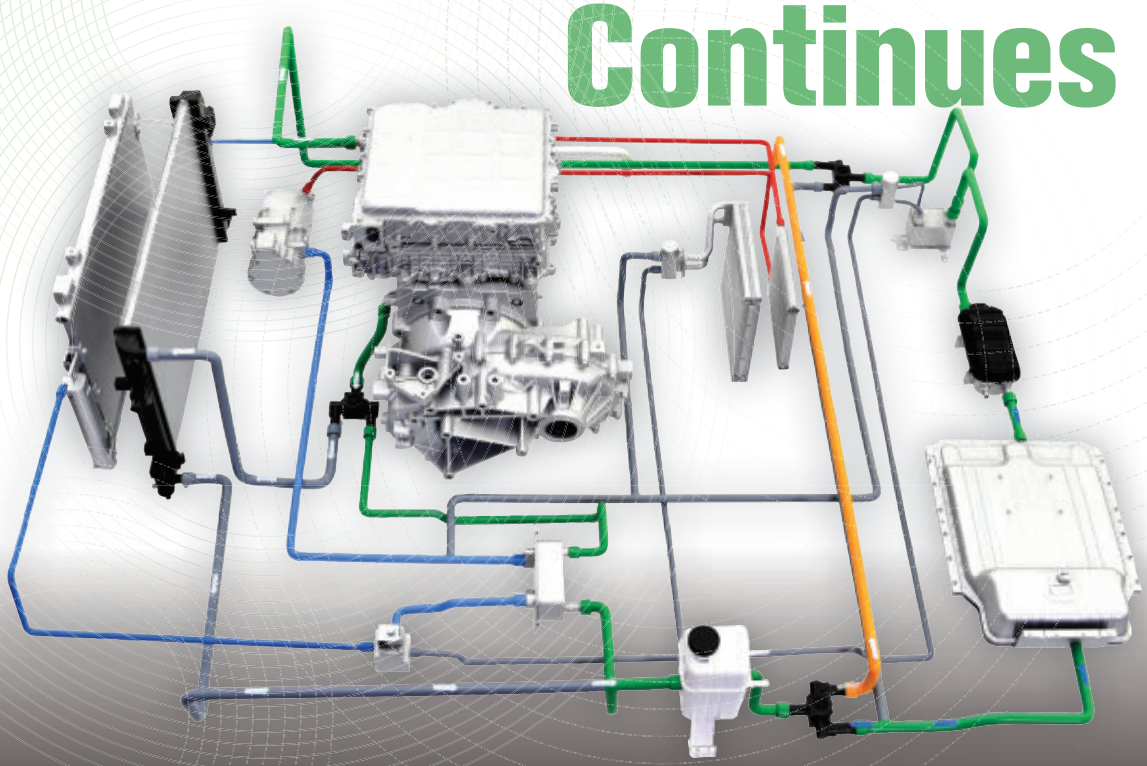
The HVAC 'EV-olution' Continues



Electric vehicles use efficient heat pumps for climate control, but basic refrigeration principles still apply.

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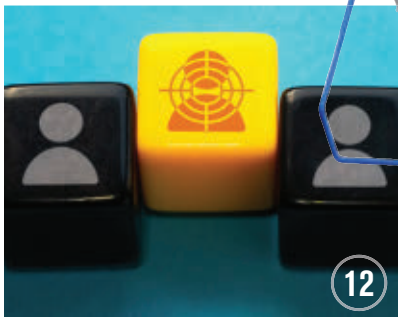

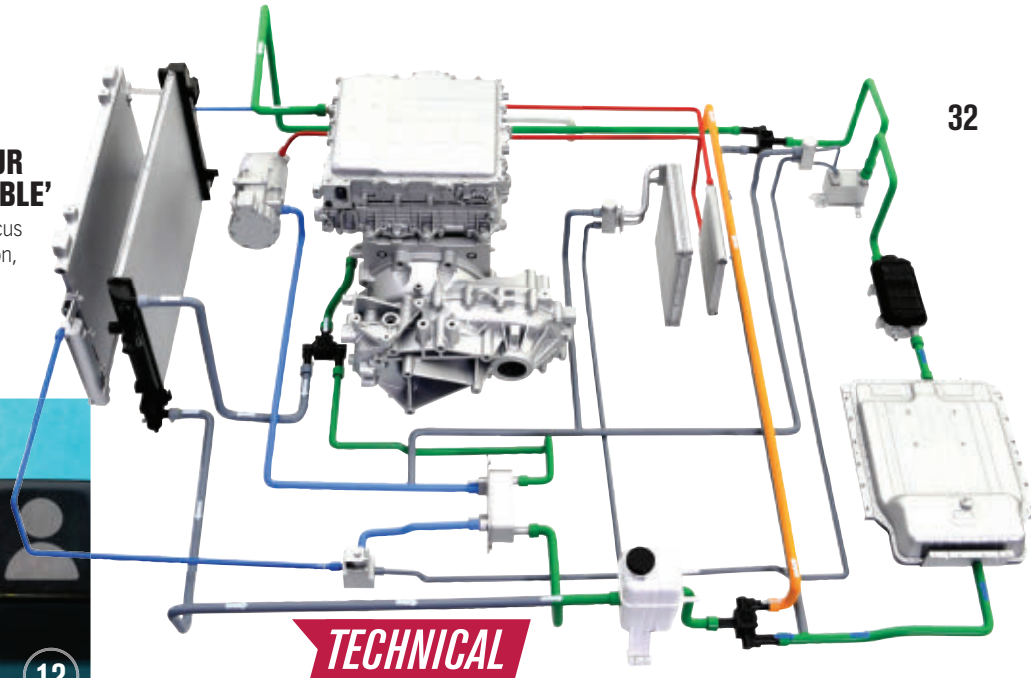

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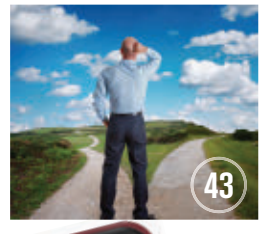

IN EVERY ISSUE

VIDEO

2023 BEST YOUNG TECH INSIDE TIPS

Brandon Steckler, Motor Age technical editor, offers inside tips for new and young automotive repair technicians entering the industry.

WEB EXCLUSIVES

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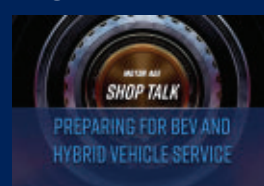
SHOP TALK: PREPARING FOR BEV AND HYBRID VEHICLE SERVICE



Are you an automotive service provider looking to expand your business? Have you considered entering the world of electric vehicle service?

As the Battery Electric Vehicles (BEVs) market grows, so does the need for specialized service and maintenance. In this video, Scott Brown, technical editor for PTEN, walks through some key considerations in working on BEVs, including obtaining tools designed to diagnose and service electric and hybrid vehicles.

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EDUCATION

FORD DONATES $1M TO TECHFORCE FOUNDATION TO SUPPORT SCHOLARSHIP PROGRAM

The largest scholarship donation in TechForce history will nearly double the amount of scholarships awarded to financially-struggling students who are pursuing their career to become an auto technician this year.

Ford Motor Company Fund and Ford dealers across four U.S. regions – Atlanta, Chicago, Dallas, and Phoenix – joined together to donate $1 million in scholarship funding to help students pursue careers as automotive technicians.

The auto industry has long faced a shortage of technicians due to fewer students entering and graduating from post-secondary programs, according to TechForce Foundation.

Despite annual demand for 258,000 new technicians, there are only 48,000 graduates from technician programs each year nationwide. The gap is likely to widen over the next decade without new graduates as there are projected growth rates of 14 percent in Arizona, 10 percent in Texas, 7 percent in Georgia, and 3 percent in Illinois for this career field respectively.

"As we move toward an electrified future, these career opportunities are exciting and require skilled technicians who are proficient in STEM-related study," said Elena Ford, chief customer experience officer.

SCAN THE QR CODE TO READ THIS AND RELATED ARTICLES ONLINE:

"Working together with the Ford Fund and our dealers to offer this scholarship program means we will welcome a new generation of diverse students to the industry, and hopefully into our Ford family, to help us better serve our customers."

The Ford Auto Tech Scholarship, which will be administered by TechForce Foundation, is open to current and future students who are enrolled in post-secondary auto or auto and diesel technician training programs in the Greater Atlanta, Chicago, Dallas, and Phoenix areas.

The scholarship will be applied to the student's school tuition account and may be used for all cost of attendance, including tuition, tools, living expenses, and transportation.

"These scholarships will go a long way in engaging students, particularly those from under-resourced communities, to consider careers in automotive technology and service," said Jennifer Maher, CEO, TechForce Foundation. "We're excited about working with the Ford Fund and Ford Dealer partners to help create a path to careers students may not have considered before."

For more information and to apply for the Ford Auto Tech Scholarship, go to bit.ly/3KLuNgi.

Applications are due by June 30.

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ELECTRIC VEHICLES

ONE-THIRD OF AMERICANS WOULD CONSIDER BUYING AN EV, POLL REPORTS

A recent poll conducted by Reuters and Ipsos found that 34 percent of Americans would consider buying an EV for their next model.

According to a recent online poll conducted by Reuters and Ipsos, one-third of Americans are at least thinking about buying an EV for their next model.

The poll, which surveyed 4,410 Americans across the country, found 56 percent of respondents would be willing to pay no more than $49,999 for an EV. Although to note, despite Biden's EV incentives passing back in August 2022 ($7,500 EV tax credits and other battery and EV manufacturing incentives) to help shift the industry toward electric models, EVs are still priced above $50,000.

The poll also found that 35 percent would want an EV that could travel at least 500 miles on a charge, while 37 percent would want a minimum of 300 miles.

With over 80 EV models on the market, only nearly 6 percent of all U.S. sales in 2022 were EVs.

However, as automakers continue to invest heavily into EVs and Biden moves to adopt new regulations to meet his goal of 50 percent of all new vehicles sold in 2030 to be EV or plug-in hybrid models, this percentage is sure to increase in the coming years.

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REGULATIONS

CERTIFICATION REQUIREMENTS WHEN SERVICING A/C SYSTEMS

As the air conditioning season approaches, it's important to note the training and certification needed to service mobile air conditioning systems.

As the air conditioning season approaches, the National Institute for Automotive Service Excellence (ASE) is reminding service technicians that they must be trained and certified through an EPA-approved organization, such as ASE, to service mobile air conditioning systems.

The credential from this program is also required to purchase automotive refrigerants in containers 2 lbs and larger.

"Spring is here and shops will be seeing more customers bringing in vehicles for air conditioning service and repair," said Tim Zilke, ASE president and CEO. "To service these vehicles, technicians must pass an EPA-approved program to legally perform air conditioning service

>> CONTINUES ON PAGE 10

TRAINING AND RECOGNITION

TOP ASE TEST-TAKING TIPS

Because many people experience test-taking anxiety, the National Institute for Automotive Service Excellence (ASE) has put together useful tips and online resources to help take the fear out of testing.

Need help preparing for an ASE certification? Visit passthease.com to view Motor Age Training's library of books, practice tests, and video resources. You'll be sure to pass your ASE certification exam – guaranteed.

What if I'm not a good test-taker?

ASE tests focus on knowledge of the skills required to do a certain task, not on theory. This makes ASE tests relevant to what's done on the job, not in a laboratory. ASE's test-taking tips provide an interactive look at the different types of ASE questions.

Will I have enough time to complete the test?

ASE lists the number of questions and allowed times for each test in its study guides. To learn how to use the computer-testing interface and learn time-saving tips, review the YouTube video entitled "A Look at the ASE Testing Platform" on the ASE Campus YouTube channel.

What if I'm not sure about computer-based testing?

Test takers don't have to be a computer expert to take an ASE Computer-Based Test (CBT). In fact, they don't even need to know how to use a PC's operating system. To see how easy it is to take an ASE test, view the ASE Testing Platform webinar on the ASE Campus YouTube channel.

What if English is my second language?

If English is your second language, individuals may bring a standard, published English-to-foreign language dictionary to use during testing. If you speak Spanish, every ASE test features a button on the testing interface that launches an English-Spanish glossary of technical terms.

What if I'm just not prepared?

ASE offers free ASE study guides. The guides contain a detailed "roadmap" for each test, along with sample questions and information on training resources. You can also check out an official ASE practice test.

Motor Age Training is another great resource. They offer various ASE test prep options from study guides, e-books, and practice tests to an on-demand one-on-one instructor experience.

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Are there any test sites near me?

ASE offers its tests at nearly 500 secure, proctored centers across the country and has a wide availability of times for testing appointments. You can search for a test center and testing appointment before you register and pay for tests by clicking here.

An infographic featuring common questions and solutions, like those listed above, can be found at ase.com/dist/docs/ASE-Fear-Factor1.pdf and is ideal for posting in shops or providing to service professionals.

EDUCATION

GARAGE GURUS ACCEPTING 2023 SCHOLARSHIP APPLICATIONS THROUGH MAY 31

Up to $30,000 in scholarships will be awarded to future automotive technicians.

The Garage Gurus announced its 2023 Automotive Technician Scholarship Program is open and accepting applications.

Now in its ninth year, the Gurus will again award up to $30,000 in scholarships to future automotive technicians who are accepted or currently enrolled in accredited, U.S.-based automotive technical schools, colleges, and universities, or enrolled full-time at a U.S. high school.

"We continue to see the effects that technician shortages across the automotive aftermarket have on shop owners and customers, so being able to support students who want to establish a career in the repair industry is especially fulfilling," said Dennis Sheran, executive director, Garage Gurus. "Through this annual program, as well as our online and onsite training classes, Garage Gurus stands committed to helping address skills gaps and to providing the proper education for those that are looking to begin and enhance their own careers."

Applications are available on the Garage Gurus website for the opportunity to receive one of 12 $2,500 Garage Gurus Automotive Technician Scholarships for the 2023-2024 school year.

All materials must be submitted by May 31. Winners will be announced on or about July 1.

In addition to the application, students are also required to submit two (2) letters of recommendation from non-family members as well as a typed essay or video introducing themselves and indicating "Why I Want to Be a Top Technician."

To learn more or to apply, go to garagegurus.tech/about/scholarships.html.

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>> CONTINUED FROM PAGE 8

work. The ASE refrigerant recovery and recycling review and quiz offers a convenient way for professional technicians to quickly meet EPA requirements for performing air conditioning service."

The ASE refrigerant recovery and recycling program is EPA-approved, meets Section 609 regulations, and is offered in two ways.

TO BE CERTIFIED, TECHNICIANS NEED TO PASS A TEST DEMONSTRATING THEIR KNOWLEDGE OF THE TRAINING MATERIAL.

One way, the most convenient method, is at asecampus.com. The other way is by mail by going to ase.com/request-ase-materials. A printed booklet can be sent, with payment due when the completed quiz is submitted for scoring.

Training and certification programs must cover the use of recycling equipment in compliance with industry standards, regulatory requirements, refrigerant containment, and the effects on the environment.

To be certified, technicians need to pass a test demonstrating their knowledge of the training material.

For more information about the ASE refrigerant and recycling program, go to ase.com/refrigerant-recovery-and-recycling-program.

For help in preparing for ASE certification, go to passthease.com. Motor Age Training's library of books, practice tests, and video resources is edited by ASE Master Technicians with years of experience in repair processes. Each product is designed to help you prepare for and pass your ASE certification exam – guaranteed.

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SAFETY INSPECTIONS

TEXAS SENATE TRANSPORTATION COMMITTEE PUTS AN END TO ANTI-CAR SAFETY BILL

The Texas Senate Transportation Committee rejected legislation that would have eliminated Texas vehicle safety inspection program.

The Texas Senate Transportation Committee rejected legislation that would have eliminated Texas' vehicle safety inspection program, according to a press release from the Automotive Service Association (ASA).

Senate Bill (SB) 684's committee substitute failed by a vote of three in favor and five against. Research clearly demonstrates that regular testing of a vehicle's tires, brakes, windshield wipers, lights and beams, seatbelts, and airbag systems plays a critical role in preventing many injuries and deaths, ASA's press release noted.

