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Technical Knowledge for Independent BMW Service Professionals

Speedometer I Diesel I Plastic Repair

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Technical Knowledge for Independent BMW Service Professionals

If It's Not One Thing It's Another

Tracking down the cause of one problem can lead to other issues. A speedometer repair on this BMW evolved into something deeper.

Measure what is measurable and make measurable what is not.

~ Galileo Galilei

Imagine this 2001 BMW 740i in very good condition that's had some past TLC but had other recent shops "have a go at it." This adventure all starts with a question: "Can you get the speedometer working?"

This is a first time customer that was advised from another customer/friend about; "having the correct tools."

For the uninitiated technician that's never seen one of these models, this is an example of a complex and early CAN adapted vehicle.

The approach and customer interaction

The conversation should begin with some background and specifically; who owned it, how and where the vehicle came from. One piece of information came from a paid invoice from a BMW dealer that diagnosed a right rear wheel speed sensor defect. It is assumed the speedometer uses the R/R speed sensor data to operate the speedometer.

Hint: Never assume and keep it simple.

A short road test may be the best way to see speed sensor data with the vehicle owner, while attempting to prove some answers to multiple theories. This model does have a DLC (OBD II) very close to the cup holder mounting of the center console. The customer did note "This is where the other shop plugged in a tool." DME and EGS data can be accessed at the OBD II connection.

Road test with the customer

Quick and simple is the tool that offers wheel speed data that is current and is visible with screen captures. One choice is a tablet/Android device that offers wheel speed data in real time. With recorded speed at the EGS and no instrument speed, there was a problem that needed some investigation. The images were "stitched together" to offer current EGS data and give the customer the insight of what one controller has access to.

Simply explained for the customer is how the wheel speed data is transferred (shared) via CAN from one (multiple) controller(s) to another. The OBD II connection is not going to offer all of the information needed to solve the primary question.

Hint: A defective ABS system will allow the rear wheels to spin up at road speed on the hoist. An operating ABS system will NOT allow the rear wheels to spin at road speed. Here's why.

If the vehicle has the rear wheels spinning and the fronts are not, the ABS assumes the vehicle is in a skid or front wheel lock-up.

It's no different when driving on loose gravel or snow. If any of the wheels are determined as "locked" or "stopped" while rotating and one or more of the other wheels are still in motion, the ABS activates.

This BMW has this behavior on the hoist with the rear wheels spinning. If the ABS has a defect, the ABS doesn't intervene and now the rear wheels rotate faster without ABS intervention.

Many vehicles have similar qualities. The difference is with all wheel drive with all four wheels spinning. The vehicle may complain, but it can get some road speed.

For added measure, the customer felt far more confident when the diagnostic tools were attached to the BMW 20 pin proprietary port with a live session.

Tools used:
90 amp clean and stable power supply
INPA with laptop, Launch EasyDiag with Android tablet
Bluetooth Oscilloscope and Android tablet
Multi-meter and amp clamp

Definitely old school

Start was with a complete scan and measure/save the condition of all installed network controllers within this vehicle. Do this at the 20 pin port.

Maybe there can be something recorded and usable for future diagnosis. Also noted is the BMW 20 pin data link at the R/F fender. At this connection, the entire network and all controllers are accessed.

The current lists of recorded faults are:

- DME - 8C (Activation map cooling)
- EGS - 3C (Transmission switch)
- MID - 03 (no valid status response TELEPHONE)
- ABS - 5C (Pressure sensor test) recorded during the road test
- ZKE - 07 and 08 (Seat heater circuit open both L and R)

A quick road test with the customer confirmed that the speedometer was not operating, but the EGS displayed wheel speed data with an Android software package at the 16 pin OBD II connection.

Note that all 4 wheels were sending equal rpm road speed data from the ABS control unit, to the EGS, via CAN messages.

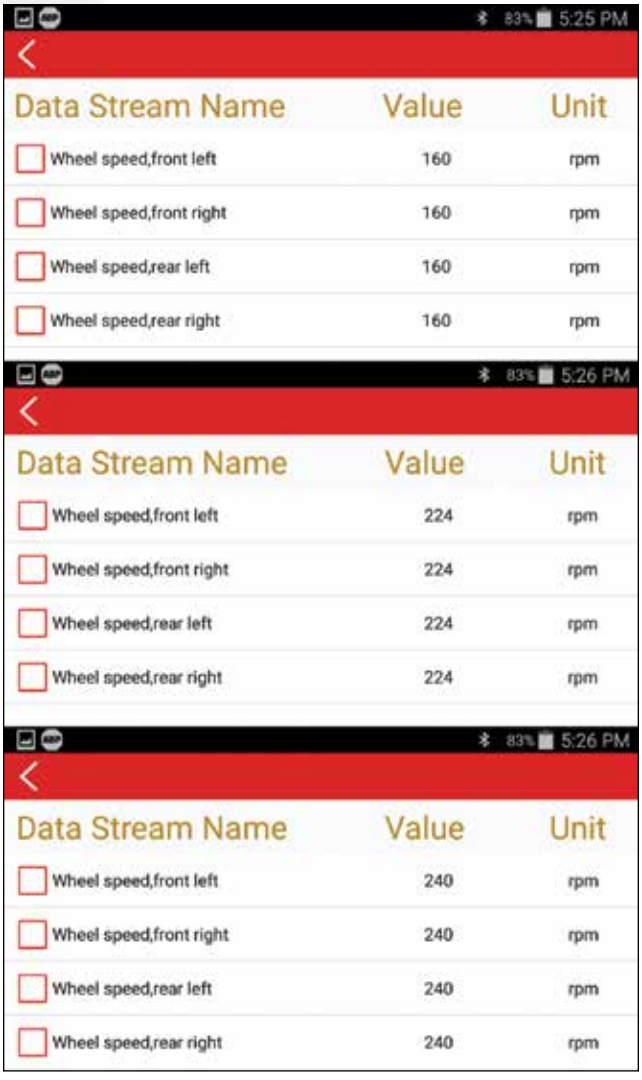
The vehicle owner now has the confidence that the previous repair facility may not have diagnosed the primary concern correctly and that this assignment is to continue and repair the primary concern, which was an inoperative speedometer.

Old and new thinking – different but the same

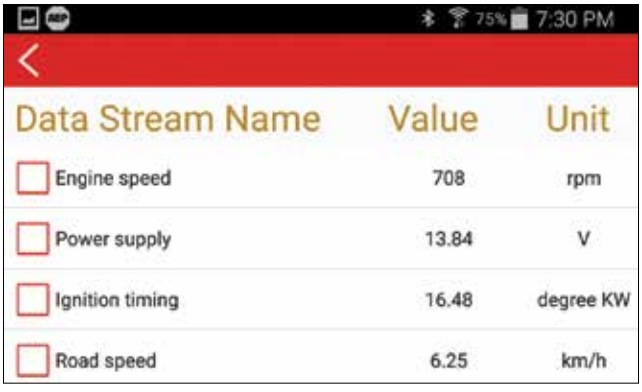
INPA with a laptop is quite the versatile tool when dealing with older models that require a diagnosis with access to bi-directional control. The Launch EasyDiag is a quick diagnostic tool running on a tablet but does not have access to bi-directional control.

