E-85

Gasoline fuel composed of 85% ethanol and 15% gasoline. E85 refers to an ethanol fuel blend of 85% ethanol fuel and 15% gasoline or other hydrocarbons by volume. In the USA the precise ratio of fuel ethanol to hydrocarbon may vary in step with ASTM 5798 which specifies the allowable ethanol content in E85 as starting from 51 to 83%. This may be because the lower calorific value of neat ethanol makes it difficult to crank engines in relatively cold climates without pre-heating air intake, faster cranking, or mixing varying fractions of gasoline in line with the climate. Cold cranking in cold climates is the primary reason ethanol fuel is mixed with any gasoline fraction.

Earthmoving Machines

SAE defines three different types of earthmoving machines:

- Equipment: Set of components mounted to the base machine to fulfill the primary design function
- Attachment: Optional assembly of components that can be mounted to the base machine for a specific use
- Component: Part or assembly of parts of a base machine, equipment, or attachment"

For more information on the *Identification Terminology of Earthmoving Machines*, see **J1057_199905** [12].

EAS (Electrically Assisted Steering)/EPS (Electric Power Steering)

This steering system eliminates all hydraulic components and fluid. An electrical motor replaces the pump. EAS or direct wattage steering completely eliminates hydraulic fluid and also the accompanying hardware from the facility mechanism, creating a complete EPS system. An EPS steering mechanism uses an electrical motor attached either to the steering rack or to the steering column via a mechanism and torque sensor. A microprocessor or electronic control

unit and diagnostic software control the steering dynamics and driver effort. Inputs include vehicle speed, steering wheel torque, position, and turning rate. There are four primary styles of electrical power assist steering systems:

1. Column-assist type: During this system, the facility assist unit, controller, and torque sensor are attached to the steering column. The ability assist unit is the motor and the controller is the electronic control unit, and therefore the torque sensor measures the load on the steering wheel.
2. Dual pinion–assist type: During this system, the facility assist unit is attached to the gear pinion shaft. The facility assist unit sits outside the vehicle passenger compartment, allowing assist torque to be increased greatly without raising interior compartment noise.
3. Rack-assist type: During this system, the facility assist unit is attached to the gear mechanism rack using either a dual pinion or a belt drive from a motor to the rack. It is located on the rack to permit greater flexibility within the layout design. Some OEMs use the belt-drive system.
4. Direct-drive type: During this system, the gear mechanism rack and power assist unit form one unit. The mechanism is compact and fits easily into the engine compartment layout. Direct assistance to the rack enables low friction and inertia (resistance to a change in motion), which successively gives a perfect steering feel.

FIGURE E.1 Electric power steering system.

BACHTUB DMITRII/Shutterstock.com.

EBA (Emergency Brake Assist) or BA/BAS (Brake Assist)

Automobile braking technology applies the brakes in an emergency situation through the use of ABS. The system detects the force placed on the pedal in

emergency braking situations, and because drivers tend to brake without enough force in these situations, it boosts the brakes to the calculated speed at which the pedal is pressed to achieve full braking power. Brake pressure is then increased to the point just before ABS would kick in, provided the foot pedal remains pressed down. This shortens the stopping distance and reducing the likelihood of accidents. If an emergency develops, a slow reaction and lesser-than-maximum braking input could lead to insufficient time or distance to avoid a collision. EBA or BA can detect panic stops and apply maximum braking effort quickly. It deduces braking behavior by assessing the speed at which the foot pedal is activated. If the system identifies an emergency, it spontaneously initiates full braking faster than any driver can move their foot. Emergency stopping distances will be shortened, reducing the likelihood of collisions. The BA system can enhance braking effort and reduce stopping distances by up to 70 ft at 125 mph. The BA detects circumstances during which emergency braking is required by measuring the speed with which the foot lever is depressed. Some systems additionally take into consideration the speed at which the pedal is released, pre-tensioning the brakes when a panic release of the throttle is noted. When emergency braking is detected, the BA system automatically generates a maximum brake boost to mitigate the driver's tendency to brake without sufficient force. BA can reduce the stopping distance. It may be a lower level of automation than a forward collision alert or avoidance system, which can initiate braking on its own if the on-board computer detects an imminent collision. For more information on this, see **J3063_202103** [8].

EBCM (Electronic Brake Control Module)

A control module that processes all ABS (anti-lock brake system) information and signal functions. It receives and interprets voltage pulses generated by the wheel speed sensors as the exciter teeth pass by the probe. The EBCM uses this data to determine impending wheel lockup and when and how to activate the ABS modulator valves.

E-Coil

Electronic ignition coil in the shape of an "E." For more information on this, see **J139_202002** [2].

Eccentric

The relationship of two round parts having different centers; a part which contains two round surfaces, not on the same center.