"Today, the Texas Senate Transportation Committee did the right thing for the state by defeating this bill," said Bob Redding, ASA's Washington, D.C. representative. "Texas has a successful vehicle inspection program that protects the motoring public. This private-public partnership program should not be eliminated. Instead, the legislature should heed its own 2018 study's recommendations and consider adding additional inspection items to the program."

The ASA release noted the association "appreciates Senators Royce West, Carol Alvarado, Sarah Eckhardt, Kelly Hancock, and Phil King for their time to listen to the policy experts, examine the empirical evidence, and voting to protect Texas communities.

Being a long-time supporter of vehicle safety inspections, the ASA opposed this bill as well as an earlier version that would have changed the state's inspection requirement from every year to every five years."

The association thanked its Texan members and allies who contacted their state legislators to educate them on this issue and urge them to oppose the bill.

SCAN THE QR CODE TO READ THIS AND RELATED ARTICLES ONLINE:

How to make your team 'un-poachable'

Change your mindset and focus on three levers: compensation, conditions, and connections.

BY RICK WHITE // Contributing Editor

As you know, the auto repair industry is facing a technician and advisor shortage none of us has ever seen, making it increasingly difficult to find qualified staff. You're looking high and low for your next hire to handle the workload your shop is inundated with. But while you're looking, so is your competition. I'm willing to bet your competition is reaching out to your team, trying to lure them away multiple times a week. It's a vicious cycle that results in a high turnover rate in the industry. So, how do you ensure that your team stays with you and doesn't become poached by competitors? In this article, we will explore some of the factors that

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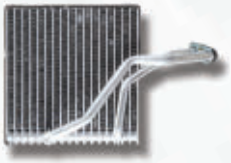

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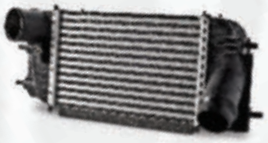

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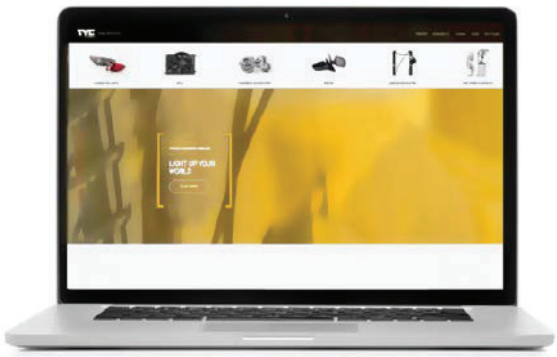
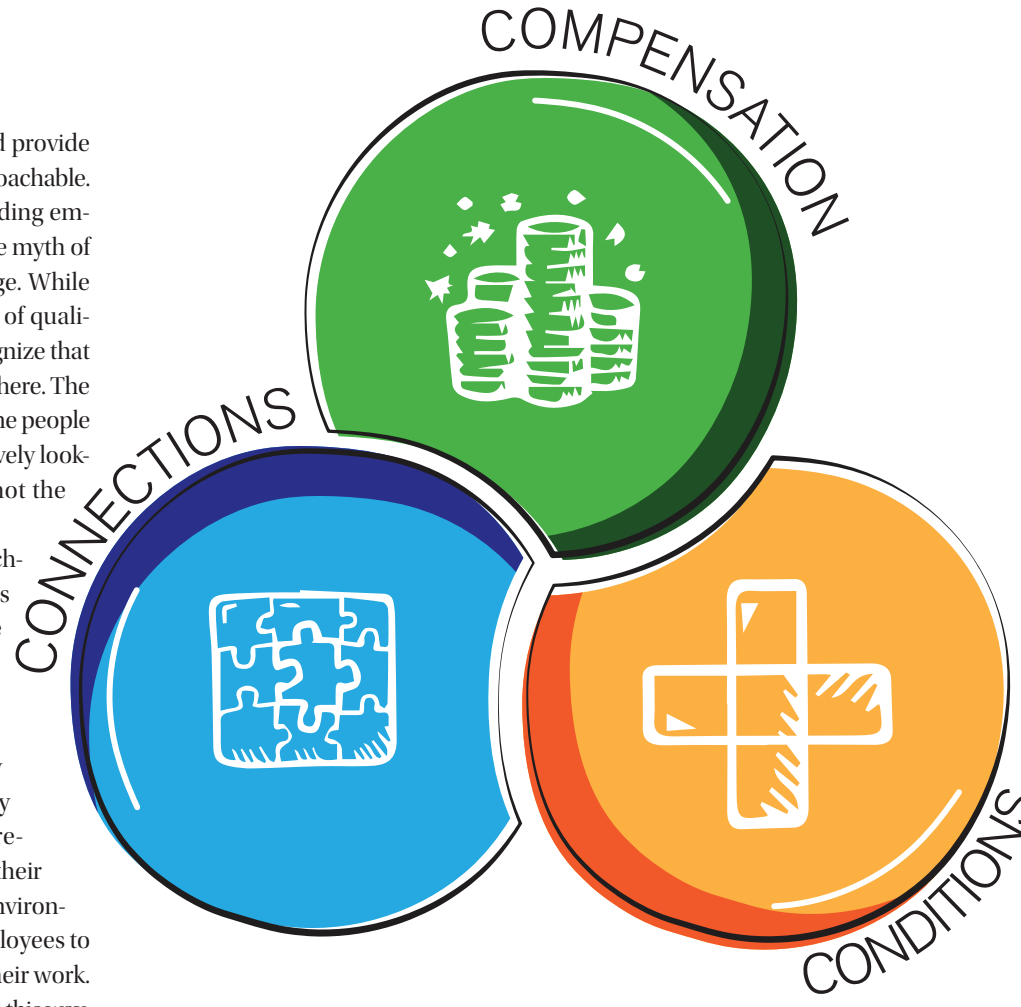




lead to employee turnover and provide tips for making your team un-poachable.

The first step in understanding employee retention is to dispel the myth of the great tech/advisor shortage. While it's true that there's a shortage of qualified staff, it's important to recognize that there are still good people out there. The challenges facing you are that the people you're searching for aren't actively looking for a change, and you're not the only one on the hunt.

What makes someone poachable? Many techs and advisors feel like they're just a cog in the wheel, a unit of production. They feel unseen, unappreciated, and undervalued. They aren't aware of whom they serve or the difference they make, and there's no measurement of their success beyond their paycheck. This kind of work environment makes it difficult for employees to feel engaged and invested in their work. And when a team member feels this way, they become poachable.

How much feedback, encouragement, or recognition are you providing regularly? I can hear you now thinking, "I don't do all that touchy-feely stuff, Rick. No one ever did it for me." I get that. It was the same for me. But they aren't you or me, and this isn't then. For you to have the team you want, it means seeing them, hearing them, and appreciating them. Otherwise, I guarantee you're seeing your employees as a burden, obligation, or nuisance. To make your team un-poachable, you need to change your mindset and focus on three levers: compensation, conditions, and connection.

Compensation: It's more than just competitive pay

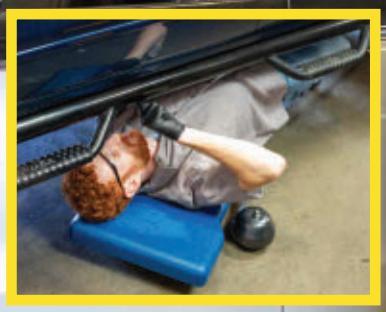
Offering competitive pay is essential to attract and retain employees. I've been asked recently whether a flat rate or hourly pay plan is the best way to pay a tech. My response surprised the shop owner who was asking. My answer was, "Whichever one they want." The days of having a blanket pay plan that you use with everyone are over. Being a leader isn't like playing checkers, where every piece moves the same. It's a chess game where every piece moves and behaves differently. However, it's important to remember that money is a satisfier, not a driver. Once an employee's basic needs are met, money loses its motivational power. So, while you should offer a competitive compensation plan, you need to focus on other areas to keep your team engaged. When was the last time you looked at your benefits package? According to a recent poll of technicians at the Automotive Management Network (www.automotivemanagementnetwork.com), better health, dental, and vision insurance, no weekend or evening hours, and a generous retirement plan are the top three reasons for leaving one shop for another. Don't tell yourself you can't afford these things, because that keeps you stuck right where you are. Figure out how you can afford them, and you'll be well on your way to nailing the first lever.

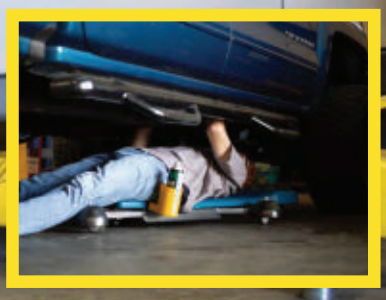
Conditions: comfortable, well-equipped and safe

The conditions of your shop environment are the second lever you need to review. There are three conditions to be aware of. The first is a clean, comfortable work environment. Once again, what was OK for you and me isn't anymore. There are too many options pulling people from this industry. Working in the sweltering heat or freezing cold with ice falling down your back isn't going to entice someone into the auto repair industry when they can get a job for $20 an hour stocking shelves at Target.

The second condition is they want to

WORK MEETS COMFORT





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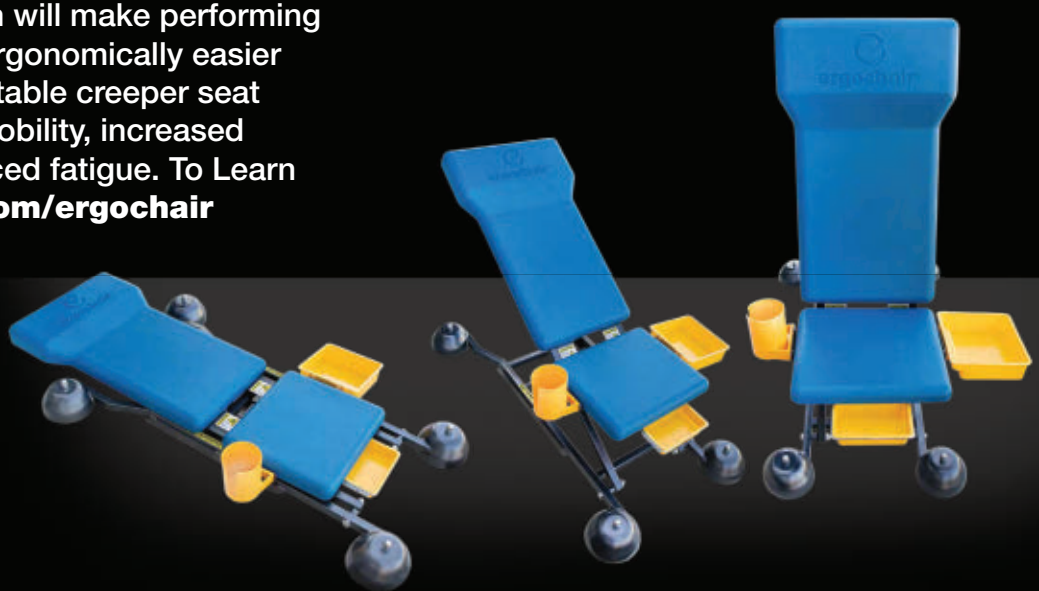

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work in an orderly and well-equipped workplace. You've seen shops so cluttered you have to "go outside to change your mind." Not only are those shops dangerous to work in, but the clutter also kills productivity. Keeping your shop neat, where everything has a designated home, makes it easier to find the tools, equipment, and even keys when they need them. Technicians and advisors also want to work at a shop that's well-equipped with the latest tools, machines, and software. All of this makes their lives and jobs easier, which means more money for all.

The third condition is safety, physical and psychological. Physical safety means equipment is maintained and staff members are trained on the proper use of the equipment. A great example of physical safety is lift safety. Do you have your lifts inspected daily, weekly, and monthly, according to recommendations from the American Lift Institute (www.autolift.org)? Are all your technicians certified by the American Lift Institute? If an accident ever occurs at your shop, OSHA will want to see these documents. But then there's psychological safety, a term that encompasses how it feels to work at your shop. You want to create an environment that's accepting, caring, challenging, fulfilling, and fun. How often does a tech or advisor come to you admitting he or she made a mistake? Or do you find out after he or she tried to hide it? How often does one of your team call you out on something you promised to do but haven't done yet? These answers are a great indicator of the level of psychological safety in your shop.

Connections create a team instead of just employees

Creating a strong connection with each team member is the holy grail of employee retention. This means getting to know your team members and building a relationship with them. It means being a coach, a mentor, and a friend. Unlike the hiring process, where you're limited to the amount of information you can ask about, once they're hired, you want to know everything you can about them and their family. The more you know, the better you can connect. The days of staying aloof and distant from your team members are gone. But it doesn't mean it has to be complicated or expensive. Something as simple as one of your team coming into work and finding their favorite candy bar with a thank you note for something special he or she did the day before will mean more to him or her than you'll ever know.

Creating a strong connection means creating a team when many shops just have employees. It means them getting to know each other better. It could be learning something new about each other at the weekly company meeting. It means doing fun things outside of work that they decide on that allow for deeper connections between team members. You might say, "Rick, I don't have time for this." I get it. But let me share with you a recent study in which three friends and three acquaintances were asked to build as many Tinkertoy kits as possible within a given time frame. At the end of the allotted time, the group of friends built nine kits, while the acquaintances built only two and a half. What this study clearly shows is that friends work better together. And Gallup Research Group has found that an employee is seven times more likely to stay at a business when they have a best friend at work.

If you'd like a white paper giving you ideas on how to recognize your team doing amazing things, simply go to www.180biz.com/recognition.

To make your team un-poachable, ensure that each team member feels seen, heard, and appreciated. Money might attract them, but it's the quality of your connection with them that keeps them.

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RICK WHITE is a business-turnaround and exponential growth expert who helps auto repair shop owners go from struggling to stay open to being recognized as the go-to shops in their market. He helps business owners with average shops transform their shop into the shop of the year in the industry.

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A ROAD PAVED WITH ANALYSES

APPLYING NEWLY LEARNED TECHNIQUES CAN BUILD CREDIBILITY, INCREASE EFFICIENCY, AND ENHANCE HOW WE INTERACT WITH OUR CUSTOMERS.

BY MARIO ROJAS // Contributing Editor

DIAGNOSTICS:

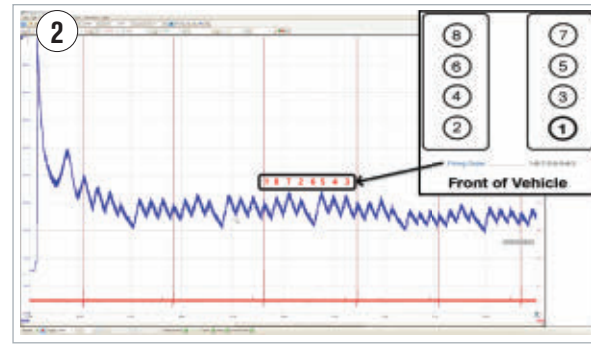
Newly learned skills often allow for unobtrusive testing procedures that can allow a technician to disassemble only what's needed. An example of this application of newer testing techniques is carried out below. A 2009 Chevrolet Suburban 5.3L arrived at the shop **(Figure 1)**. According to the repair order, the vehicle was experiencing a misfire and the MIL was illuminated.

Verify the customer's concern

Walking out to the lot, I contemplated a plan of attack. Concerning misfire troubleshooting strategies, there's always a fork in the road. One path leads to a mechanical failure/cylinder wash possibility. The other encompasses all the other possibilities; air/fuel concerns, ignition, electrical, etc. Oftentimes, the injector of a misfiring cylinder is disabled, preventing cylinder wash under weak/no spark conditions.

Not everyone agrees with that being the first step. I do it because mechanical failures are typically a facile verification,

1 **SUBJECT VEHICLE** is a 2009 Chevy Suburban 5.3L with a misfire condition at all times.