Note that this Launch specific test offers road speed at the DME.

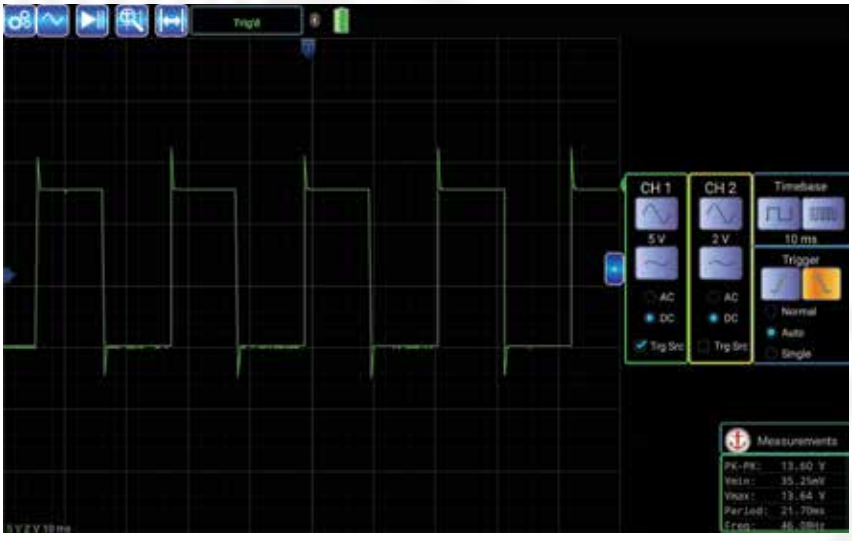
This test offered no visible road speed indication at the instrument cluster.



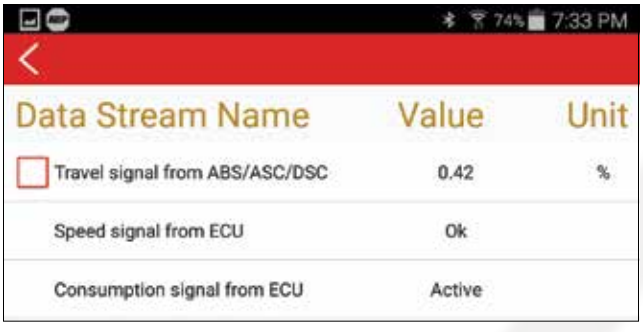
Road speed test



Launch Idle Test



R/R ABS signal - Note that this signal was "stretched in DC mode." This signal also sends the trip odometer data.



Instruments travel signal

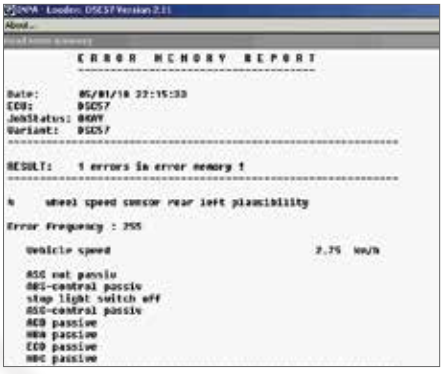
Can the ABS sensors be measured?

At the ABS controller, the sensor previously diagnosed by the dealer was tested with an oscilloscope and with the rear wheels spinning in Drive and at idle.

One interesting piece of information was discovered looking at the "defective LCD display." The trip odometer was counting but with no road speed indication.

Was the instrument cluster defective?

Proof and a measurement are in view at Instrument Cluster Electronics. The ABS is sending the correct Travel Signal message with no road speed indicated at the cluster.



L/R sensor error

Is there something missing?

Some patience and a detailed schematic will help, constant testing and searching for fault recordings may take time to "catch the culprit."

Side note: What are the chances that the upper radiator outlet was leaking (intermittent spray when hot) during the hoist tests? Is that why both tools recorded the "140 Output Thermostat Mapped Cooling" error?

Replace radiator and bleed the system immediately.

There is some good fortune at times when "repeat the test" offers a result that may confirm a suspicion. After the radiator replacement and during the road test, one new fault was recorded.

Fortunately for the vehicle owner, a new BMW replacement sensor for the R/R side was previously purchased. That sensor is now used for the L/R side.

Replacing the sensor however was a traumatic affair. After 17 years of attachment to this BMW, it was "difficult to convince it to let go."

Hint: Never allow a BMW to get the better of an argument!

With the new sensor installed, the following image offers some satisfaction that the "trauma" was worth it in the end. The primary question is answered.

A road test with INPA confirms the IKE reads the correct data with no faults.

Note that this INPA specific test offers road speed at the Instrument Cluster and is trimmed to fit this article. The image to the right indicates no rpm, but the "Read CAN" button was used to acquire rpm via CAN. At the IKE, the correct rpm signal is read within the lower image, off throttle and coasting.

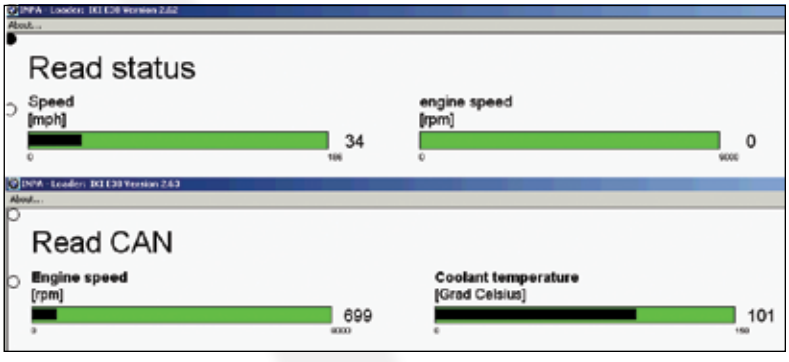
The view of the speedometer solves one interesting mystery but the road test repeated the ABS/DSC fault previously recorded. During the fault recording, the ABS warning lamps were active. Fortunately, the vehicle owner was aware of the initial fault recordings and ABS warnings on the cluster.

The DME again recorded a previous fault. It required a new map controlled thermostat assembly.

ABS - 5C (Pressure sensor test) recorded during the road test

DME - 8C (Activation map cooling)

Operating Speedometer



Merged speed test

Explanation and operation "If – Then – Else"

The ABS/DSC pressure sensor test is described as such:

- In BMW terms, the device in question is called a pre-charge pump.
- The BMW number is 34516781435 with a heart attack when priced.
- The pre-charge pump operates under the following conditions:
  - Road speed greater than about 20 mph
  - Engine speed greater than 2000 rpm
  - Engine torque greater than 100 Nm

A simple test

If the driver accelerates above the set conditions and the ABS warning lamps are ON and a fault code is set, it is a suggestion that the pre-charge pump is defective.

If the fault is cleared and the driver accelerates below the set conditions, it is likely the ABS lamps may not switch to ON (not a perfect suggestion).

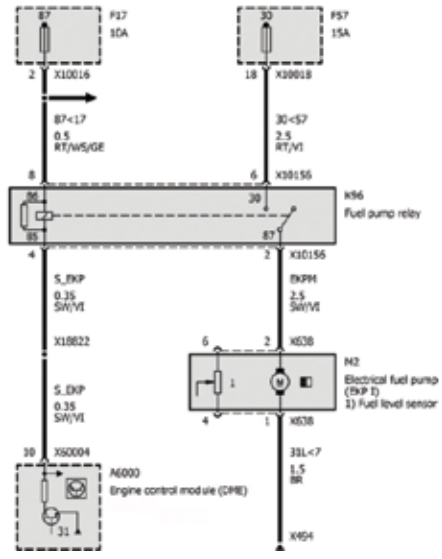
A sure test is to apply battery voltage to the heavy electrical connections at the pre-charge pump. A defective pump will likely NOT spin:

Battery positive to RED : Battery negative to BLACK

Replacement - quick and dirty:

Battery positive to RED : Battery negative to BLACK

Installed pump



Fuel pump circuit

Bleed the fluid at the outlet side until no air is visible, then torque the line.

Reverse the connections to allow any trapped air back to the reservoir.

Reconnect the scan tool and delete the ABS/DSC fault code and road test again.

Optional replacement - complete brake system flush

So a radiator, thermostat assembly, coolant, ABS wheel speed sensor and pre-charge pump were all replaced. All remaining brake fluid was washed away with a soapy water solution.

The original speedometer issue was resolved, with other anomalies and defects dealt with one at a time.

Amp clamp 01

Any remaining fault codes were cleared, and screen images were captured with a final road test. The BMW was returned to the owner.

Murphy's Law: "Anything that can go wrong will go wrong."

The BMW returned in a week or so for a no-start condition. With a fuel pressure gauge and by cycling the ignition key, no fuel pressure was evident. A 30 amp fuse was found to be burned, using a schematic.

A replacement fuse at F57 did enable fuel pressure to return, the engine ran with no faults but – for the uninitiated there is another mystery. There is a reason that seemingly points to a failing fuel pump. Can the fuel pump and entire circuit be measured? Can the pump be monitored?

This image of the Fluke meter and a simple amp clamp offers some information with a 30 amp re-setting fuse to protect the circuit at F57.

What does the fuel pump look like with an oscilloscope and amp clamp?

Some research on this pump indicates 10 commutators.

The fuel pressure gauge matches the specifications.

The fuel flow rate matches the specifications.

The fuel tank is near full of premium fuel.

The fuel pump calculation is as follows:

60,000 milliseconds (ms) divided by 11.21 ms = 5352.36 rpm < Suspect rpm

The harness at the fuel pump under the rear seat offered identical results but the pump was still suspect and the engine ran for an extended period of time.

There were allowances of time to work with this BMW and attempt to duplicate the defect. In the shop, the BMW worked perfectly every time it was moved, driven and tested.

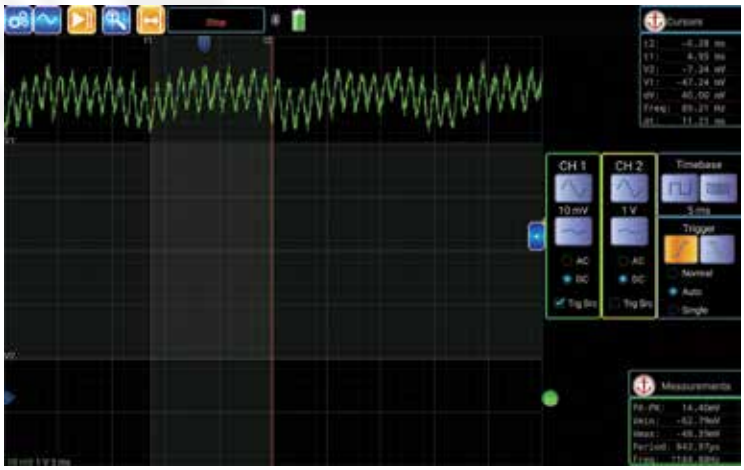
It certainly didn't happen according to the "plan."

The fuel pump eventually failed (burned fuse) and the car returned in a few weeks. This time with the same tests, same tools and the oscilloscope, the test caught the pump failing in a dramatic fashion. Despite the failing pump, the engine ran with no faults recorded.

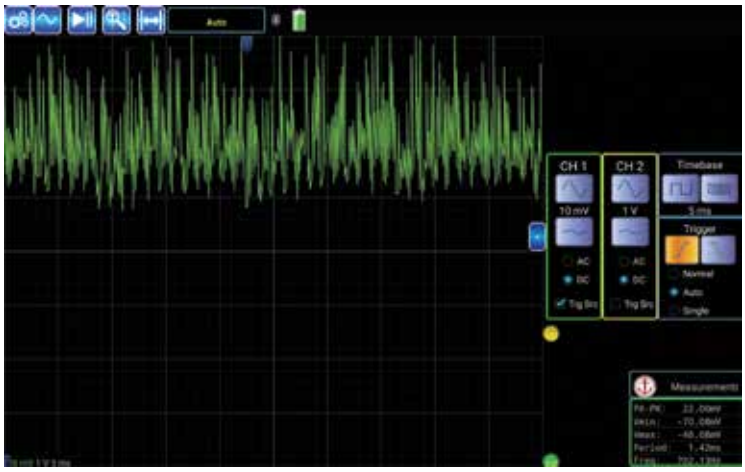
The oscilloscope never lies.

The fuel tank was quite close to full and, fortunately, the fuel pump was still operating. At the test port and adapter, the fuel was emptied safely into numerous fuel bladders and stored.

Again for the uninitiated, removal of the fuel pump is a simple task, but pay very close attention to the fuel pump motor connections. Anything that resembles blackened crimps at the wires is suspect. Replace the female blades with tight fitting versions and DO NOT solder the wires. Crimp the barrels with a suitable tool to ensure a proper fit.



Original pump



Defective pump

New pump

What was learned?

Modern tools are simple in nature and work well. In this case, most of the diagnostics were completed with an Android tablet. This included live data and a Bluetooth-connected oscilloscope with a simple amp clamp.

The advantages are portability and the ability to connect quickly.

Taking the time to test, the older software still performs flawlessly.

The software on the laptop with INPA works very well with these older models. The major difference with INPA is bi-directional control with the entire vehicle. You get what you pay for.

Dust them off once in a while, there are secrets to uncover.

NOTE: Anything that was "ISTAfied" previously at the dealer will NOT allow the GT1 to access DME live data. – This was tested with two serial data interface connections and caused the loss of numerous hair follicles.

Anything else?

Fortunately the vehicle owner was quite patient with plenty of understanding for the anomalies. The "special" captured images tell such a story, especially since rodents had a party inside the BMW air box.

So this article is presented to give the reader something to think about when using equipment to measure anomalies or defects. Some different approaches were employed, and we resurrected "from the dust of time" older tools that still work.