THE RELATIVE COMPRESSION (RC) test shows a mechanically faulted cylinder.

but their repairs can be the costliest of misfire causes. Traditionally, I'd troubleshoot misfires commencing with spark, then fuel, and finally compression, only to find out many times that mechanical integrity was amiss. After all that diagnostic time invested, the client would be informed of the necessary repairs but frequently decline them.

Luckily, this vehicle allows for a "clear-flood" mode. Upon cranking the engine under wide-open throttle (WOT) conditions, the ECM will cut off the injector command across all cylinders, allowing for indefinite starter operation.

Theoretically, each compression stroke loads the starter equally. I listened to the relative compression from each cylinder via the rhythm it produces while cranking. A failing result is an audibly uneven rhythm.

Once I heard the irregular cranking rhythm, I released the throttle, the engine started, and I could hear/ feel a "dead" misfire (along with the MIL on), verifying the client's concerns. A DTC scan revealed a lone P0306 - Cylinder #6 misfire. Nonetheless, I wanted to verify whether the ECM cylinder identification was accurate.

Synchronized relative compression test

Synced to coil #1 (utilizing a secondary ignition lead), and with an amperage clamp around a battery cable, the relative compression (RC) test showed a visual representation of the test I did listening to the cranking rhythm **(Figure 2)**. The firing order is necessary to decipher which amperage/compression peak correlates to which cylinder.

Looking at the waveform, compression within cylinder #1 was not looking too good, and cylinder #6 had a significant compression loss (although our scanner indicated a misfire for only cylinder #6).

It would have been foolish of me to assume that because we had a lack of cylinder compression it was necessarily a mechanical failure. My next step is always to rule out cylinder wash. Every piston has a thin protective oil film between its rings that isolates the combustion chamber from the crankcase. "Cylinder wash" is when liquid fuel dissolves that oil film, which results in insufficient ring sealing. Excessive combustion gasses and raw fuel enter the crankcase and cylinder wall/ring damage ensues. In severe cases, bearing/piston failure follows.

I did not smell any fuel odor at the dipstick. Nonetheless, I attached a piezo-electric (pulse) sensor to the dipstick tube, which confirmed no sign of combustion leakage into the crankcase from cylinder wash during this second RC test. Now I had diagnosed a mechanical integrity issue. At this point, any time being spent chasing ignition or air-fuel ratio faults would be fruitless.

I could have easily stopped there, having ruled out a lower end sealing issue, sent out the cylinder heads for service, and been done. But this is about growing our knowledge base, so consider what may be learned.

The intake pressure pulse

I continued testing by moving the piezo sensor to the intake manifold in place of the brake booster. If you've never used a pulse sensor, this sensor reacts to changes in pressure. In the same way a relative compression test measures theoretical compression differences across cylinders, the intake pulse test measures theoretical intake pull (contribution) differences across cylinders.

Employing the clear-flood mode, I attempted a third relative compression test to no avail. Due to a lack of air restriction (that would have been provided by a closed throttle blade), the intake pulse waveform was rendered unusable. I had a cap nearby that usually accompanies a smoke machine. I placed it over the throttle body to recreate the air restriction and repeated the RC test. I then deployed vertical rulers.

In my case, eight partitions (8-cylinder engine) keep everything easy on the eyes. Using a piston chart acquired from Driveabilityguys.com, we're allowed to observe each piston direction and its respective stroke within a 720-degree cycle **(Figure 3)**.

The fault could not have been clearer! But of course, the ability to acquire the waveform and pinpoint the fault only emerged because of what I had learned in the classroom. Before taking (*Motor*

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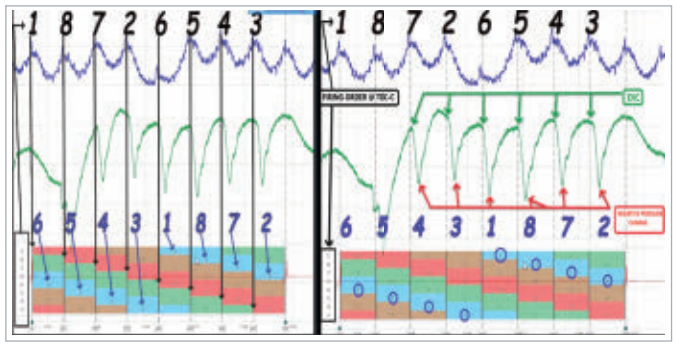


THE PISTON CHART AND PARTITIONS ALLOW for correlating the intake pulls to specific cylinders.

Age Technical Editor) Brandon Steckler's "Pressure Waveform Acquisition & Analysis: From the Inside Out" class, I had never laid eyes on such a waveform, nor what was needed to acquire and dissect it.

While viewing the capture in figure 3, I had noticed that the #1 RC peak was much improved from the previous RC tests. Compression at cylinder #1 is acceptable at this point. One shouldn't put all their eggs in one basket, nor should we commit to only one test, especially the RC test, because of several variables.

So far, I've conducted the relative compression test thrice. The first was the synced relative compression test. The second was with my pulse sensor referencing the dipstick (mentioned earlier). Finally, the third test is one which includes the pulse sensor measuring intake pulses, which I will dissect.

The piston chart

I'll admit the piston chart was daunting at first. My head was spinning! But with a bit of practice, it became invaluable. So I then overlaid some data to clarify what I was looking at.

Starting from the top of the waveform on the left side of Figure 3, each cylinder's top-dead-center compression stroke (TDC-C) peak is marked in black on our blue amperage waveform per the firing order. Beneath that is our green intake pulse waveform, also following the firing order, but instead begins with cylinder #6 (cylinder #1's companion cylinder). I then referenced the piston chart.

The cylinder #1 cycle: The TDC-C peak lines up at the beginning of the red power stroke box ("P") at the very top of our piston chart. That commences with our four-stroke cycle and continues horizontally onto a brown exhaust stroke box ("E"), a blue Intake stroke box ("I", 360 degrees after TDC-C), and ends with the green compression stroke box ("C"). Completing the 720-degree cycle for cylinder #1. The other cylinders follow suit but are simply offset from each other.

Observing the intake pulse waveform (in green), note that each intake pull is lining up with its corresponding cylinder when the exhaust valve closes (EVC). Keep in mind that during the exhaust stroke, the intake valve opens and overlap occurs (the intake and exhaust valves are open simultaneously). At top dead center of the exhaust stroke (TDC-E), EVC then takes place, which allows the intake pulls to occur (Figure 3-right). All the TDC-C events have been identified along with each respective intake vacuum pull event.

Analysis

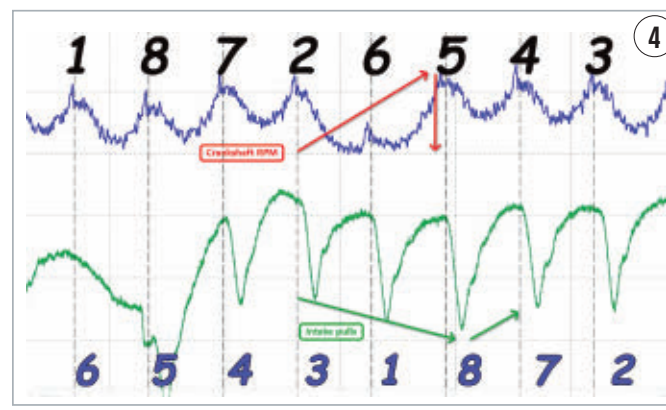
One thing I always keep in mind is never to forget the suspect! Cylinder #6 has been established as the suspect cylinder. The question should always be, "What is the suspect cylinder doing (at every point in the piston chart)?" Is the suspect cylinder piston ascending or descending? On which stroke (ascending; compression or exhaust?... descending; power or intake)? A ton of headaches will be avoided if we simply do not lose sight of our suspect.

At this point it should be pretty obvious, the nonexistent intake pulls after #6 EVC. A missing pull has occurred, followed by a deep pull after #5 EVC (which I had no explanation for). After consulting with Brandon, it turns out that this deep pull is a characteristic of the sensor we are using, a delta sensor (Piezoelectric device). The intake pressure became stable during the absent intake pull (the sensor then "relaxed") and was followed by a rapid change in pressure after the #5 EVC, resulting in a seemingly "deep" pull.

Why aren't all the good pulses even?

One more variable to consider is the effect that crank rotational speed has on the intake pulse waveform **(Figure 4)**. During a low/no compression event (cylinder #6), the crankshaft rotation momentarily speeds up (lacking compression-load) until it encounters a good compression-load from cylinder #5 (the subsequent cylinder in the firing order).

When you observe the intake pulse directly below that event, the intake pulse appears as if each consecutive cylinder is pulling more and more as the crank speeds up. Then, as the crank slows, the



MY CONCERN LIES with the anomaly seen in the green intake pull trace for the #6-cylinder intake pull.

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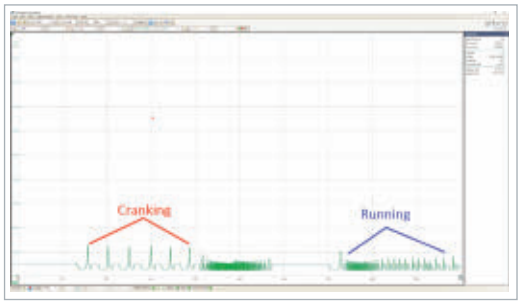

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BOTH THE CRANKING and running in-cylinder pressure waveforms were captured using the Pico scope and WPS500 pressure transducer. A wealth of information about the mechanical condition of this cylinder is available from these two waveforms alone.

intake pulse exhibits that each cylinder is pulling less and less. However, my concern remains with the lack of intake pull correlating with cylinder #6 EVC (which, of course, would have resulted in a "passing" leakdown test).

Suspecting that the intake valve was simply not opening, one could've easily stopped there and moved onto a teardown-approval from the client. But I'm always learning and thought I would use this as an opportunity to invest in my experience. I proceeded to go in-cylinder with the Pico WPS 500X pressure transducer into cylinder #6.

In-cylinder pressure testing

I began with an in-cylinder (clear-flood mode) cranking capture, which was followed by a running capture **(Figure 5)**. Taking a look at my cranking capture, something stands out to me. Remember the throttle blade is wide open/uncapped and I've measured 22 inHG during its intake stroke. **(Figure 6)**.

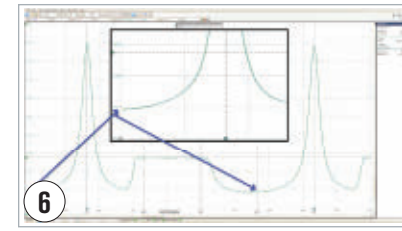
Two things are true about WOT cranking compression waveforms:

- Cranking engine speed is simply not fast enough to displace the air necessary to cause a vacuum as deep as a running engine will.
- With a WOT blade, there's inadequate air restriction at play to allow for vacuum to generate.

The 22 inHG during the induction stroke and the rounded profile of the compression waveform's intake pocket are consequential to piston ascension/descension against a closed/sealed intake valve. This result is in a peak cranking compression of only about 40 psia. The cylinder couldn't fill appropriately. It's safe to say that the exhaust plateau, created by the lack of intake valve opening (IVO) in a cranking waveform) visually resembles the characteristics of a good running waveform.

Speaking of which, the running waveform had a peak compression of about 2 psi and a clearly defined EVO/EVC **(Figure 7)**. When EVC occurs, the cylinder is sealed, but the piston is still ascending and the pressure increases (slightly before TDC-E). This is then followed by the piston descending, after TDC of the exhaust stroke (ATDC-E) and a rounding of the intake pocket occurred.

But there is something that stands out to me, and that is the pressure loss (to near barometric pressure) during the exhaust stroke, where IVO should occur. There's only one logical conclusion that I can come up with for this "dip in pressure" to occur. I can only surmise that during running conditions, the intake valve opens momentarily (ever so slightly), which vents the pressure. This is important because it steers me away from a cam lobe problem. I'll explain the reason why shortly.



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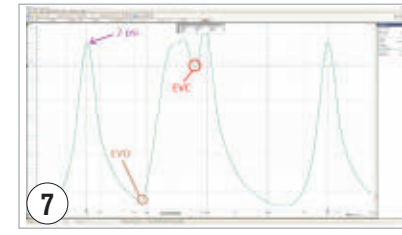
BOTH PORTIONS OF THE CAPTURE DISPLAY in-cylinder vacuum. This shouldn't be possible as the throttle blade is open, equalizing the intake manifold pressure to the atmosphere. It is clear that the cylinder cannot inhale.



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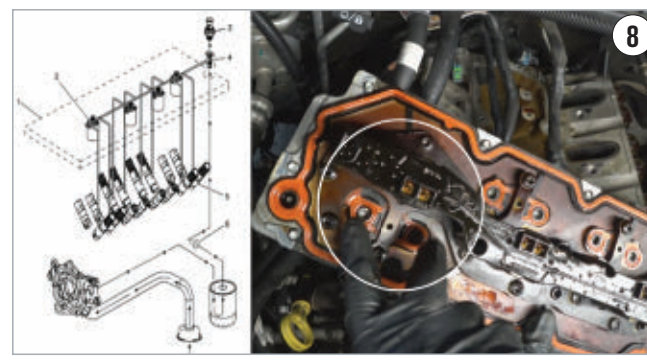
WITH PEAK COMPRESSION of only 2 psi, and indications that the cylinder is not leaking, it proves that the cylinder simply cannot fill with air.

Armed with this data, we explained to the customer that removal of the valve cover was not only justified, but necessary. And that at this point we're expecting to see two things; No intake valve operation, and also good exhaust valve operation (this will become relevant soon).

I'm going in!

With the valve cover removed and the engine cranking, an inoperative intake valve and an properly operating exhaust valve are observed. This is important to note because this vehicle incorporates an AFM (Active Fuel Management) system, otherwise known as "cylinder deactivation."



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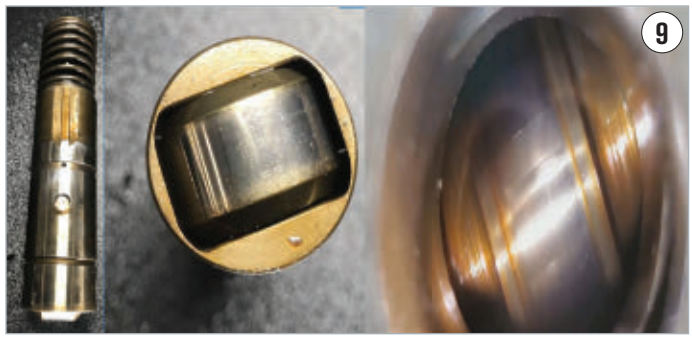
THE VALVE LIFTER OIL MANIFOLD (VLOM) is the device which manages the operation of the intake and exhaust valve lifters for specific cylinders during active fuel management mode.



UPON INSPECTION, the lifer and the cam lobe appear to be in excellent condition. The root cause of the fault had yet to be determined.

Service information reveals that four cylinders can be deactivated upon ECM command, using special lifters, oil passages, and four solenoids that are part of the VLOM (Valve Lifter Oil Manifold) assembly **(Figure 8)**.

The ECM accomplishes this by grounding the command side of the solenoid. While energized, the solenoid opens its valve, allowing for pressurized engine oil to enter both the intake and exhaust valve lifter bores simultaneously, ergo, deactivating that cylinder. This is a pretty big deal since (depending on the scenario) it can lead to a misdiagnosis if disregarded.

Is the AFM solenoid the root-cause fault?

Since cylinder deactivation is achieved with pressurized oil, one can simply remove that from the equation (since the engine not running). If the issue was a stuck-open AFM solenoid valve, the inoperative intake valve should become operational when oil pressure is not available. So, I rotated the engine manually with a wrench and confirmed there was no intake valve operation.

There is another way we can rule out a stuck-open solenoid. As one solenoid controls two lifters at the same time, **(Figure 8 - right side)** if only one lifter was inoperative, it's logically not likely the result of a stuck-open AFM solenoid valve. That scenario would affect both the intake and exhaust valves.

At this point, I brought my data to the client's attention and merely suggested replacing the VLOM assembly as a precautionary measure (because of its known high failure rate). I mentioned this along with the removal of the cylinder head for lifter/cam lobe inspection (the lifter is beneath the head). If one lifter requires replacement, all lifters should be replaced, according to service information.

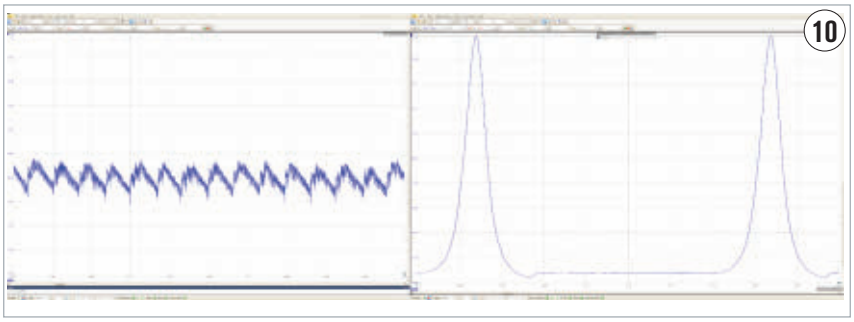
Upon approval, the cylinder heads and the suspect lifter were removed from the engine. Nothing apparent could be noted; it looked perfect from the outside. The cam lobe was also found to be in pristine condition, as suspected **(Figure 9)**. I was left with only one logical conclusion: The lifter collapsed under the tension of the valve spring upon IVO.

This explains the "pressure dip" we saw in our running capture in Figure 7. The failing intake valve lifter collapsed and inhibited proper valve opening, but it had enough resistance to overcome the valve spring tension (just enough to open that intake valve momentarily). And that is why I did not previously suspect the cam lobe was worn.

Building confidence

When you pinpoint a failure, it facilitates confident interaction with the client. It's the difference between saying "it's a collapsed lifter," and saying "let's replace all valvetrain components." So, we confidently requested approval for replacing all lifters and having the heads sent out to our local machine shop, providing a warranty. The client didn't bat an eye; the repair was approved. Although we did send the heads out to the machine shop, it was simply to ensure there were no other issues that may surface late, after assembly.

After I received and installed the



BOTH THE RC CAPTURE and the in-cylinder cranking compression waveform were acquired after the repair and both confirm the fault has been rectified.

heads, I decided to confirm the repair, before completing the reassembly. Cranking the engine manually, the #6 intake valve was now operational. A uniform cranking rhythm was heard, an even cranking amperage waveform was exhibited, and no misfires were felt. In the in-cylinder cranking waveform, the exhaust plateau was no longer present and a peak compression of 173 psia was measured **(Figure 10)**.

Verifying the repair

Lastly, I'd like to say that if it were not for in-class training, i would still be oblivious to these testing techniques. I encourage all not only to go to training but to take advantage of every minute you spend in there. Technology will continue to advance, and so should our diagnostic process and client interaction/education.

Although I did my best to include as much information as possible, this case study couldn't possibly substitute in-class training. It sure can give you an inside look at what you can expect, though!

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MARIO ROJAS is an L1 ASE Master certified Diagnostic Technician from Miami, Florida. He first began working on cars as a way to supplement his income until finally stepping into the industry full-time in 2013. He's now working at Autobahn Performance, a shop that specializes in European vehicles. Rojas also shares some of his work on his YouTube channel, *Super Mario Diagnostics*, in the hopes that his audience will appreciate what it takes to troubleshoot and repair the modern automobile, and to steer everyone into continued training.

STELLANTIS

CONNECTED SERVICES ARE POPULAR FEATURES in newer vehicles. The 2024 Jeep Wrangler interior features a 12.3-inch Uconnect 5 touchscreen radio with standard wireless Android Auto and Apple CarPlay.

DISCONNECTED:
DELVING INTO TELEMATICS PROBLEMS

ONCE YOU KNOW HOW A PARTICULAR SYSTEM WORKS, YOU'LL BE MORE LIKELY TO FIND THE CURE TO KEEP YOUR CUSTOMER'S VEHICLE 'CONNECTED.'

BY DAVE HOBBS // Contributing Editor

When it comes to telematics, it's like anything else: knowledge is power. Just apply your diagnostic mindset to the data you obtain from service information and have a thorough understanding of the vehicle. Don't be intimidated; just treat it like any new system you have faced over the years.

Here's the scenario: another phantom complaint of multiple "crazy intermittent electrical problems" comes into your bay. The vehicle is a 2013 Chevy pickup truck still in use by one of your fleet customers. The truck's instrument panel cluster (IPC) is lit up like a Christmas tree with warning lights. You scan for DTCs / All modules. One of several B-, C- and U-codes you pull is C0561 – "Stability control serial data message invalid." You think, "Hmm . . . serial data message invalid, and crazy intermittent electrical problems? The two just might be tied together." This is a frequent scenario in today's work bays.

You've been down this road before with a similar GM truck and a simple fix. You look for GM PIs (preliminary information) in the factory source (SI2000) and find GM PIT4169F, which mentions the C0561. Unfortunately, it leads you nowhere. What's next? A closer visual inspection seems to be in order. Then you see it: a second DLC under the dash! Where does it go? What does it do? It looks like an aftermarket device – could this be the problem? You find another GM PI **(Figure 1)**, remove the "extra DLC wiring" and "aftermarket black box," clear all the DTCs, drive the truck a couple of days (to ensure no problems reoccur) and the vehicle is repaired. But what about the fleet's aftermarket gadget? Welcome to the evolving world of vehicle telematics!

ALLDATA

THIS TSB IS PERIODICALLY UPDATED. Recent versions show photos of where some aftermarket telematics are often installed on the vehicle. Among other symptoms, this TSB mentions the DTC C0561 stability system data issue that is often caused by other problems.

Vehicle telematics defined

According to Wikipedia, "Vehicle telematics is the convergence of telecommunications and information processing." The term later evolved to refer to automation in automobiles, such as the invention of the emergency warning system for vehicles. GPS navigation, integrated hands-free cell phones, wireless safety communications, and automatic driving assistance systems all are covered under the telematics umbrella."

A brief history of vehicle telematics

The concept of telematics dates back to the late 1970s in France. Actual working examples came decades later when some very important inventions were made. You may be young enough to have grown up using GPS, the internet, and cell phones. The Global Positioning System (GPS) didn't become practical or affordable for several years after President Reagan signed an executive order allowing for future civilian usage.

GPS first became active for the US military after a constellation of 24 satellites began launching in 1978. Between the 1980s and 1990s, the US government was using GPS for military use. By the mid 1990s, they began allowing civilian access to the GPS system.

When the 1996 Cadillac came out with OnStar (the first OEM telematics), the future began evolving into the telematics we know today. Early cellular communications were slow and unreliable – like the internet! Thanks to improvements in cellular communications and internet performance, telematics has exploded with innovation.

Today's telematics technologies

Fast forwarding to today's telematics, we can rely on a door unlock, remote engine start, tire pressure status, oil life or vehicle location within a few seconds of requesting those functions on our smart phones! **(Figure 2)**.

Components/systems involved with modern telematics:

- GPS receiver (and antenna)
- Vehicle electronics interface (including factory wired connections onto a serial data bus and aftermarket DLC-plug-in devices)
- Audio/infotainment systems interface
- Cellular phone transceiver (and antenna)
- CAN chip for monitoring (and limited control) of data bus by third party (i.e. OnStar call center, fleet management provider, etc.)

Factory (OEM) vs. aftermarket telematics components

Whether there is a failure of the telematics system to provide turn-by-turn directions or an intermittent CAN bus communications failure, you must know the answers to the "what, where, when, and how" questions that pertain to a telematics system. Telematics typically fall into one of these general categories.

Aftermarket telematics:

Usage-based insurance (UBI)- Primarily for reducing insurance rates, most of these are small self-contained adapters/dongles that snap (very snugly) onto the vehicle's existing DLC. Monitoring the odometer and the times of day / night the vehicle is being driven helps insurers determine the risk factor for accidents. The driver who drives 5,000 miles a year and usually during the day is exposed to less risk than the driver with 10X the annual miles driving after midnight. The dongle/telematics adapter includes its own cell phone transceiver to upload mileage and time information to the insurance company's telematics data provider. Some have built in accelerometers to detect hard braking, cornering, and acceleration. Insurance telematics may also include vehicle speed via integrated GPS receiver or VSS from the vehicle's OBD II generic data stream to determine if the client is speeding or running traffic lights.

Some insurance telematics dongles are linked to the customer's smart phone on the initial installation. Phone usage / texting while driving can then be monitored by the insurance company to help them set a lower rate or deny a discount based on that risk factor. Insurers that also provide emer-

DAVE HOBBS/FORD MOTOR COMPANY

(LEFT) BIDIRECTIONAL COMMANDS AVAILABLE on my personal 2021 Ford Escape, (Center) current location, fuel range and alerts (washer fluid is low). (Right) dealer name and (estimated) oil life.

gency roadside assistance for vehicle lock outs (e.g., AAA) can tie into the vehicle's data bus to command (via a bi-directional command) the power door locks to activate, eliminating the need to dispatch an ERS truck to do the job.

Financial services/geofencing/aftermarket repair shop- If an owner is behind with their payments at a "buy here/pay here" dealership, the lender can disable the vehicle from starting, but only after sufficient warning is given to the borrower. The telematics receives a message allowing for a delay in disabling subsequent vehicle starts if the borrower catches up on their payments. The vehicle cannot be disabled during operation because of safety concerns. This type of telematics is more apt to be hidden from view.

Geofencing is another function of telematics. A GPS internal to the telematics unit signals back to the primary account holder (parent of young driver/adult caregiver of an elderly driver) the location of the vehicle as well as any unsafe driving occurrences. This type of telematics can assist in monitoring inexperienced drivers or locating a lost older driver with mental cognitive issues.

"Aftermarket repair shop" telematics units are usually passive "read-only" dongles plugged into the OBD II connector to simply monitor generic CAN data for distance driven, DTCs, battery voltage, etc. **(Figure 3)**. As with other aftermarket telematics hardware, they usually communicate with the service provider via an internal cell phone. The dongles are able to be accessed (via vehicle service reports) by the consumer or the installing repair shop to allow for alerts when urgent repairs or even important preventive maintenance services are recommended. Oil changes and 12-volt battery replacements are easier to predict with telematics.S ome aftermarket telematics include a blue tooth remote mic and speaker to allow for voice interactivity with the telematics provider.

Fleet management- While the other categories of telematics are a mix of passive aftermarket (plugged into the DLC directly or through an extender cable), fleet telematics often come in a variety of forms of hardware configurations and installation formats so you may have to look a little closer for them. As with other types of telematics listed, these units usually rely on the vehicle's generic data stream to determine the proper scheduling of preventative maintenance.

In the world of large fleet management, every penny saved adds up to huge opportunities for a company (or government agency) to make the most of their fleet's budget. For this reason, fleet telematics devices are designed with an emphasis on reducing engine damage, wasted fuel (i.e., excessive engine idle time) and driver abuses. Detectable abuses can range from driving outside geographical boundaries, driving recklessly, or fueling up their personal vehicle instead of their fleet vehicle.

Connectivity and crashes

GM's OEM telematics started out in the late '90s with one module that communicated with the vehicle's electronics (hard-wired into the data bus) called the VIU (vehicle interface unit) and another module VCU (vehicle communications unit) that provided connectivity via the OnStar call center. Using the 2G cellular network, it was high tech (for the late '90s). There was no such thing as a "smart phone" at that time. Cell phones were huge "bag phones" or handheld phones the size of a brick.

DAVE HOBBS

EVEN THOUGH RIVAL ATT handles the OnStar network for GM, Verizon is a huge player in telematics – with aftermarket hardware and telematics management, and for Fleet services telematics hardware and data programs.

In the event of a collision, the OnStar VIU detected the crash (via a J1850 data bus message from the SIR module) and the VCU "called in" the emergency. Within seconds (really minutes) Onstar called your GM vehicle. If you didn't answer, an ambulance was dispatched to the last known GPS coordinate of your vehicle. From 2002 to 2006, OnStar service was made available beyond GM vehicles. Select Acura, Audi, Isuzu, Subaru, and Volkswagen models featured GM's OnStar through a special licensing agreement.

Aftermarket OnStar?

Telematics technology has shifted toward more utilization of smart phones on some OEM telematics strategies. GM launched OnStar FMV (For my vehicle) in 2011. Not designed specifically for GM vehicles, it was an aftermarket kit that consisted of a replacement rear view mirror (12-volt powered) and three iconic OnStar buttons. Having the ability to (Bluetooth) pair with your cell phone (the FMV mirror had a built

speaker and mic).

FMV performed many of the same (subscription based) features the true OEM OnStar did, minus vehicle electronics interactivity. It was discontinued in 2014. GM currently has OnStar Guardian, which is based on your smart phone's connection with the world and not the vehicle.

Exit old-school 2G telematics!

In December of 2022, cellular providers began eliminating their legacy 2G network coverage to focus on 4G and 5G. A few 2015 model year GM vehicles and all 2014 and previous models with GM OnStar became obsolete due to reliance on the older network.

Proceeding with diagnostics

Once you've got your answers to "who, what, when, where and how" questions regarding the telematics complaint in your bay and the vehicle is not working as designed, complete a thorough search of TSBs and tech tips within published service information.

Software fixes

The fix for various OEM telematics system quirks is sometimes as simple as a software update. For example, Mitsubishi's Connect (OEM telematics) on their 2018 Eclipse Cross can lose certain functions if your customer crosses an international border (i.e., Mexico or Canada) and comes back to the United States. The fix was easy if you follow TSB–18–54–001.

Battery drains – Maybe it's not telematics?

You may run into a complaint of an intermittent battery drain on a vehicle with OEM telematics. You "think" you've located a parasitic battery drain that goes away when you pull the fuse for the telematics module. Drains present for one minute and then not present for nine minutes, are NORMAL on GM's OnStar. GM shifts their telematics modules from high power (ignition on, OnStar button pressed / actively communicating) to low power (ignition on but OnStar not requested).

In the middle are the telematics modes of "sleep" (nine minutes) and digital standby (one minute). GM's Preliminary Info bulletin PIC4935F describes the process and even gives mA drain over time specs specific to various telematics generations.

5 AESWAVE

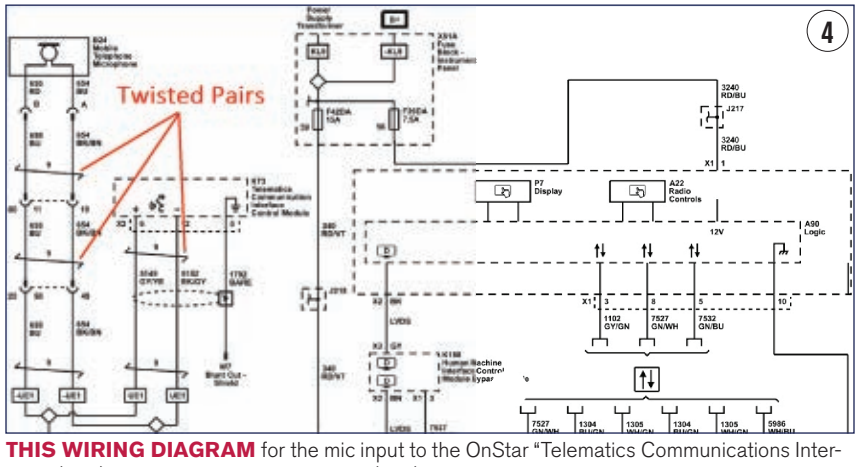
AFTERMARKET TELEMATICS can occasionally throw your diagnostics for a loop. Why not leave it plugged in by using a breakout box as a "Y" adapter while scoping bus activity with and w/o the customer's dongle connected?

Audio issues

Some OEM telematics are wired into the vehicle's audio system for your customer to hear interactions with turn-by-turn directions or a request for your personal status when a crash is detected. Your customers need quality audio and microphone performance if they expect to hear (and be heard by) a telematics call center rep. Telematics audio (input or output) is low level (unamplified) and susceptible to RFI issues. RF shielding and twisted pair wiring are used to eliminate static/noise **(Figure 4)**. Something as simple as back probing a microphone connector with excessive force can damage terminal retention inside the connector creating noise and signal loss.