Part of the article is also intended to provide answers to multiple defects found with the vehicle over a period of time. With each repair and captured images, the customer had the sense of trust that the repairs were warranted and required. •

BMW Diesel Overview

Since the early 1900s, the diesel engine has been widely used in many industries to power vehicles and equipment. They have remained popular because of their overall efficiency and durability, although in the United States this may not be as apparent as in other countries. Worldwide, diesel vehicles account for 50 percent of vehicles on the road. In the United States, fewer than 10 percent are diesel!

BMW has been in the diesel engine club for quite a while. In the mid 1980s, they released their first diesel engine, the M21. This was based on the venerable M20 engine but with strengthened components to handle the increased forces from a diesel engine. It was available in both 3 Series models as well as 5 Series. It's rare to see a BMW diesel from the 1980s in the United States. Any models you may come across are most likely gray market imports.

Thermal Efficiency

By operating at a much higher compression ratio than gasoline engines, diesel engines are able to compress the fuel/air mixture until ignition occurs. As the pressure inside each cylinder rises, the temperature also rises until spontaneous combustion occurs. The compression process lets the engine squeeze a little more energy out of the fuel. Diesel engines are known to have the highest thermal efficiency of any internal combustion engine design. This means diesel engines create the least waste energy [heat] of any internal engine design. Less waste equals more power and efficiency.

Glow Plugs

Diesel engines use glow plugs to aid in starting and smooth running. By increasing the temperature in each cylinder with a glow plug before cold start-up, proper combustion can be completed quicker, particularly when the engine is cold or in low ambient temperatures. In most modern diesel engines, the glow plug system is inactive until temperatures are below a set point. Most commonly, this is around 40 degrees F. The colder the ambient temperature, the longer that glow light will stay lit! On many diesel engines with bad glow plugs or glow plug modules, the vehicle may not want to start at all if the glow plug system is not operating correctly.

BMW diesel engines have a primary driver for the glow plug system, known as the glow plug preheating control unit. These are failing more frequently as many engines reach higher mileage. Most commonly, the control unit sets glow plug circuit faults for multiple cylinders. Rough running is often noticed during cold starts if there are issues with the glow plug system. During diagnosis, don't forget the basics!

Always start by ohming out each glow plug if bad plugs or the control unit are suspected. Correct resistance values may vary, but you should never find infinite resistance on a glow plug. Although glow plugs are easy to test with a multi-meter, the time-consuming part of testing is the necessity to first remove the intake manifold. This is the case with BMW's M57 and N57 diesel engines. The glow plug control unit is located under the intake manifold as well and can be tricky to remove because of its awkward location. In addition, it may be necessary to remove coolant pipes during module replacement.

If a faulty module is being replaced, it's wise to replace all of the glow plugs at the same time. It's also important to monitor coolant temps during glow plug diagnosis. If a lazy thermostat is keeping the coolant temps too low, this can result in excessive glow times, shortening the life of the module and glow plugs.

A side note: In higher-mileage vehicles, the glow plugs may become stuck in the cylinders from carbon buildup and corrosion, making them all but impossible to remove without stripping out the threads in the cylinder head. By pre-treating with a penetrating oil spray and getting the vehicle to full operating temperature before attempting removal, the risk of engine damage can be lowered. Do not heat

Opposite Page: A pressure controlled media blaster has anti-clogging purge action! It's best to use medium or fine walnut shells for de-carbon services.

the glow plugs directly! This can quickly destroy the aluminum head and ruin your day. If the glow plugs do break off in the cylinder head ... well, have fun. Many tool manufacturers offer removal kits for broken glow plugs.

Fuel System

BMW utilizes a common rail direct injection fuel supply system on their modern diesel engines. It shares many of the same design principles as their gasoline engine counterparts. By directly injecting diesel fuel into the combustion chamber at extremely high pressure, more even fuel atomization is ensured. This allows for an efficient combustion event that can create more usable power. Pressures at the fuel rail are in excess of 30,000 psi! Fuel pressure this high can be fatally dangerous if proper safety precautions are not followed.

BMW uses Bosch Piezo-electric fuel injectors on their direct injected engines. By using Piezo-electric elements in the fuel injectors, the DDE (Digital Diesel Electronics) can control fuel injection duration down to the millisecond. The fuel injectors contain a quartz Piezo actuator. By introducing an electrical current to the Piezo actuator, it actuates the pintle to release fuel spray.

This is where fuel pressure is at its highest, as it must overcome the spring pressure inside the injector at upwards of 30,000 psi. The extremely high pressure vaporizes the fuel into a fine mist, which readily ignites once cylinder pressure is high enough. Piezo injectors can be operated much faster than a standard injector, allowing for much tighter control over fuel delivery. This can drastically increase efficiency and power output.

The classification values are visible on the plastic base plate on the injector. Note the fragile line fittings, be careful not to damage them.

When repairs are made to the fuel system, it must first be safely depressurized. This doesn't mean crack open a line on the fuel rail. This will damage components as well as send atomized fuel spray across the engine. By using factory level scan equipment, the fuel system can be safely depressurized to ensure a safe working environment.

Because of such high operating pressures, BMW fuel injectors lead a difficult life. At high pressure, any contaminants in the fuel supply system can quickly destroy fuel injectors as well as the supply system sensors. For example, if the high pressure fuel pump fails, it may send debris into the fuel rail. This will quickly clog and render the fuel injectors useless. At this point, the fuel rail, injectors, high pressure pump, and rail sensors would all have to be replaced. Thankfully, BMW has designed a fairly reliable fuel supply system, and these systems don't usually fail catastrophically.

Fuel injector issues still arise from time to time. Usually, these issues appear as rough running at idle. On the M57 engine, smooth running faults are commonly stored for cylinders experiencing rough running conditions. Smooth running values can also be viewed live with factory-level scan equipment to

The mini slide hammer is a must for both gas and diesel injectors.

determine which cylinders are running poorly. Zero-quantity adaptation faults can be stored for cylinders as well. This fault is almost always a bad injector.

If diagnosing a faulty fuel injector, it's possible to move the injector to a different cylinder to see if the rough running will follow the injector. Each injector has a specific classification value that determines flow characteristics. These values must be entered for each fuel injector on the corresponding cylinder. Failure to store proper injector classification values can cause issues in itself and should not be overlooked when swapping or diagnosing injectors. This is a critical step with BMW injectors and can only be done properly with BMW ISTA software or a comparable factory-level tool.

When replacing fuel injectors, care must be taken not to damage them. Particularly on diesels, the injector can become quite stuck in the cylinder head. BMW offers a small slide hammer tool that threads onto the fuel injector to aid in removal. This is a necessity! If the fuel injector is equipped with a Teflon seal ring, do not use any chemicals or lubricants on the seal. It's best to keep the seal covered until it's ready to be installed. Always replace the copper crush washer as well, if so equipped.

BMW injectors incorporate a fuel injector return line. This is where unused fuel is returned to the fuel system. The return line setup on the fuel injector is quite small and prone to damage if not properly secured. If the return line feed is damaged at the fuel injector, the entire injector must be replaced. These are not cheap! Be careful.

Verification of Update Status

The fuel injection system is controlled by the DDE. The first step in any diagnosis is to run a full scan of the vehicle as well as verify current I-level or Integration level of the vehicle. On BMW vehicles, the I-level is used to verify update status of all connected vehicle control units. Many issues and problems can be eliminated by updating vehicle systems to a current I-level. Most SIBs (Service Information Bulletins) list the I-level for the corresponding bulletin, so it can be quickly determined if the vehicle requires updates.