Data bus communications issues

With OEM telematics, electronic modules (and software) are designed to be compatible. Regardless, hardware (and



4 GM/AC DELCO

THIS WIRING DIAGRAM for the mic input to the OnStar "Telematics Communications Interface" (K73) module also goes to the HMI (K74) which is used for voice recognition, Bluetooth, and USB jacks on the vehicle. The HMI module could be a spot to look for mic wiring issues. Testing telematics microphones is a job for small back probes and a lab scope to observe changes in AC voltage (and frequency) as you speak into the mic.

HYUNDAI MOTOR COMPANY

HYUNDAI

Technical Service Bulletin

GENERAL INFORMATION	22-GI-002H (6)
DATE: MARCH, 2022	MODEL: ALL WITH DLC

SUBJECT: AFTERMARKET DONGLE INSTALLED AT DLC

DESCRIPTION: Some customers may install aftermarket dongles for various purposes. These dongles may interfere with the CAN system and cause various issues such as:

- 12v battery drains when vehicle is parked several days
- Loss of Control Area Network (CAN) communication
- Possible interference with Blue Link and Genesis Connected Services
- Various telematics concerns and Over the Air update related failures
- Check Engine light on
- Shifter System Malfunction warning on cluster
- Various drivability issues that cannot be duplicated at dealers
- Various DTC related to modules, such as P060141 - Internal Control Module Memory Check Sum Error

APPLICABLE MODELS:
All vehicles with a Data Link Connector (DLC)

SAMPLE DONGLES:

Dongle location at DLC	Insurance Dongle	GPS Dongle

ANOTHER TSB addressing aftermarket insurance and GPS tracking dongles.

OEM TELEMATICS

So much has changed since General Motors first launched OnStar in 1996 Cadillac models. Today, almost every new vehicle has a form of telematics that is either standard equipment or a factory option. A partial list is below.

Acura - AcuraLink
Audi - myAudi
BMW - ConnectedDrive
Buick - MyBuick
Cadillac - MyCadillac
Chevrolet - MyChevrolet
Chrysler - UConnect Access
Dodge - UConnect Access
Fiat - UConnect Access
Ford - FordPass
GMC - OnStar
Honda - HondaLink (Ver.2)
Hyundai - BlueLink
Infiniti - InTouch
Jaguar - InControl
Jeep - UConnect Access
Kia - MyUVO
LandRover - InControl
Lexus - Enform
Lincoln - Lincoln Connect
Mazda - Mazda Mobile Start
Mercedes - Mbrace
Mini - MINI Connected
Mitsubishi - Mitsubishi Connect
Nissan - NissanConnect
Porsche - PorscheConnect
RAM – Uconnect Access
Subaru - Starlink
Suzuki – Suzuki Connect
Tesla – TeslaApp
Toyota – Entune 3.0
Volkswagen - Car-Net
Volvo – Sensus Connect / On Call

Depending on where you are (geographically), the marketing terms and available features for OEM telematics vary between vehicle models/years and the country code. For example, GM used the term OnStar originally, then it added more brand-specific titles. To get a more detailed idea, here is a link to a competitive feature chart from MyCar, a Canadian-based aftermarket telematics company: https://bit.ly/3V52X3G

software) can have flaws. You could have (in rare cases) corrupted bus messages originated by the OEM telematics module. Diagnose those scenarios like you would for any other factory electronics module.

For the aftermarket telematics, there are plenty of OEM-specific TSBs addressing insurance, fleet and aftermarket telematics data bus corruption complaints **(Figure 5)**. But they can only be guilty of data corruption if they connect into the serial bus on the vehicle (via wiring). When you spot a simple DLC telematics dongle, a DLC breakout box can be effective in determining if the bus is intermittently shorting low (or high) via a lab scope when the dongle is plugged in **(Figure 6)**. If you do a little scanning and scoping with the knowledge of how a particular telematics system works, you'll be more likely to find the cure to keep your customer's connected vehicle "connected!"

SCAN THE QR CODE TO READ THIS AND RELATED ARTICLES ONLINE:

DAVE HOBBS is a senior technical trainer and curriculum developer for Delphi Technologies Aftermarket at BorgWarner Inc. He's Master ASE-certified with L1 (advanced engine performance) & L3 (hybrid) specialist certifications.
He has extensive OEM service and field engineering expertise, with more than 30 years of experience in troubleshooting vehicle systems electronics, with 15 of those years in the independent aftermarket repair business. He has 20 years of experience in training engineers (worldwide) and service technicians in both the OEM and aftermarket arenas, as well as experience in working with postsecondary vocational / community college students as an adjunct instructor.

The HVAC 'EV-ol

HYUNDAI MOTOR GROUP

CHEK-CHART PUBLICATIONS

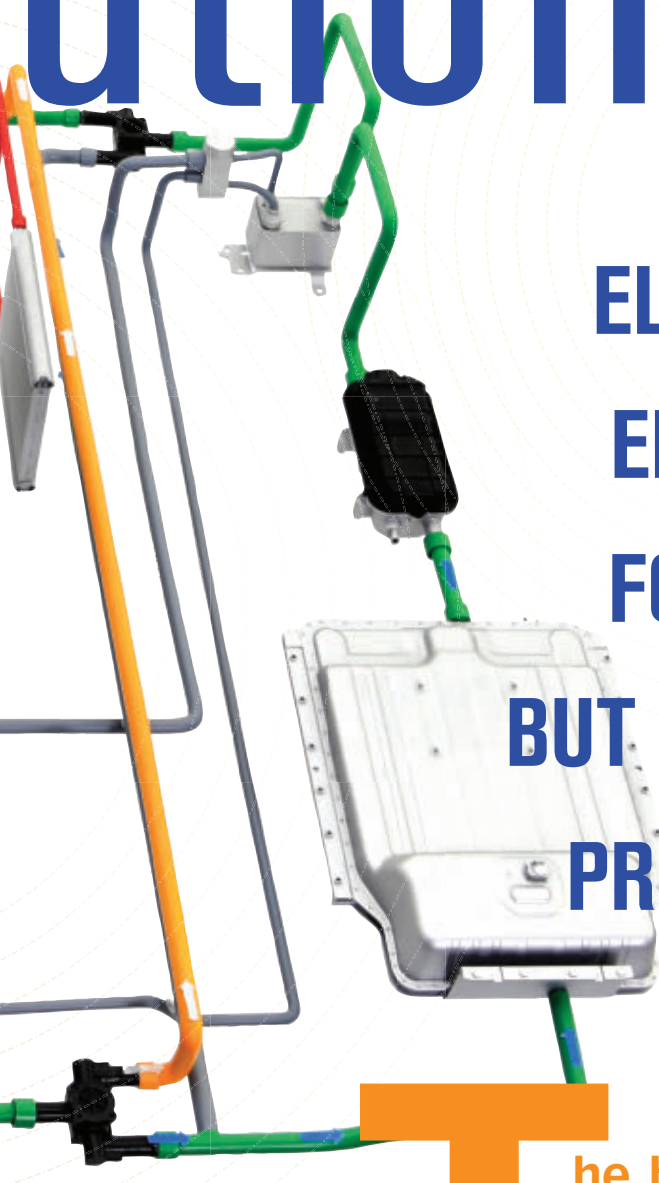
1

EARLY VEHICLES DID NOT HAVE HEATING SYSTEMS or even roofs. The occupants were on their own to provide protective clothing from harsh weather. The riders selected a combination of rain or winter jackets, gloves, hats, goggles, scarves, and blankets to retain warmth.

ution continues

ELECTRIC VEHICLES USE EFFICIENT HEAT PUMPS FOR CLIMATE CONTROL, BUT BASIC REFRIGERATION PRINCIPLES STILL APPLY.

BY CHRISTOPHER J. HOLLEY // Contributing Editor



THIS HIGH-EFFICIENCY HEAT PUMP system is the one found in the Hyundai Kona EV.

The heat pump climate control system of an EV is a bit more intricate than that of a typical ICE vehicle, but the basic principles of refrigeration still apply.

With the auto industry's rapid movement from internal combustion engines to electrified powertrains, the task of conditioning the vehicle's interior is changing significantly. Auto manufacturers are quickly adapting heating, ventilation, and air conditioning (HVAC) equipment to fit electric vehicles' (EV) needs. For technicians expected to repair EVs, the learning curve is steep. However, the situation for current technicians is no different from what previous generations of techs tackled as vehicle technology advanced.

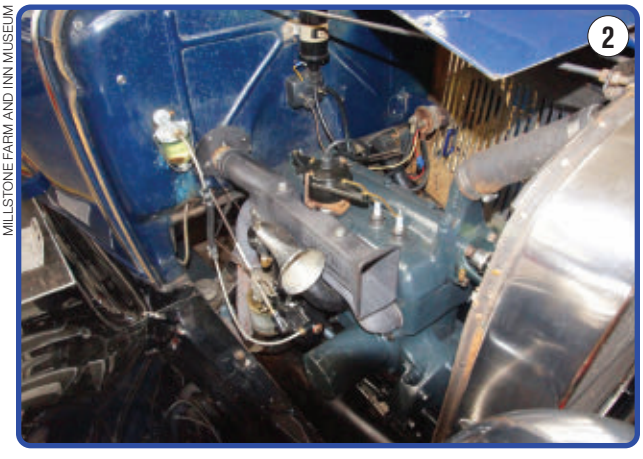
The history of HVAC

Over 120 years ago, the automobile was in its infancy. As such, the vehicle occupant's heating consisted of coats, blankets, winter caps, face coverage, gloves, and boots for the operator and riders **(Figure 1).** The occupants' comfort was a minor manufacturer's concern during the open-cab, horseless carriage period. In addition to winter clothing, some owners installed brick boxes into their cars to provide a source of heat. In both cases, the occupant's heating relied upon a source other than the vehicle.

The methods of occupant heating changed as vehicles moved from the open carriage design to enclosed cabins in the early 1910s. First, the enclosed interior provided additional occupant protection from harsh weather and cold temperatures. Then, in the 1920s, closed-body vehicle production surpassed open-body models. At about the same time, the original equipment manufacturers (OEMs) developed exhaust heaters to provide vehicle interior heating. The exhaust heaters used engine exhaust to warm a radiator-like exchanger placed under the vehicle floor or at the feet of the riders.

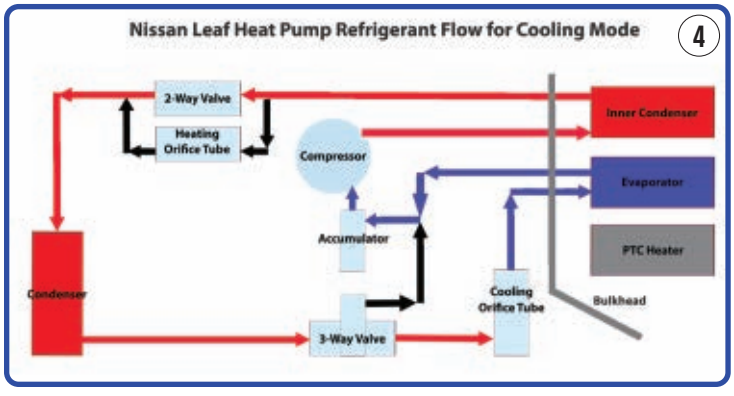
By the late 1920s, the OEMs began casting (or fabricating) shielding around the exhaust manifold. Air was channeled, with the aid of the engine's radiator fan, over the exhaust manifold, and the shielding directed the heated air to the vehicle's interior **(Figure 2)**. The engine proved to be an excellent source of heat, but the use of engine exhaust raised concerns about exhaust emissions entering the car. At the same time, some manufacturers developed gasoline heaters (with similar emis-

COURTESY OF DAVE SHOWAN, MILLSTONE FARM AND INN MUSEUM



WHEN VEHICLES PROGRESSED TO ENCLOSED INTERIORS, the OEMs developed manifolding and shielding around the exhaust manifold. Air was blown across the hot manifold, and the shielding guided the heated air to the vehicle's interior. The heating proved acceptable, but there was always a concern about exhaust gas emissions entering the car.

THE A/C LINE PRESSURES and the interior temperature were monitored on a Nissan Leaf. Additionally, compressor RPM and desired interior temperature PIDs were observed. In cooling mode, the high-side pressure reached 147 psi, and the low-side pressure was 29 psi, at 70 degrees F. ambient temperature. The compressor speed was 3,500 RPM, and its rate fell as the interior temperature dropped. The vent temperature plunged to 38.3 degrees F and then stabilized at 42.8 degrees F after ten minutes.



IN THE DIAGRAM, RED REPRESENTS the high pressure/high temperature, blue represents the low pressure/low temperature, and black signifies passages unused during cooling mode. The temperature of the high side, measured with contact thermocouples, remained steady from the compressor to the front condenser inlet. The condenser dropped 10 degrees F. from the inlet to the outlet. A significant temperature drop occurred between the 3-way valve outlet and the inlet to the evaporator. A temperature drop nearly 30 degrees F. was monitored.

sions concerns), which remained an option for specific vehicle models until the 1960s.

It wasn't until 1930 that General Motors produced the modern industry standard heater core. Hot coolant from the engine was plumbed into a heater core (a small radiator) under the dash. A blower motor moved air across the heater core. The heat picked up by the passing air was distributed to various discharge nozzles at the dashboard. As years passed, a maze of ductwork feeding a series of discharge vents was placed at multiple interior locations.

As automotive technology advanced, repair technicians had to master new concepts, which included the evolution of coolant (from water to mixed blends), pressurized cooling systems, and air conditioning (A/C) operation. Although air conditioning was an option for some automakers starting in the 1930s, it was not until after WWII that manufacturers began standardizing the location of the significant components.

All domestic auto manufacturers had similar A/C systems, but when the Asian cars hit the US market, there were new systems to learn. As a result of the oil embargo in the 1970s, additional operating methods (such as cycling A/C systems) were introduced. The complexity grew with each technological advancement. And with the advent of computer controls, the system's efficiency increased appreciably, but so did the intricacies of repairing the systems. Then, like today, those technicians had to constantly learn emerging technology and apply that newfound knowledge, whether they wanted to or not if they desired to stay in the automotive industry.

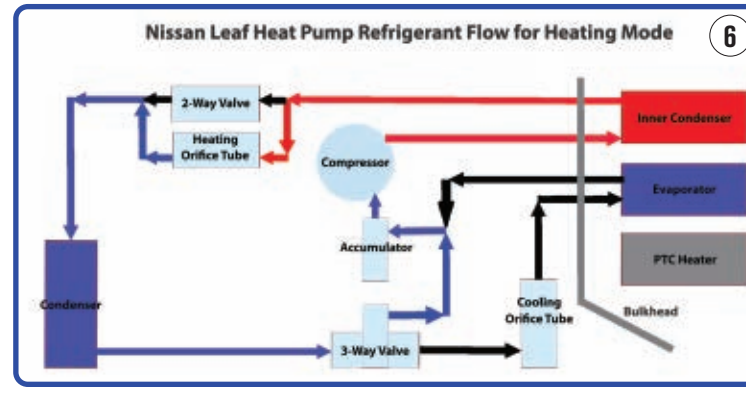
So, what is the latest heating and cooling technology that technicians in the EV era must learn? It is the heat pump. The heat pump system encompasses vehicle interior heating with the air conditioning system. The first mass-produced heat pump usage was established by Nissan, which installed a heat pump on the Leaf over a decade ago.

Before we get in-depth about heat pump systems, a few clarifications need to be mentioned. First, some texts suggest that the compressor's scroll spins in its normal direction during A/C cooling and is rotated in the opposite direction for the heating mode. Thus far, this writer has yet to come across a heat pump system with a compressor that reverses.

THE NISSAN HEAT PUMP SYSTEM is one of the least complex in production. However, the maze of HVAC lines is convoluted. Depending on the position of the two-way and three-way valves, heating, cooling, and de-icing can be achieved. The lines are labeled to help HVAC students at Pennsylvania College of Technology understand the refrigerant flow.

IN COOLING MODE, the line temperature analysis provided similar results to conventional A/C systems. The compressor speed also dropped within an rpm range that paralleled traditional A/C designs. However, in heating mode, the significant temperature changes at the front condenser were different from the usual, and it was "cold" to the touch. In de-icing mode, the evaporator and the heating orifice are bypassed to allow heated high-pressure refrigerant to flow through the front condenser to melt the ice.

IN THE DIAGRAM, RED REPRESENTS the high pressure, blue represents the low pressure, and black signifies passages unused during heating mode. The maximum vent temperature was 147.7 degreesF, with a compressor speed of 3200 RPM. Once the interior temperature stabilized, the compressor rate dropped to 1500 RPM, with a vent temperature of approximately 105 degrees F. The high-side pressure temperature dropped almost 20 degrees F. between the compressor and the inlet to the heating orifice valve. Across the heating orifice valve, the temperature dropped nearly 50 degrees F. Interestingly, the high- and low-side pressures stayed in the 40-psi range.



Second, it is a gross understatement to say a vehicle's heat pump has a solenoid-controlled reverser or slider valve (like a house HVAC design) to allow or redirect the refrigerant flow from the compressor. Yes, the refrigerant in an automotive heat pump system is permitted or blocked from flowing. However, there are multiple solenoids, restrictions, and condensers throughout the design, depending upon the application.

While the first heat pumps had an acceptable interior warming performance at temperatures slightly below 32 degrees F., with advancing heat harvesting techniques, heat pumps have developed into a more viable low-temperature choice for interior heating. Although another heat source may be developed in the future, because of the benefits of the heat pump systems, many, but not all, auto manufacturers are adopting them.

The two significant advantages of a heat pump are its ability to heat and cool the cabin air and provide more heat energy than is required to operate it. The heat delivered versus the input power is known as the coefficient of performance (COP).

A positive temperature coefficient (PTC) or resistive heater will have a COP of nearly one. Therefore, it cannot deliver more heat than the energy supplied. However, the heat pump systems can achieve a COP more substantial than one. For example, many manufacturers list a COP of 2.0 – 5.4, which means a heat output of double to over five times the input energy required to operate it.

The limiting factor of a heat pump is that the system is most efficient at a narrow temperature band near or just below 32 degrees F., but the efficiency drops as the temperature falls. Therefore, a heat pump cannot provide adequate interior heat and requires a backup heat source, a resistive or PTC heater. As previously discussed, the heater draws more battery energy to supplement the heat pump and maintain interior temperature.

Modern cars have never had significant insulation to maintain the interior temperature, thus exacerbating the heating problem. Additionally, each vehicle has a positive airflow ventilation system to provide constant fresh air into the interior to keep the occupants in a pleasant atmosphere with the windows shut. So, the HVAC system's capacity must be several times larger than required based on air volume. The result is more energy consumed to maintain the interior temperature (in colder ambient temperatures), which shortens the distance the EV can travel because it depletes the HV battery.

Many manufacturers are utilizing efficient seat and steering wheel heaters to combat the loss of cabin heat. As with gasoline vehicles, the seat and steering wheel heater transfer warmth to the occupants via conduction. Heating the person rather than the air can reduce the heat pump or heater usage. However, minimizing cabin air heating can only be expected to work so well in frigid temperatures, and there will still be a loss of energy from the battery thermal management system.

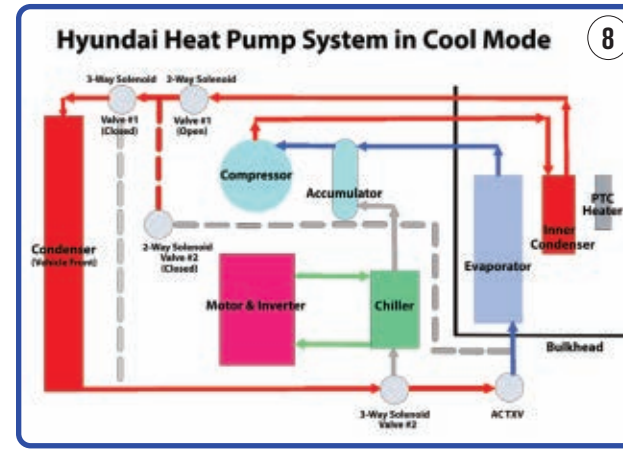
"THE TWO SIGNIFICANT ADVANTAGES OF A HEAT PUMP ARE ITS ABILITY TO HEAT AND COOL THE CABIN AIR AND PROVIDE MORE HEAT ENERGY THAN IS REQUIRED TO OPERATE IT."

Currently, BMW, Hyundai, Jaguar, Kia, Mini, Nissan, Polestar, Subaru, Tesla, Toyota, Volkswagen, and Volvo offer a heat pump as a standard or an optional component in at least one of their hybrid or electric vehicles. Chevrolet and Ford do not provide heat pumps for EVs. However, all the manufacturers listed have a standard or optional "cold weather" or "comfort" package that includes a combination of heated seats, steering wheel, windshield, mirrors, batteries, and PTC or resistive heaters.

Cooling mode of the Nissan Leaf

The Nissan Leaf is the least complex system on the list of vehicles. Therefore, we will begin with an examination of its heat pump system **(Figure 3)**. When the cooling mode is selected, the scroll compressor pushes a gas refrigerant through the bulkhead and into the inner condenser housed in the HVAC box **(Figure 4)**. Then the refrigerant flows through the inner condenser and back toward the motor bay. After passing through the bulkhead, the refrigerant flows to the two-way valve.

While still in cooling mode, the two-way valve bypasses the heating orifice tube and allows the refrigerant to move to the condenser at the front of the vehicle. After it passes through the front condenser, the refrigerant approaches a second valve, called a three-way valve. The valve is constructed to allow re-

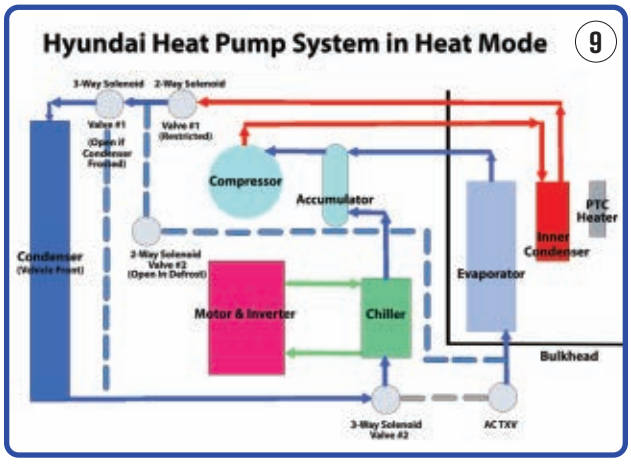


IN THE DIAGRAM, RED REPRESENTS the high pressure, blue represents the low pressure, and gray signifies blocked or unused passages during cooling mode. Kia/Hyundai's heat pump system consists of two two-way solenoid valves and two 3-way solenoid valves. The refrigerant flows from the compressor through the inner condenser, 2-way valve #1, 3-way valve #1, the outer condenser, 3-way valve #2, and across the A/C TXV. At that point, the pressure drops across the TXV, and as the refrigerant flows through the evaporator, it takes on heat.

frigerant to pass through the cooling orifice tube (restriction) and move back into the HVAC box as it enters the evaporator. Ultimately, the refrigerant goes from the evaporator to the accumulator and then back to the compressor.

The refrigerant exiting the compressor is a hot, high-pressure gas that passes through the inner condenser and the two-way valve to the front condenser. The refrigerant gives off latent heat at the front condenser and changes from a high-pressure gas to a high-pressure liquid. After the front condenser, the refrigerant goes through the three-way valve and onto the restriction. Across the restriction, the high-pressure liquid pressure becomes a cold, low-pressure liquid that passes through the evaporator. The refrigerant takes on heat and changes into a low-pressure gas. Finally, the gas flows from the evaporator to the accumulator and back to the compressor.

Except for the inner condenser and the two- and three-way valves, the HVAC cooling mode is very similar to the operation of a conventional vehicle's HVAC refrigerant loop. The inner condenser takes the place of the traditional heater core. But in cooling mode, it does nothing except allow the refrigerant to pass through **(Figure 5)**. In addition to the inner condenser, a positive temperature coefficient (PTC) heater is housed in the HVAC box. The two-way valve is in bypass mode, and the three-way valve permits the movement of refrigerant to the system's restriction when in cooling mode.



IN THE DIAGRAM, RED REPRESENTS the high pressure, blue represents the low pressure, and gray signifies blocked or unused passages during heating mode. The complexity of the HVAC heat pump system is displayed when heat is required. If just heating is needed, the refrigerant leaves the compressor, passes through the inner condenser, and across the two-way solenoid valve #1, where the pressure drops. The refrigerant will take on heat as it passes through the outer condenser, and at three-way solenoid valve #2, the refrigerant is diverted to the liquid-to-liquid chiller. At the chiller, heat from the motor and inverter is added to the refrigerant to increase heat for the inner condenser. If defrosting is needed, two2-way valve #2 is opened, and low-pressure refrigerant is passed through the evaporator. The evaporator removes moisture from the passing air.

Heating mode of the Nissan Leaf

Switching from cooling to heating mode requires the activation of the two-way valve to force refrigerant to flow through the heating orifice tube **(Figure 6)**. At the same time, the three-way valve moves to bypass the restriction and evaporator routes the refrigerant directly to the accumulator.

When in heat mode, the hot, high-pressure gaseous refrigerant flows from the compressor to the inner condenser, where the refrigerant gives off heat and changes to a hot, high-pressure liquid. The pressure drops across the heating orifice tube, and a low-pressure liquid flows to the front condenser. The refrigerant absorbs heat from the ambient air at the front condenser, changing from a cold, low-pressure liquid to a cold, low-pressure gas. Lastly, the refrigerant moves through the three-way valve to the accumulator and returns to the compressor. In the heat mode, the evaporator is bypassed **(Figure 7)**.

During de-ice mode, the heat pump prevents the icing of the front condenser during pre-conditioning battery charging. The three-way valve routes refrigerant across the cooling orifice tube and through the evaporator, while the two-way valve is opened and bypasses the heating orifice tube. The pressurized refrigerant flows through the system to warm the front condenser to warm it and melt the ice.

The Hyundai and Kia heat pump configuration is like the Nissan system. The similarities include a compressor, an inner condenser, an outer condenser (Hyundai/Kia term), an evaporator, an accumulator, and a PTC heater. However, the system has increased heat output and window defrosting. The system has two two-way solenoid valves, two three-way solenoid valves, a thermostatic expansion valve (TXV), and a liquid-to-liquid chiller *(You can view an illustrative GIF of the Hyundai system by scanning the QR code at the end of the article).*

Alternative designs

When in cooling mode, the compressor pumps the high-pressure gaseous refrigerant through the inner condenser, the two-way solenoid valve #1 (in its open position), and through the 3-way solenoid valve #1, routing the refrigerant through the outer condenser **(Figure 8)**.

The outer condenser gives off heat, and the refrigerant changes from a hot, high-pressure gas to a hot, high-pressure liquid. Next, the refrigerant flows through three-way solenoid valve #2, across the TXV and through the evaporator. The TXV (variable restriction) drops the system pressure, and once in the evaporator, the cold, liquid refrigerant takes on heat and cools the air flowing over it. Ultimately, the low-pressure gas refrigerant flows through the accumulator and returns to the compressor.

In heating mode, the high-pressure gas refrigerant exits the compressor and enters the inner condenser housed in the

HVAC box **(Figure 9)**. The inner condenser gives off heat to the air passing over it, and the refrigerant changes from a hot, high-pressure gas to a hot, high-pressure liquid. After the refrigerant exits the inner condenser, it passes across the 2-way solenoid valve #1 that acts as a restriction, dropping the refrigerant pressure and temperature.

The low-pressure liquid moves through the three-way solenoid valve #1, which allows the refrigerant to flow through the outer condenser at the front of the vehicle (unless frost is detected on the condenser, then it will divert the refrigerant around the condenser). In either case, the refrigerant travels through the three-way solenoid valve #2. If the refrigerant moves through the outer condenser, it picks up the heat, and the refrigerant changes state to a gas. Conversely, if the refrigerant bypasses the outer condenser, it remains a low-pressure liquid.

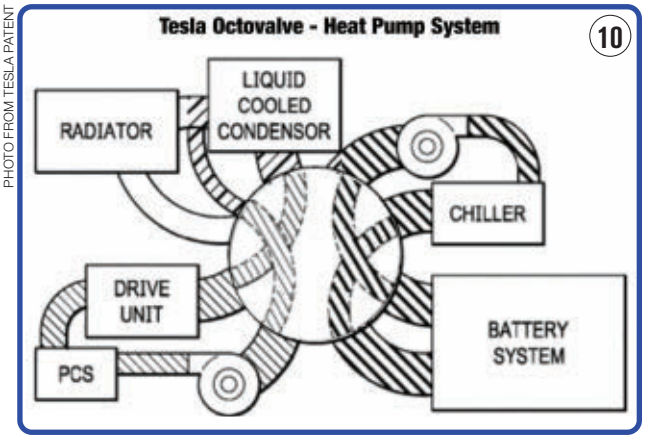
In either case, the refrigerant is guided through the chiller, which picks up heat, and the remaining low-pressure liquid changes its state to a gas. The refrigerant enters the accumulator and subsequently moves back to the compressor.

If the defroster is desired, the two-way solenoid valve #2 (located between two-way solenoid valve #1 and three-way solenoid valve #1) permits low-pressure/low-temperature liquid refrigerant to flow through the evaporator. The air in the HVAC box is dehumidified before the inner condenser heats the air. The refrigerant from the evaporator returns to the accumulator and back to the compressor.

Tesla's innovation

The Nissan, Hyundai, and Kia heat pump systems are similar in design, with the components located throughout the underhood area and under the dash. However, the Tesla heat pump system is much more compact, allowing a better fit into tight spaces under the hood. To achieve compactness, Tesla developed the Super Manifold, a two-layer printed circuit board (PCB) assembly that houses the refrigeration system on one side, while the other side is plumbed for coolant.

PHOTO FROM TESLA PATENT



TESLA'S HEAT PUMP SYSTEM comprises a compact unit that features the Octovalve – a two-tiered, eight-port (four-ports per level) valve. The Octovalve moves coolant through a combination of five loops to create twelve heating and three cooling modes. The five loops include the liquid cooled condenser, the chiller, the batteries, the power conversion system, the drive unit, and the radiator.

> **REMEMBER, JUST LIKE THE TECHS OF YEARS PAST, CONSTANTLY UPDATING TRAINING IS NECESSARY TO REPAIR THE CUSTOMER'S VEHICLE CORRECTLY THE FIRST TIME.**

To manage the heating and cooling loops of the Tesla heat pump system, Tesla devised a pair of four-way valves stacked on top of each other and attached them to a coaxial motor. The valve assembly is called the Octovalve **(Figure 10)**. Its design allows refrigerant and coolant to flow through a series of channels to provide heating or cooling without mixing. With the Octovalve system, a ninth pipe configuration works as a bypass to the radiator circuit.

The refrigeration loop consists of a liquid-cooled condenser (LCC), a cabin condenser for the heating modes, a chiller, and a cabin evaporator for the cooling modes. There are five coolant loops in the system. In addition to coolant loops for the LCC and chiller, there are loops for the batteries, the Power Conversion System (PCS) and drive unit, and the radiator to provide proper cooling or heating. With the multiple orientations of the Octovalve, Tesla has developed a system with twelve heating and three cooling modes.

While it would be beneficial to investigate all the heat pump systems in greater depth, it is simply impossible to achieve in a few pages. With each passing year, system refinement will continue. Until a specific heat pump design becomes the standard, enjoy the "Wild West" and remember, just like the techs of years past, constantly updating training is necessary to repair the customer's vehicle correctly the first time.

SCAN THE QR CODE TO VIEW THIS ARTICLE, INCLUDING THE ILLUSTRATIVE GIF, ONLINE:

CHRISTOPHER J. HOLLEY is a professor of automotive technology in the School of Engineering Technology at Pennsylvania College of Technology (Williamsport, Pa.). Since 2003, Holley has primarily instructed electrical/electronics, heating, ventilation, and cooling (HVAC), and vehicle performance classes. He is an ASE Certified Master Automotive Technician with several advanced ASE certifications and has authored over 300 published magazine contributions.