In addition to requiring updates, DDE can have problems of its own. The DDE control unit houses individual drivers for each fuel injector. In certain cases, the drivers can fail inside the control unit. The problem if the driver fails is that the DDE will not recognize the internal failure.

A BMW ICOM interface or factory level pass-through device is a necessity to diagnose and update vehicles.

There are two fill locations for DEF on the X5. The larger DEF tank fill is directly next to the oil filter housing. The smaller active tank fill is located on the passenger front of the engine bay.

Most commonly a failed injector driver will manifest as a rough running in one or more cylinders. Often, smooth running faults are stored and the vehicle will point blame toward the fuel injectors. Even after swapping fuel injectors and performing a de-carbon service, these faults can return with a bad DDE. The only way to be certain of a bad DDE is to monitor the fuel injector signal with an oscilloscope. Only then can you verify proper grounding of the fuel injector circuit.

When diagnosing customer complaints of rough running, carbon buildup can often be the main culprit. The BMW diesel has a few issues that make carbon buildup worse. First, the fact that BMW diesels are direct injected leads to carbon buildup. Without fuel washing over the intake valves during engine operation, carbon will begin to take hold and begin to build up. This carbon can originate from the crankcase ventilation and exhaust gas recirculation systems.

A failed DDE is the last place you might suspect an issue.

Carbon generally builds up around the intake valves and intake ports closer to the valves. As the buildup gets worse, air flow begins to be disrupted to each cylinder. Not enough air entering the engine affects the combustion cycle on both diesel and gasoline engines. This is often felt as a slight misfire at idle or slight engine load. Most commonly, the rough running is worse when the engine is first started, not at full operating temperature. Many manufacturers have struggled with carbon buildup on direct injected engines, and the struggle continues. De-carbon services are a fact of life with BMW diesels. Depending on how the vehicle is driven, every 30–50K miles a de-carbon service should be performed. Also, there are chemicals on the market that can help prevent carbon build-up on the intake valves.

Invest in a walnut shell blaster, it will definitely be put to use often. BMW offers a very nice media blasting machine that is very reliable. Less expensive options exist but these units usually clog up constantly and become a headache. Intake port adapters are also a requirement when performing a de-carbon, otherwise media can quickly cover the engine. Not good! BMW offers specific intake port adapters for different engines.

Due to the intake design on the M57 engine, there are two different intake ports: One set of intake ports

Manifold pressure sensors have a high failure rate due to fouling from carbon buildup.

is in the standard position on the cylinder head of the engine, and the second set travels straight down through the valve cover. Through use of swirl flaps in the intake manifold, intake tracts can be switched depending on engine load. The upper intake port that passes through the valve cover assembly on M57 engines generally has more carbon buildup then the secondary intake port, as this is the primary air path under load.

BMW uses swirl flaps in the intake manifold to control and divert air flow from the primary intake runners to the secondary ports. These swirl flaps are located at the base of the intake manifold toward the cylinder head. These flaps can become heavily coated in carbon buildup, which restricts their movement if left unchecked. Eventually, the swirl flap system can become completely seized from carbon buildup.

During a de-carbon service, it's also necessary to inspect and clean the intake manifold. These intakes, particularly on the M57 engine, can become loaded with carbon. You will knock considerable sticky black carbon out of the intake runners, which can become quite thick. Be careful while cleaning the intake. Use of chemicals is only recommended when directed, as the use of inappropriate chemicals can damage and warp the intake manifold. Lots of picks, scrapers, and patience are necessary here.

The M57 and N57 engines both have charge air pressure sensors on the intake manifold. These are susceptible to failure because of blockage from

The EGR valve is mounted between the intake manifold and throttle unit. Also note the small flex pipe on the EGR. These do fail occasionally, leaking exhaust gases.

This view of the inside of the exhaust system shows just how clean BMW diesels really are! The DEF injector can be seen top left.

carbon buildup as well... lots and lots of carbon. These pressure sensors generally cannot be cleaned or repaired and must be replaced if found to be faulty.

Don't forget to inspect and clean the EGR (Exhaust Gas Recirculation) valve if necessary during de-carbon service. On the M57 engine, this is located

forward of the throttle unit. Due to air flow around the valve, carbon tends to build up around the valve sealing surface, eventually disrupting full airflow and in extreme cases restricts the EGR valve from proper movement.

The EGR valve is necessary to help lower nitrogen oxide (NOx) emissions. EGR valves operate by recirculating a small amount of the vehicle's exhaust gases back into the intake tract. BMW diesels come equipped with EGR coolers, which lower the exhaust gas temperatures on their path to the intake manifold. By using exhaust gases, it's possible to lower the oxygen content of the intake charge. The goal of this is to lower peak combustion temperatures, which can greatly reduce NOx emissions. This is particularly important in diesel engines, which already have extremely high combustion temperatures.

This is the "mixer" which aids in vaporizing injected DEF fluid.

This is the active DEF tank on an E70 chassis diesel. Located in the passenger front wheel well, access is very limited without removal.

Exhaust Emissions Components

The final and most commonly repaired components of many BMW diesels are the exhaust emissions components. Modern BMW diesels have a multi-stage exhaust treatment system that scrubs even more NOx from the vehicle's exhaust.

The exhaust first travels through the DPF (Diesel Particulate Filter). This is a specialized oxidation catalytic converter designed to trap the heavier "sooty" diesel exhaust. The DPF is equipped with differential pressure sensors to monitor exhaust flow through the DPF. These sensors can become damaged and clogged with exhaust soot occasionally. If diagnosing a faulty DPF sensor, always check and clear the feed lines of any blockage during diagnosis.

After traveling through the DPF, the exhaust is sent through BMW's SCR (Selective Catalyst Reduction) component. This is the final resting place for any nasty NOx that has passed through the exhaust system.

The SCR system uses Diesel Exhaust Fluid (DEF) to lower NOx levels. DEF fluid is basically a urea and water mixture. By injecting the DEF fluid into the exhaust, it becomes vaporized in the hot exhaust stream. The chemical reaction between the DEF and NOx in the diesel exhaust breaks down the nitrogen oxide into nitrogen and water. This system is widely used by most diesel engine manufacturers and has proven to be the most effective tool to lower NOx emissions levels.

The entire exhaust system as well as the EGR system are monitored closely with NOx sensors and Exhaust Gas Temperature (EGT) sensors. These sensors do fail occasionally. However, always check for necessary updates to the DDE when replacing sensors. Often software update is a necessary step to complete the repair.

BMW uses a urea dosing valve mounted at the front of the SCR converter to inject DEF into the exhaust stream. This is followed by a "mixer" gasket to aid in DEF vaporization.

These valves are exposed to extreme conditions and occasionally fail. During inspection, check for any DEF residue or blockage around the nozzle. A leaking dosing valve can wreak havoc on the exhaust system!