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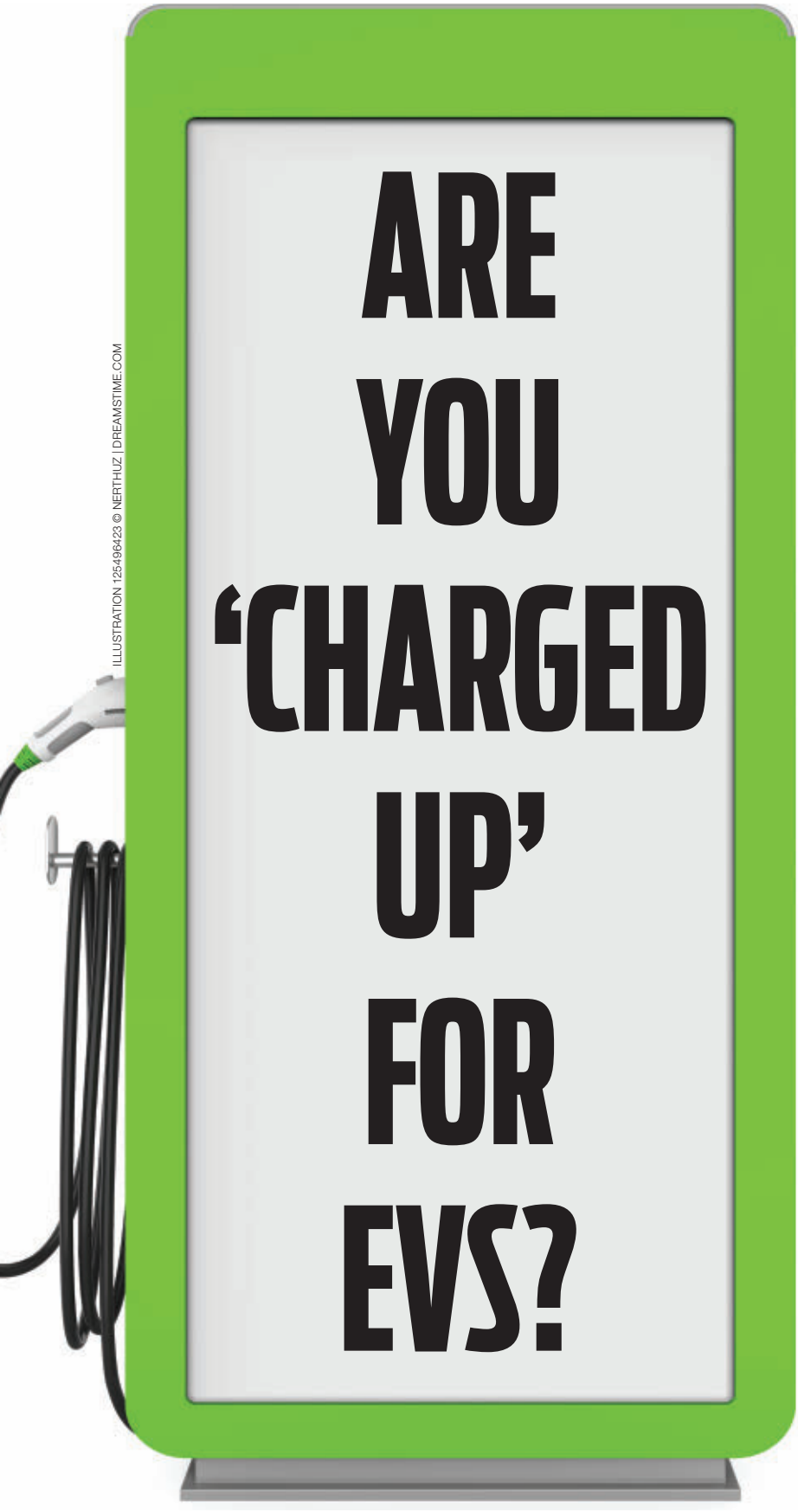

ARE YOU 'CHARGED UP' FOR EVS?

ALTHOUGH THE PERCENTAGE OF ELECTRIC VEHICLES IN THE CAR PARC REMAINS LOW, SHOPS NEED TO TAKE A STRATEGIC APPROACH TO PREPARE TO SERVICE THEM.

BY JEFF COX // Contributing Editor

There is no question that the electric vehicle (EV) movement is in full swing. In 2022, Tesla sold 1.3 million units, an increase of 40 percent over the prior year. There is no doubt there is tremendous consumer demand for this segment of vehicles. So, does that mean that we will be servicing nothing but EV vehicles in the near future? Well, not exactly. The percentage of EV vehicles in comparison to the entire car parc is still very low. In fact, it is still less than 5 percent of the cars that are on the road today. Now, I am not suggesting we ignore EV vehicles. Rather, we need to take a strategic approach and prepare to service them.

We often hear that EV vehicles don't require any maintenance. And yes, the internal combustion engines (ICE) have been an important role service work. But the future for aftermarket service is still very bright. In this article, I would like to highlight some key services that carry over from a traditional vehicle and note some changes to services, if any exist.

If you ever had the opportunity to drive an EV, the first thing you will notice is a lack of sound coming from the now absent engine and exhaust. Instead, you

ALTHOUGH IT WILL BE A VERY LONG TIME until we see a significant number of EV vehicles in our service bays, we must use this transition time to prepare and train for them, whether it is as simple as how to properly rack an EV or more complex, such as safely servicing high-voltage components.

now hear the slight hum of the electric motor, which allows you to focus on lots of other noises, vibrations, and harshness (NVH). NVH has been a growing service segment and will certainly continue to be with EV vehicles. NVH is nothing new, but this service category is going to continue and may even play an even more important role in the future.

Tires

They're black, they're round, and they are on every car, regardless of what is used to propel the vehicle. With that being said, you will often find tires on an EV vehicle that may have some marking that signifies it was manufactured for the EV market. Companies such as Goodyear, Bridgestone, and Michelin all have developed tires to reduce the amount of noise transmitted to the cabin compartment. They are doing this by adding foam and other sound-deadening materials to the inside of the tire. When an EV comes in for a tire repair, it will require a slightly different service than a traditional tire repair. Once the leak is identified, you will have to remove the section of foam — if equipped — from the tire. If the tire has a highly tacky adhesive, do not buff or use a cleaner on the spot. Use a scraper to remove any debris, then use a plug/patch combo to complete the repair. If the tire has a cured adhesive, you will use the traditional service procedure which will require buffing the area of the injury. Once the tire is repaired, you can either discard the piece of sound-deadening material, or you can use a little adhesive to reinstall the foam. In addition to the tire repair, an EV vehicle is going to wear tires nearly

COURTESY OF TECH TIRE REPAIR SOLUTIONS

WHEN AN EV COMES IN FOR A TIRE REPAIR, it will require a slightly different service than a traditional tire repair. Once the leak is identified, you will have to remove the section of foam — if equipped — from the tire.

COURTESY OF TECH TIRE REPAIR SOLUTIONS

ONCE THE TIRE IS REPAIRED, you can either discard the piece of sound-deadening material or you can use a little adhesive to reinstall the foam.

20 percent faster than a traditional ICE vehicle. This is due to the weight and torque of these vehicles.

> ALL OF THIS IS CRITICAL IF WE WANT TO REMAIN A VIABLE SOURCE OF VEHICLE REPAIR FOR CONSUMERS.

Brakes

We have all heard about how regenerative braking is going to make brakes last "forever," and it may prolong the life of the pads. But we all know that a properly performing brake system is more than just pads and rotors. If the hydraulic braking system is not used often enough, the components that allow the caliper to slide might start to stick. Caliper slide service is going to play a big role in maintaining a hybrid. You may even see excessive rust buildup on the rotor, which will require reconditioning of the rotor to ensure the surface meets the correct roughness average (RA). In addition to the caliper slide service and brake rotor reconditioning, the braking system is still a hydraulic system that uses traditional brake fluid, and over time that brake fluid will degrade. The Motorist Assurance Program (MAP) supports testing brake fluid by either using a copper test strip or a pH test strip. Both of these methods allow you to quickly test the fluid to see if there is degradation. If you prefer copper test strips, then any test strip that shows more than 200 ppm requires a fluid exchange. If you use pH test strips, anything less than 6.5 indicates the brake fluid has become corrosive and will require a fluid exchange.

Fluids

Obviously, without an internal combustion engine there will not be engine oil to change. But that doesn't mean there are no fluids that will need to be serviced. EVs still use coolant. This coolant is used to cool the battery, the inverter, and other associated parts. In addition to the EV powertrain components, there are coolant lines, chillers, pumps, and other items that relate to the cabin's HVAC system. This complex system will require service as these components wear out. The coolant used is not the typical inorganic (IAT) or organic (OAT) type of coolant, because the electrical components will be submerged into the fluid. This requires a dielectric coolant.

In addition to coolant, there are transmission fluids, motor fluids, and greases that will all require service at some point.

Even with all the development of technology, the EV vehicle share of the car parc remains small and will take a very long time until we see a significant number of EV vehicles in our service bays. However, we must use this transition time to prepare and train whether it be as simple as how to properly rack an EV or more complex, like safely servicing high voltage components. All of this is critical if we want to remain a viable source of vehicle repair for consumers.

PHOENIX SYSTEMS

THE MOTORIST ASSURANCE PROGRAM (MAP) supports testing brake fluid by either using a copper test strip or a pH test strip. Both of these methods allow you to quickly test the fluid to see if there is degradation. Any copper test strip that shows more than 200 ppm requires a fluid exchange.

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JEFF COX is the president of the Automotive Maintenance and Repair Association. Jeff has been in the automotive aftermarket industry for 25 years, starting as a technician before transitioning to leadership. Jeff is an ASE Master Technician and holds a bachelor's degree in Automotive Technology from Southern Illinois University. He also holds a master's degree in Organizational Leadership. Jeff and the AMRA team are dedicated to helping build trust between the customers and the repair shop through their Motorist Assurance Program, better known as MAP.

PHOTO 117240045 © ANDREUSK | DREAMSTIME.COM

WELCOME BACK TO ANOTHER EDITION OF "THE DATA DOESN'T LIE," A REGULAR FEATURE IN WHICH I POSE A PUZZLING CASE STUDY, FOLLOWED BY THE ANSWERS TO THE PREVIOUS ISSUE'S PUZZLE.

A FORK IN THE ROAD:

WHERE DID THE COMPRESSION GO?

PRESSURE TRANSDUCER TESTING CAN SEEM LIKE AN IMPOSSIBLE TECHNIQUE TO MASTER, ESPECIALLY WHEN MULTIPLE FAULTS EXIST.

BY BRANDON STECKLER // Technical Editor

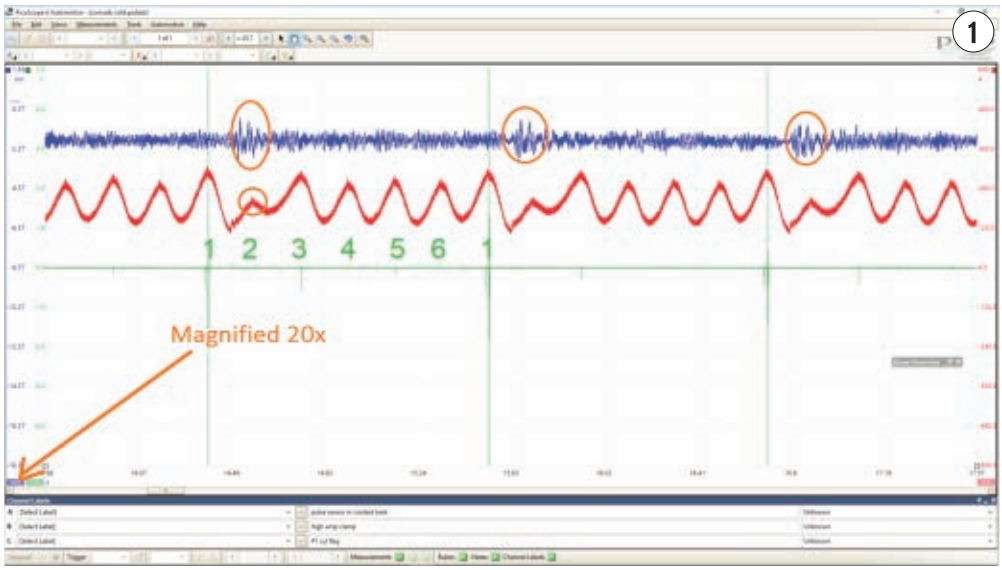
Using specialized tooling to locate engine mechanical faults is tricky at first, but when there is more than one issue, it can seem like an impossible technique to master, especially for a novice.

This case came from great friends of mine at **Black Hills Tire in Rapid City, South Dakota.** They were faced with a 2014 Ram ProMaster van with a 3.6L V6 engine. The vehicle came to the shop with an overheating concern and a loss of antifreeze from the cooling system, but no visible leaks were present.

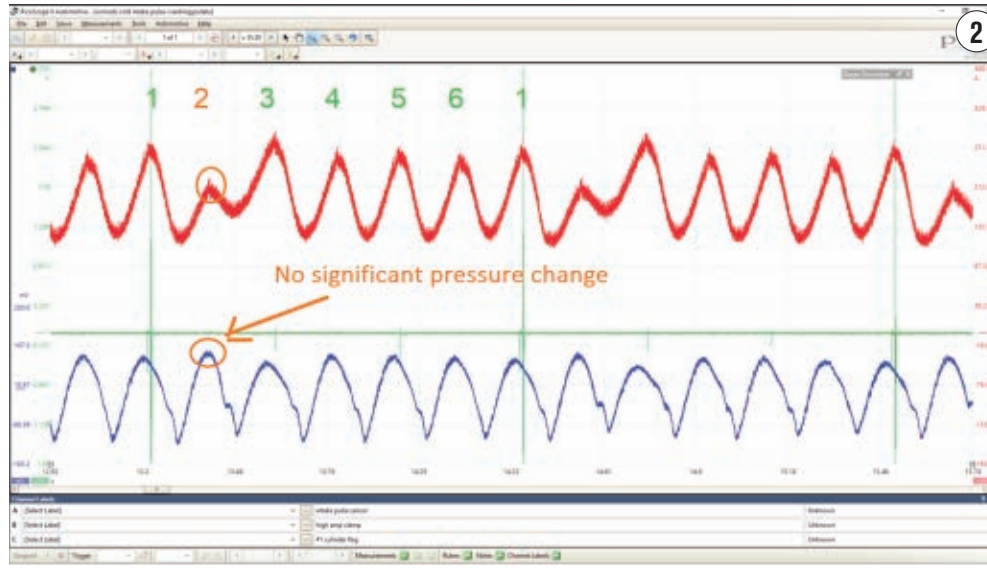
Quick to grab their Pico lab scope, current probe, and delta sensor, they cranked the engine over several times while obtaining starter current (for relative compression), and pressure pulse data from the cooling system reservoir **(Figure 1)**. This data indicates a few important pieces of information pertaining to the health of each of the cylinders, which cylinder is faulted, and most importantly, at what area of the cylinder the fault is occurring.

After having referenced the firing order in service information and capturing the #1 ignition event (for synchronization of top dead center for cylinder#1), they began their analytic process. It was quite visible to me that there is a disturbance in the coolant reservoir pressure (In blue) that correlated with the #2-cylinder relative compression hump.

Logic would tell you that the #2 cylinder is leaking compression into the cooling system. However, if you look more closely, you can see the blue cooling system pulse trace has been magnified 20x to see this disturbance. Even though there is clear evidence that the cooling system has been compromised and is allowing cylinder #2 to shed its contents into the cooling system, I believed we were dealing with an additional complication. With the amount of loss indicated by the #2 relative compression hump, I would have expected the cooling system trace to indicate a much larger distur-



THE RELATIVE COMPRESSION TRACE (RED) indicates a loss of compression for cylinder #2. The cooling system pulse trace (blue) shows pressure change/activity in the cooling system that correlates with the compression loss.



ALTHOUGH THE (RED) RELATIVE COMPRESSION TRACE indicates loss of #2 compression, the intake pulse trace (blue) shows no correlating significant change in pressure.

bance than what was present (had the head gasket been the only leak point).

A second approach

The process was repeated but this time with the delta pulse sensor interfaced with the intake manifold **(Figure 2)**. Like the coolant system pulse trace, this area also delivers a ton of information quite easily. The same #2 cylinder is shown as being compromised (in red). After viewing this data, my question became, "Where is the #2-cylinder compression going?"

Visible in this capture is a lack of significant rise in the blue trace (at the same time that the red trace indicates a leak for cylinder #2). According to the blue trace, what can be determined?

The data doesn't lie

With all the information in front of us, we were faced with deciding how to proceed. Here are some bullet points of what we knew to be factual, and I will ask all of you, diligent readers, for your input:

- Misfire present; cooling system antifreeze level is low with no visible leaks
- Relative compression trace demonstrates cylinder #2 has a significant loss
- Cooling system pulse trace indicates almost no rise in pressure when cylinder #2 completes its compression stroke
- The small size of the pulse doesn't seem to correlate with the large relative compression loss

Given this information, what would you recommend doing next?

- Repeat the test and place the pressure pulse sensor in the exhaust system and/or dipstick tube
- Replace head gasket and recondition cylinder head because of poor intake valve seating
- Defer to a different test due to inaccurate results from this test
- Replace head gasket for suspect bank

Be sure to read next month's Motor Age issue for the answer to this month's challenge and what was discovered!

SCAN THE QR CODE TO READ THIS AND RELATED ARTICLES ONLINE:

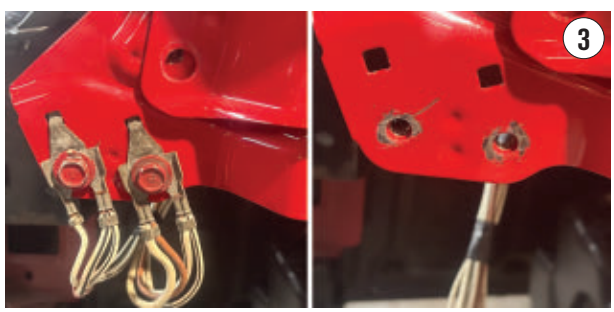
SOLVED: (April 2023, *Motor Age*) 2015 Lexus CT200h 1.8L, DTC P261B

What would you recommend doing next, given the data bullet points in last month's challenge?

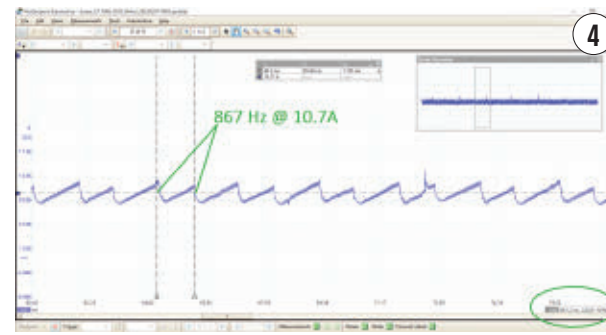
1) Replace the electric water pump
2) Replace the electric water pump relay
3) Reprogram PCM to correct for faulty software
4) Remove the bumper for further testing, more unanswered questions

For those of you who chose answer #4, congratulations! Even with the already acquired data, we cannot condemn the electric water pump or the relay, nor can we claim that the PCM software is corrupted.

Like any other electrical component, the relay and the water pump must have an adequate voltage and ground supply to function correctly. Referring to the wiring diagram, the water pump and the relay share the same ground.



THE COLLISION DAMAGE was repaired flawlessly, but the ground points were poorly referenced because their mounting surfaces had been painted. After the ground locations were properly prepared, the vehicle functioned as designed.



THIS POST-REPAIR CURRENT PROBE TRACE displays the pump amperage to have increased, and the speed to have increased as well.

As the water pump is commanded by the scan tool, the PCM energizes the relay. Current flows through the coil side of the relay (making it a magnet) and draws the switched contacts closed, supplying current through the water pump. With current flow comes heat and voltage drop/resistance.

If the common ground (for the relay and water pump) were in poor condition, resistance at the ground location would create a voltage drop and heat as the pump initially ran. After the pump relay was cycled off/on again, the remaining heat/voltage drop would limit current flow/magnetism through the relay.

The relay switch contact would fail to close at times. But, when it closed, it wouldn't do so properly. This created an additional voltage drop (across the contacts of the relay) and limited current flow for the water pump to function properly.

Ground #A3 (beneath the front bumper) was inspected and found to have poor contact due to a recent paint job/body shop repair (**Figure 3**). The ground location was cleaned/enhanced, and the pump then ran as designed (**Figure 4**).

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The TOPDON Phoenix Max Diagnostic Scan Tool is an OEM-level scanner with a 13.3" screen, housed in a worksite-ready exterior. The all-in-one tool offers many functionalities that expand any technician's capacity to complete even more jobs. The Phoenix Max includes a four-channel oscilloscope, ADAS compatibility, optional HD Truck diagnostics, and cloud-based programming. The high-tech MDCI (modular diagnostics and communication interface) includes the latest protocols, allowing professionals to perform more complex repairs on various automotive and heavy duty vehicles with optional add-on software.

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The Rotary R3AC Series A/C Recharging Machines are designed to automatically service the refrigerant in vehicle air conditioning systems. The product line provides professionals with a quick, efficient, and cost-effective way to recover, recycle, and recharge R-134a and R-1234yf refrigerant gases. Powered by TEXA, the A/C machines are available in three models: single-gas R3AC50-A (R-134a compatible), single-gas R3AC60-YF (R-1234yf compatible), and dual-gas R3AC80-AYF (both R-134a and R-1234yf compatible). Each machine is Wi-Fi enabled, updates automatically, and can connect to peripheral devices, such as smartphones and printers. Remote monitoring is also available through a mobile app.

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MOTOR TruTech is a web application designed to provide vehicle service and repair data available within days of OEM publication for domestic and import cars, light trucks, vans, and SUVs. Users receive immediate access to necessary vehicle data for performing maintenance and repairs. Additional features include advanced global search with filters, ensuring users get best possible matches based on search criteria; a single location for all associated content (repair details, required tools, warnings alongside service procedures) for efficient repair times; and access to MOTOR's parts and labor times to quickly identify necessary details to perform vehicle service.

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FOR ELECTRIC AND HYBRID VEHICLES

The EV Battery + Coolant Leak Detector from Redline Detection is designed to ensure EV battery enclosures, battery coolant systems, and other EV system components are safely sealed to prevent the intrusion of water, dust, or other contaminants that could cause a catastrophic thermal event. Using patented technology, BCLD creates a signature air that pinpoints the precise location of leaks with 100 percent accuracy, the company says. BCLD also uses Redline's PurgePulse technology to vacate all coolant fluid from the battery pack before testing. This technology is already mandated essential by OEMs in 160 countries for lid-off repairs, after any collision, and as regular preventive maintenance.

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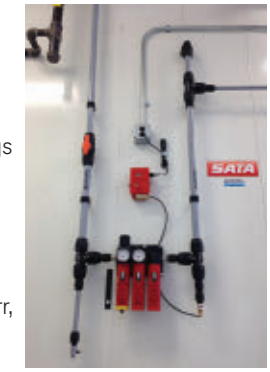
UPGRADE YOUR SHOP, UPGRADE YOUR AIR



DanAmAir is a fast, flexible and easy-to-modify aluminum pipe system for compressed air in any shop or garage. It's all about pushing clean air. DAA provides clean air quality with optimum flowrate performance. Our Press-to-Connect fittings feature a full-bore design for turbulence free air delivery. This quick, instant connection eliminates the need to thread, solder or glue, accounting for far less installation times than traditional copper or black pipe. Designed with simplicity in mind, DAA allows you to do-it-yourself. Measure, cut, de-burr, then simply Press-to-Connect, equaling lower installation times and cost. All fittings arrive pre-torqued for immediate assembly and pressurization, as well as being interchangeable, allowing for ease of future addition or expansion. Product design and support is readily available from Dan-Am Company.

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AVAILABLE WITH OR WITHOUT IQUITY

The Thraxus Elite Safety Eyewear from Radians are available with or without IQuity, Radians' intelligent anti-scratch, anti-fog technology. The Elite eyewear are engineered with the same patented edge design and cyclonic venting of the original high-performance Thraxus safety glasses. To provide a custom fit on a variety of head shapes and sizes, Elite also features three-position ratcheting temples with a wire core that allows for more adjustability. A soft brow further boosts the comfort level. Thraxus Elite IQuity incorporates even more features to offer ANSI Z87.1+ high impact protection, D4 dust and D3 liquid splash protection, as well as X anti-fog performance.

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BUILT-IN HUMAN BODY SENSOR

The SABER 2,000 Lumen LED Corded/Cordless Underhood Light, No. ATD-80365, features a human body sensor (HBS), a 360-degree microwave radar sensor that automatically activates the light when a human body is within 10' to 15' and turns off when out of range. The sensor saves on both battery power and lifecycle. The 40" light bar emits up to 2,000 lm, offers two modes (high and low), and has large, padded covered hooks that extend from 55" to 83", capable of fitting new SUVs and light trucks. The light comes with a 25' removeable cord that remains flexible in cold weather and is oil and grease resistant.

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PERFORMS EV BATTERY PACK ANALYSIS

The Autel EV Diagnostics Upgrade Kit adds EV and hybrid vehicle diagnostics without the need to purchase a new tablet. It performs a state-of-charge and state-of-health analysis for true battery condition. The kit includes the EVDiag Box, testing software, and adapters for specific EVs to enable testing of battery packs. The Upgrade Kit connects with existing MaxiFlash VCI or VCMI, and is compatible with the MaxiSYS Ultra, Ultra ADAS, MS919, and MS909.

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The WD-40 Specialist Degreaser and Cleaner EZ-Pods are ideal for greasy wheels, gears, floors, and surfaces, including concrete and stainless steel. Made from a concentrated, industrial-strength formula, the pods are portable, easy to store, and easy to use. Simply drop one EZ-Pod in 32 oz. of water for a ready-to-mix-and-go solution that dissolves in minutes. The pods work in any temperature water but dissolve best in warm water and can be used in a variety of applications like spray bottles, buckets, and power washers. The EZ-Pods can be used on sensitive surfaces like plastics, rubber, neoprene, carbon fiber, copper, aluminum, chrome, and painted areas.

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COVERAGE FOR 80 PERCENT OF TRUCK APPLICATIONS

ETE REMAN now offers both front and rear remanufactured differentials. The company offers more than 160 part numbers to cover 80 percent of domestic truck applications, with more than 27 million VIO. ETE's quality assurance makes sure that all differentials are top-of-the-line, featuring media-blasted cases and housings, pre-placed bearings and seals, tolerance-inspected parts, and more. All differentials are shipped in clean, reusable pods for security and safety. With ETE, not only can you expect the best quality, but also the best customer service with 50+ customer care reps.

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INCREASED TPMS COVERAGE FOR AFTERMARKET SENSOR BRANDS

The ATEQ Q4 2022 Software Release includes new vehicle model coverage, updated OE sensor information, increased TPMS coverage for aftermarket sensor brands, and new aftermarket TPMS sensor brands. New versions now available are for VT67, VT57, VT56, VT47, VT37, and VT36. One notable addition is the Launch Tech's LTR sensor is now available on all ATEQ TPMS tools. Additionally, the latest release offers updated coverage from over 25 aftermarket sensors.

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ENABLES SIDE-TO-SIDE SHIFTING

The BendPak EV2400SL EV Battery Pack and Powertrain Lifting System has recently been upgraded and now part of the company's Mobi-EVS lineup. The EV2400SL retains its 2,400 lb capacity but now features an integrated slip-plate deck that enables side-to-side shifting as well as more ergonomic deck handles and larger tool trays that run the length of the platform on both sides, keeping fasteners and tools within easy reach. Other notable upgrades include zero-throw tri-casters, a reinforced steering handle that can be removed and stowed when not in use, and a 2-pc lift motor cover for easier maintenance. Mobi-EVS models meet or exceed the standards prescribed by ASME PASE 2019.

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READS TEMPS UP TO 1,022 DEGREES F

The Matco Tools Maximus Diagnostic Thermal Imager is designed to diagnose problematic components related to heat, cold, and wear. It's able to read temperatures up to 1,022 degrees F. The thermal imager features a 320 by 240 resolution screen with dual cameras that provide optical and infrared images. The centerpoint measurement cursor quickly and accurately locates the problem, measures the temperature, and saves time. There are five modulated imaging modes to choose from, it offers super sensitivity of .07 degrees, a 1.5'-130' imaging distance, and it is able to store up to 20,000 pictures with the built-in 3GB storage. It also comes loaded with a database of good/bad samples as well as a lifetime of free updates.

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OFFERS FULL-SYSTEM VEHICLE DIAGNOSTICS

The Launch Tech X-431 Torque 5 is a tri-function device that serves as the VCI for OBD diagnostics in addition to a digital multimeter and a two-channel oscilloscope. The bidirectional Torque 5 also includes ex tensive coverage of European, Asian, and Domestic vehicles, with pre-installed software modules for ADAS, battery testing, immobilizer diagnostics, CodeAssist by Identifix, and more. The Android 10-based scan tool features a 10.1" color display, 4GB ram and 128GB ROM large storage, and is equipped with a high-endurance battery. It also supports CANFD\DOIP diagnostic protocol and full-system fault diagnosis, with functions such as read DTCs, clear DTCs, read data stream, special function, actuation test, coding, matching, and more.

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ALLOWS VISUAL CUES FOR RAPID TOOL SELECTION

The Tool Staging System, TSS 5.2 from Shadow Tool Company Shadow, offers the same features as the TSS 6.5 model but stands just 5'2" tall, for easier use under a lift and visual maneuvering through a large facility. The closed TSS 5.2 provides tool storage capabilities and tool staging when the system is opened and expanded, creating a barrier-free tool wall. This open access reduces physical motions, allows visual cues for rapid tool selection/return, and seamless tool inventory control to help save time, providing ergonomic relief while increasing available work hours to improve bottom line profits.

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AD INDEX

THE TRAINER #137: PUTTING THE AUTEL SCOPE TO WORK!

MANY OF YOU HAVE WRITTEN TO ASK FOR A MORE DETAILED TUTORIAL ON USING THE AUTEL SCOPE AS A DIAGNOSTIC TOOL. THIS IS THE FIRST IN A 3-PART SERIES!

PETE MEIER // Creative Director, Technical

Many of you have written Autel or me directly about a series of videos that would help you learn how to use a scope and how to interpret the patterns you see. I think that's great and I'm very excited about beginning this series. I am a firm believer that there are diagnostic challenges that you just can't resolve without a scope and the tool also makes testing nearly any system on the vehicle more efficient and more accurate with its use.

Let's get started!

The DSO, or digital storage oscilloscope, is a cousin of the multimeter you are likely using today. Both are digital instruments, rather than the old analog tools we used years ago. What this means is that the signal they are connected to is not displayed directly on the tool's screen. Instead, the tool samples the signal and converts the signals into a digital signal through an A/D, or analog to digital, converter. The accuracy of the displayed measurement is based, in part, on how many samples per second the tool can take. The more samples it gathers, the more accurate the signal display.

Here is where the scope shines over the multimeter.

The scope can sample millions of times per second while even a high end multimeter may only be able to sample 700 – 800 times per second! Another feature the scope has over the multimeter is the ability to display the signal over time on the screen. This gives us a pictorial description of what is happening and makes it easier to dissect and understand. With the appropriate accessory probe, this feature allows us to display not only electrical circuit operation, but to also display current measurements, pressure measurements and even vibration!

As you can see, using a scope can help you make more efficient diagnostic tests, saving time and improving accuracy. And while this series of videos focuses on the Autel scope in particular, the things you'll learn watching it apply to all scopes!

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