The DEF tanks have become a common failure item on many BMW diesels. These tanks are equipped with multiple sensors to monitor and condition the DEF for proper delivery. Heater circuit failures and temperature sensor failures are extremely common for BMW DEF tanks. At this time, it's necessary to replace the entire tank assembly to replace the faulty sensors. No serviceable parts are available separately from BMW for this equipment.

Unfortunately DEF fluid can be hard on sensors, particularly when exposed to air for extended periods. It's important to keep any DEF tank as full as possible. By keeping sensors covered with fluid away from oxygen exposure, their lifespan can be increased. Don't run your DEF tanks low! •

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Mastering Plastic Repair

Plastic reconstruction is simple. We offer tips on deciding between reshaping, adhesive bonding or plastic welding for your repair.

Give special attention to the area around backup cameras and blind spot monitor sensors to avoid covering them with excess coatings thickness when repairing bumper covers.

Use of plastic in vehicle manufacturing helps improve fuel economy, reduce emissions, design safer structures and create unique body shapes and aerodynamics. With every ten percent reduction in vehicle weight, engineers can extract a corresponding six-to-eight percent increase in fuel economy. By 2020 the amount of plastic used in the average car will reach almost 800 pounds, double the 2014 amount of approximately 400 pounds, according to the report "Weight Reduction in Automotive Design & Manufacture" by industry forecaster IHS Chemical. If you haven't already, you should be developing plastic repair skills. The good news is, it's easy.

Safety caution

The adhesives used in plastics repair can cause eye, skin and lung irritation. Avoid eye and skin contact. People who are allergic to isocyanate should avoid handling polyurethane and plastic adhesives. Both contain isocyanates.

New plastic parts

If installing new OEM primed plastic parts, start by inspecting the component for any damage. If you find only minor imperfections, such as fine scratches that do not penetrate through the as-shipped e-coat or primer, you can sand out the blemish using a fine grit paper such as P600 or P800. Then rub down the entire part with a ColorSystem Soft Pad Gray.

BMW has extensive experience with plastic body panels. Shown here in red are all of the plastic body panels from a 1990 BMW Z1.

Mask off areas that contain raw plastic substrates that are not to be painted.

If the panel or bumper contains raw plastic substrates, check your repair information to see if you should not paint any portion of the component. If so, mask or tape off that area of the part.

Three plastic repairs: reshape, bond or weld

Reshaping, plastic bonding and plastic welding are three different methods available for repair of exterior body and other plastic panels. Each has features that make it advantageous for some applications but perhaps less so for others. Selection of the appropriate repair method is dependent upon the type and extent of the damage. You can find guidelines for which damage conditions suggest which repair method by searching in the BMW workshop information system ISTA.

Repairable plastic components include bumpers (excluding the 2000-2003 Z8 Roadster), side sill trim, door outer skin, roof, decklid, soft top (convertible) compartment lids, and other parts made of composite materials. You cannot repair tanks that contain fluids, including fuel, coolant, brake fluid, windshield washer fluid, and other liquids. If cracked or damaged in a manner that results in the potential to leak, you must replace them.

Different plastic types require different repair procedures. However, if you are using adhesive for plastic bonding, or reshaping minor dents using mild heat, you don't need to worry about the material type. Your BMW repair information will specify which repair procedure is best for a given plastic component. You only need to identify the material type if you are using the plastic welding repair method because different plastics respond differently to high heat.

If there is no code explaining the plastic type on the part or its label, there are quick tests you can use. Sand the part. If it smears or gets rubbery, the material is thermoplastic. If instead, it gets dusty, it is thermoset. Alternately, you could heat the part to over 200 degrees C (about 400 degrees F). If it softens, it is thermoplastic.

Where it is imperative to know the plastic type to plan a repair, BMW includes some identifying code or mark on the part.

Preparation challenges in plastic repair

Wettability, or lack thereof, refers to whether a plastic material encourages or hinders a coating's ability to "wet out" or spread over, adhere to and penetrate the plastic surface. Many plastic materials are hydrophobic and tend to resist moisture absorption. Coatings will bead up rather than penetrate the surface.

Moisture absorption issues present challenges for application of liquid-based coatings. For primers, fillers, and paints, poor wettability results in surface defects such as cratering of the coating, poor leveling and weak adhesion to the plastic.

You may also see plastic materials referred to as non-polar, low energy, or inert, meaning that they are less inclined to interact chemically with other materials, including different types of plastic. The static chemical characteristic hinders the creation of a strong bond even when using plastic adhesive to attach plastic to plastic.

Some plastic materials have acceptable wetting properties, but for the majority that don't, the repair industry has developed special helpers. One is a family of cleaning agents that, in addition to degreasing, are explicitly designed to remove surface contaminants that could inhibit chemical cross-linking with a coating or adhesive. Use anything less than the BMW-recommended cleaner, and you may actually weaken the bonding performance of your repair. Even solvent, which you may think is a great all-purpose cleaner, is not acceptable for plastic. It can leave

behind chemicals that interfere with the surface changes that are needed to enhance the adhesion potential of the plastic substrate.

Another plastic repair helper is an adhesion promoter. Olefin-based plastics require the use of an adhesion promoter to modify the surface so that it creates a stronger bond with whatever you are applying to it next. Adhesion promoter enhances the cross-linking performance of the next stage, including primer, plastic filler, paint, or adhesive itself. Given that all plastic surfaces are at least somewhat slippery, and the cost of adhesion promoter is low, it is beneficial to apply it in every plastic repair situation. It is one less decision to make, one more assurance of a durable bond created.

A third special product is a plastic adhesive that is formulated specifically for bonding parts to plastic.

Incorrect surface preparation is a primary cause of poor adhesion results. Check the BMW ISTA workshop information system for step-by-step surface preparation procedures before starting any plastic repair.

Sanding and guide coat

Sanding an extra inch or two beyond the edges of the damage provides a larger contact area to allow the adhesive to create a strong bond with the substrate.

Apply a guide coat and block sand any area on which you've applied primer-surfacer or filler. Do this each time you change sandpaper grit. The guide coat will remain in any low spots, pinholes, or scratches, and help you see problems that might otherwise be hard to find. Tip: sand the area around the spot where guide coat remains, not the spot itself. The guide coat remains because the higher surrounding area elevated your sanding block. You need to sand these surrounding areas to lower them to the same height as the area where the guide coat remains. At that point, you will sand off the guide coat without dipping the sanding block into low spots. If you sand through your primer and there are still sunken spots with guide coat, stop sanding. Re-apply primer and filler and repeat the block sanding step.

Use a hard block, not your hand, for the first sanding pass. Your hand may follow the contours of any waves or imperfections in the panel. Save the hand sanding for the final scratch removal step. Use the longest block you have that fits the shape of the area on which you are working. The long block is less likely to dip into low spots and remove the guide coat, which would defeat the purpose of the block sanding process.

Sand in long strokes. Short strokes will leave undesirable choppy patterns that will be visible through the finish. Move the sanding block at a 30 to 45-degree angle up and down the repair area, then switch direction and repeat so that you are cross-sanding in an "X" pattern over the same area.

Also, don't fall into the trap of using off-the-shelf black spray paint as an inexpensive alternative to guide coat. The paint may cost less, but it will gum up your sandpaper at a rapid rate, costing you more in materials and time than using the right product.

Plastic reshaping

After being deformed, some plastics return to their original shape if you apply the proper amount of heat and pressure. A hot air gun and a reshaping tool to press the damage out are all it takes to soften and reshape deformed plastic. The trick is to apply only as much heat as needed to soften but not melt the plastic. A few hours of plastic repair training can teach you the basics. Practice will make you good at it.

Use an aluminum reshaping tool to apply pressure when reshaping plastic panels.

BMW recommends heating the plastic to 60 degrees C (140 degrees F) in the deformation area. Too much heat will damage the paint, so watch how the plastic is responding. Remove the heat once the material has begun softening. Then try pressing the damage out using the reshaping tool. When you have restored the part to its original contours, continue holding pressure on it and cool the area by spraying it with room temperature water. Once cooled, the plastic will hold its restored shape.

Reshaping can restore small dents and deformations in plastic. Reshaping is not the answer if the paint layers are pitted, chipped or separated. Visible cracks in the paint, even if you cannot see the bare material below, reach to the surface of the component. They cannot be simply painted over. Due to different expansion and contraction rates of the plastic and the coatings as ambient temperatures fluctuate, the cracks will reappear in the paint after a short time. In that case, you will have to sand down to the bare plastic surface and re-apply the primer and finish coatings.

Similarly, reshaping cannot handle cracks or cuts penetrating the underlying plastic material. Without additional repair steps focused on the fissures, they will re-open after you complete the paint and refinish work.

Watch out for sensors

The BMW Advanced Driver Assistance System (ADAS) uses cameras or safety sensors embedded in or positioned behind bumper covers, fenders or other vehicle components. Sensors for Blind Spot Monitoring (BSM), Adaptive Cruise Control (ACC) and other ADAS safety-related technologies require special attention when conducting a nearby repair.

BMW position statements say that the company does not permit body fillers and plastic repair materials (adhesive, welding rods) in front of the sensor or camera. You must also keep any paint basecoat and clearcoat layer buildup below the maximum thickness allowed by BMW for the area over the lens. Excess paint film or even a transparent sticker over the lens can negatively affect what that sensor picks up.

For models that have blind spot monitor sensors mounted behind or in the front bumper, the BMW repair manual states that filler material cannot be inside a 10 cm radius around the sensors. Manufacturers typically house blind spot monitor sensors behind the bumper cover, but be sure to verify the location for the BMW model you are repairing.

The best way to determine whether a vehicle includes a camera or sensor in the area you plan to repair is to check the vehicle-specific BMW body repair manual for guidelines before beginning work on exterior plastic parts. If you are unsure about whether the vehicle includes ADAS-related cameras or sensors, punch the VIN into the OEM repair database and pull the build data.

If you suspect the vehicle may have been in an accident, it is a good idea to check for previous collision repair work. A light sanding of the area where you will be working should reveal whether any prior repairs have affected the area.

The blind spot monitor sensors are constantly checking for the presence of any objects in a pre-defined space around the vehicle. If the position of the sensor in its mounting bracket has changed

Recalibrate adaptive cruise control or other sensor technology mounted in or behind the front or rear bumper covers after the sensor or its mounting bracket have been removed and re-installed.

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from its factory settings, it alters the accuracy of the distance observations it is reporting to the PCM. If your repair involved removal and re-installation of a blind spot monitor sensor, reshaping, adhesive bonding or plastic welding, you must, as a post-repair step, calibrate the sensor using a high-level diagnostic tool.

Plastic bonding

Bonding using plastic adhesive is painless. The adhesive cures at room temperature, and is best for plastic components which cannot tolerate the application of heat. You can use plastic bonding for both thermoplastics and thermosetting plastics, so there is no need for advance identification of the type of plastic. There may be strength, rigidity, or other requirements that restrict whether you can use adhesive on a specific application, so check your BMW repair information as well as the instructions from the glue manufacturer.

Adhesive bonding of plastic involves the application of adhesive, primer, and filler if needed. There is a preparatory stage before each step to make the bond between it and the next leg in the process chemically stable for long-term durability.

The first step even before sanding is to clean the plastic with ColorSystem Antistatic Cleaner, HydroColor Cleaner Plus or HydroColor Cleaner (25 g/l). Cleaning prevents any contaminants from being rubbed deeper into the plastic substrate. Then you can sand the damage and feather into the surrounding paint using a 3-5 mm DA sander with P320/P400 grit paper. After sanding, clean the area again using either BMW ColorSystem Aerosol Antistatic Cleaner or ColorSystem Plastic Cleaner.

Reinforce holes by embedding mesh material in the adhesive (A). Keep the gun nozzle in the puddle as you apply adhesive (B). Nozzle submersion prevents air bubbles from forming in your repair.

Plastic primer provides a base for the adhesive, filler compound and paintwork. It is necessary to create a strong bond between the substrate and the plastics adhesive. BMW ColorSystem Polyolefin Adhesion Promoter Aerosol is the required primer for use with Teroson PU 9225 (a.k.a. Terokal 9225) plastic repair adhesive. Apply Polyolefin Adhesion Promoter to the now bare, clean plastic.

Let it flash off for ten minutes at 20 degrees C (68 degrees F), then apply Teroson plastic adhesive to the repair area. Keep the gun nozzle submerged in the adhesive during application. Nozzle submersion will help avoid the formation of air pockets in the repair area.

Use a fabric mesh to reinforce holes and cracks as you repair them with plastic adhesive. Start with smaller mesh patches for the bottom, then add progressively larger pieces until you have filled the opening. Do not add metal reinforcement when bonding exterior panels or components, as that could diminish passive pedestrian protection in the event of an accident.

You can reduce the time needed to harden the adhesive down to about 15 minutes using an infrared heater set to between 60 degrees C (140 degrees F) and 70 degrees C (158 degrees F). The adhesive acts as both a bonding agent and filling compound. Add a little extra adhesive to account for shrinkage as it hardens.

Allow the Teroson to fully dry, then sand with P320 grit paper and final sand using P400 - P500. Clean the area again with Antistatic Cleaner or ColorSystem Plastic Cleaner.

Apply Polyolefin Adhesion Promoter again, this time to prepare the new, cured adhesive to chemically bond with a primer that you'll apply before moving to the filler or paint stages. After the adhesion promoter has flashed off, apply one coat of ready-to-spray ColorSystem Plastic Primer. Flash off for ten minutes at 20 degrees C (68 degrees F).

You are now ready for the third stage; application of 2K filler if necessary. There are different combinations of primer-surfacer, 2K filler, flex additive, hardener and thinner to consider. Which you use depends on the basecoat/clearcoat system you will apply, whether you are in an area that requires the use of low-VOC coatings, and the type of plastic you are repairing. For example, in California and other low-VOC regions, you cannot use a hi-def filler on plastics such as ABS or polycarbonate. Check your BMW body repair manual or ColorSystem Manual for detailed information about the primer, filler, hardener and other additives to use for the vehicle and plastic type you are repairing.

Now you are ready for the basecoat/clearcoat steps. But that's another article.

Repairing cracks or holes

Cracks and holes having 25 mm or less diameter can be filled in by bonding or plastic welding. For adhesive bonding of cracks or holes, use the BMW Plastic Repair Kit (BMW part number 51 91 0 398 655). The kit contains a Teromix adhesive gun with dual pistons for use with the 2K product, adhesive remover, plastic primer, and a Teromix static mixer to combine the epoxy and catalyst just before delivery to the plastic repair surfaces.

Drill a small (6 mm) hole at each end of a crack to prevent it from extending further during or after repair. Regardless of diameter, if the crack or hole extends to the edge of the panel, BMW does not permit repair. Refer to your BMW repair manual for adhesive recommendations and instructions.

Plastic welding

Plastic welding offers a complete fusion of the plastic, and can repair large areas of damage.

The most important thing to know about plastic welding is that you must weld like-plastic to like-plastic. A durable weld only forms when the plastic parts being welded melt together and link at the molecular level. Therefore, the two plastic parts must have similar melting points and chemical properties or they will not be able to establish a durable joint. You cannot weld dissimilar plastics together.

Polypropylene (PP), polyurethane (PUR), polyethylene (PE) and thermoplastic elastomeric olefin (TEO), plastics that are commonly used in automotive applications, each have different chemical properties and melting points.

In plastic welding, the component and a plastic rod (filler material) are fused together with a blast of hot air. Selection of the correct welding rod is critical. Whatever substrate you are welding, you must use the same rod material: polypropylene to polypropylene, polyurethane to polyurethane, polyethylene to polyethylene.

If the substrate is not labeled and you cannot tell what it is made of, you'll need to test different plastic rods for their adhesion compatibility. Even within a single plastic category, there are blends and other differences that affect your repair options.

For example, the temperature for welding low-density polyethylene (LDPE) must be set lower than that for high-density polyethylene (HDPE). Be careful to select a low-density rod for plastic welding of LDPE. The amount of heat required to melt a high-density rod would permanently alter the molecular structure of a low-density polyethylene substrate. Although you could use an LDPE rod on an HDPE plastic panel, you won't have to think about it if you always match the rod type to the substrate.

Additionally, different types of welding equipment have different settings to reach and maintain a specific temperature range. Always check your equipment instructions for the correct temperature settings for welding a specific plastic type.

Welding technique

The key plastic welding technique is to control the application of heat so that it is just enough to melt the plastic in the repair, but not so much as to transfer a large amount of heat to the surrounding area. Three factors – rod angle, filler rod depth and rate of forward movement help you create the ideal weld. First, hold the welding rod at an angle of just less than 90 degrees to the surface. Second, apply just enough pressure on the rod to keep its tip in the weld pool throughout the process. The angle and depth of the rod in the weld pool help ensure that the filler rod and the plastic part melt at the same time.

Third, move forward at a rate that makes a small buildup of molten plastic roll in front of the rod as you work. You won't be moving so fast that the plastic does not fully melt, or so slow that heat is potentially spreading out to cause deformation beyond the repair area. Follow these guidelines, and you will be able to set the welding temperature on the Plastic Fusion machine to the BMW-recommended 480 degrees C (896 degrees F) even though different thermoplastics melt at different temperatures.

Weld-repair a crack or hole

To repair a hole or crack in thermoplastic, start by sanding any coatings down to the bare plastic substrate. You must weld both sides of the hole or crack to create a high-strength bond. Work the underside of the panel first. Sand the edges of the damaged area into a wedge or, with thin material, a slightly indented shape. BMW recommends using P80 to P120 grit abrasive with a variable speed dual-action (DA) sanding tool set to low speed.

Plastic welding a bumper tab involves laying a heat-softened plastic filler rod so that it bridges over the missing part of the tab (steps 1 and 2), applying pressure to the tab until it hardens and cools (step 3), and cutting out a new slot to match the size and shape of the original (step 4).

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Use a finer P320/P400 to feather the repair area into the original paint finish. Remove all sanding dust and other contaminants (transferred from your fingers, etc.) with the appropriate cleaner.

Start the plastic welding process on the underside first. If the opening is wider than your plastic repair rod, you can lay strips on top of each other with a 50 percent overlap. Once you have covered the underside, add another layer perpendicular to the first. The overlap will strengthen your repair and not be visible from the top of the panel.

Repeat the steps for the top side of the part. Once the weld has cooled, sand the surface using P240-P320 grit paper. Sanding prepares the visible side of the part for filler and paint.

Rebuild a bumper tab

Reworking a bumper tab is different from repairing a hole or crack. The tab is a slot into which you press the bumper retaining bracket. The retaining bracket has a protruding lip that prevents the bumper cover from popping back out. Until recently, plastic bumper tabs were not repairable if damaged. The new BMW-approved Plastic Fusion welding machine now allows you to rebuild broken bumper tabs.

Start by removing all coatings down to the bare plastic substrate. Do this on both the top and bottom sides of the part. Use P80-P120 grit sandpaper.

Make a slight indentation into the broken edges of the bumper tab. Cut a section of filler rod material to approximately twice the length of the bumper tab opening. Starting on one narrow end of the bumper tab opening, plastic weld this filler rod to the tab. Wait for the weld to cool. Then heat the filler rod until it is just soft enough to bend and bridge over to the other end of the tab opening. Your weld should fill the tab opening and extend out to the original edge of the bumper tab flange where it was damaged.

Once you have welded both ends, and while the filler material is still slightly warm, use flat locking pliers to flatten the repair area. Turn the bumper tab over and repeat the plastic welding process on the other side. Cut or grind out the bumper tab opening to restore it to its original location and dimensions. Sand the edges smooth and test for bumper retaining bracket fit.

As with adhesive bonding, when welding exterior plastic panels, metal reinforcements must not be used for reasons of pedestrian protection.

Finishing the Weld

Most weld repairs to thermoplastics can be sanded to improve finished appearance. Sanding will not reduce the weld strength. Refer to your BMW body repair manual for recommendations on the best progression from coarse to fine grit papers.

After welding, sand the area with P240 - P320 grit paper. Clean using Aerosol Antistatic Cleaner or ColorSystem Plastic Cleaner. Apply Teroson repair adhesive if needed to build up the repair area, and allow it to dry. Sand it with P320 grit and then again using P400 - P500. Clean the area again with Antistatic Cleaner or ColorSystem Plastic Cleaner, then apply Polyolefin Adhesion Promoter Aerosol to prep the repair for application of primer. Flash off for ten minutes at 20 degrees C (68 degrees F).

As with adhesive bonding, refer to your BMW body repair manual or ColorSystem manual for application-specific recommendations about 2K primer-surfacer, filler, flex-additive, hardener and thinner to use before basecoat/clearcoat application.

Bonded by affection

Use a value comparison to determine whether to repair or replace a damaged part. BMW recommends repair whenever the labor time and material cost is less than 50 percent of the cost of a new component.

There is something truly satisfying about restoring damaged plastic back to being a fully functioning component. Combine the usage instructions from plastic adhesive and welding equipment manufacturers with your BMW repair information and you are well on your way to becoming a plastic repair master. •

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