ECM (Engine or Electronic Control Module)

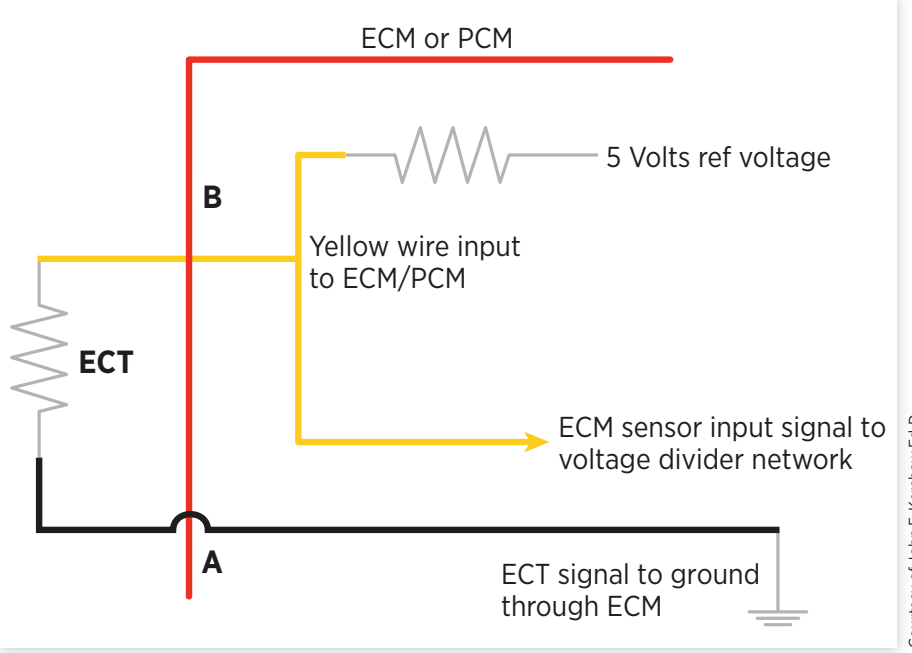
The on-board computer of the engine management system that controls fuel and emissions, as well as diagnostics, for the engine management system of the

vehicle (also sometimes referred to as the electronic control unit [ECU]). The Society of Automotive Engineers (SAE) standard J-1930 standardizes this term along with PCM (powertrain control module) that provided computer management of both the engine and transmission. The CPU (central processing unit) is mounted on one or more circuit boards and installed in a metal case to provide shielding from EMI (electromagnetic interference). The wiring harnesses that connect the ECM/PCM to the input sensors and output actuators connect to multi-pin connectors. These controllers manage all of the separate and linked electronic systems through a CAN (controller area network) in the vehicle. For more information on this, see **J1930DA_202105** [1].

ECT (Engine Coolant Temperature) Sensor

Threaded in the engine coolant jacket in direct contact with the engine coolant. The coolant sensor contains a thermistor used to measure the engine coolant temperature. The ECT is a thermistor in a circuit which is a variable ground, which uses a voltage divider network where the voltage is divided between the sensor input and a sensor ground inside the computer. The computer provides a 5-V reference signal to the ECT sensor. When cold, the sensor provides high resistance, which the computer reads as high signal voltage. As the engine warms up, the thermistor sensor resistance becomes lower and the signal voltage drops, so that is the difference. For more information on this, see **J1930DA_202105** [1].

FIGURE E.2 Engine coolant temperature.



Courtesy of John F. Kershaw Ed.D.

ECU (Electronic Control Unit)

An automotive engine or system management computer generally used by several different OEMs. It is another term that describes an ECM; see **ECM**.

EDR (Event Data Recorder)

A monitoring device that is generally part of a supplemental restraint system. It is used to monitor and record vehicle operating conditions and store them in memory for extraction. It is referred to as the automotive black box. Some OEMs call the EDR an SDM (sensing diagnostic module). For more information on this, see **J1674_201807** [6].

EEPROM or E^{2}PROM (Electronically Erasable Programmable Read Only Memory)

This computer chip can be erased and reloaded with new information using a special software program. EEPROMs can be completely or partially reprogrammed using appropriate software from the engine manufacturer. EEPROMs do not have to be removed from the ECM for reprogramming. The programming information is downloaded from a personal computer to the programmable memory of the ECM through a DLC. All vehicles equipped with OBD II are equipped with EEPROMs. The ability to program customized information and operating parameters means that the same model engine can be tailored to respond to unique operating conditions and commands. GM also calls the EEPROM a Flash prom of E^{2}PROM. For more information on this, see **J1930DA_202105** [1].

EFI (Electronic Fuel Injection)

A fuel injection system that uses an engine management computer to control the opening time of solenoid-controlled fuel injectors that are called actuators. System operation is based on a series of input sensors and the system can be an open loop or closed loop with an oxygen feedback sensor

EFT (Engine Fuel Temperature) Sensor

Some vehicles are equipped with an electronic returnless type of fuel injection. These systems use an engine fuel temperature (EFT) sensor to give the engine management computer data regarding the temperature and, therefore, the density of the fuel. For more information on this, see **J1930DA_202105** [1].

EGR (Exhaust Gas Recirculation)

An emission control device to reduce NOx (oxides of nitrogen) by adding spent gas or exhaust into the combustion chamber to lower combustion temperature. For more information on this, see **J1145_201109** [3].

Elastomer
A natural or synthetic polymer with elastic properties, e.g., latex.

Electric A/C Compressor
A high-voltage 201 V alternating current (AC) motor operates a scroll-type air conditioner (A/C) compressor for use on hybrid electric vehicles (HEV) and electric vehicles (EVs). An AC inverter supplies the AC to operate the compressor and does not require an ICE to operate it. Polyol ester A/C refrigerant oil that is non-conductive is required. Other refrigerant oils will contaminate the A/C system.

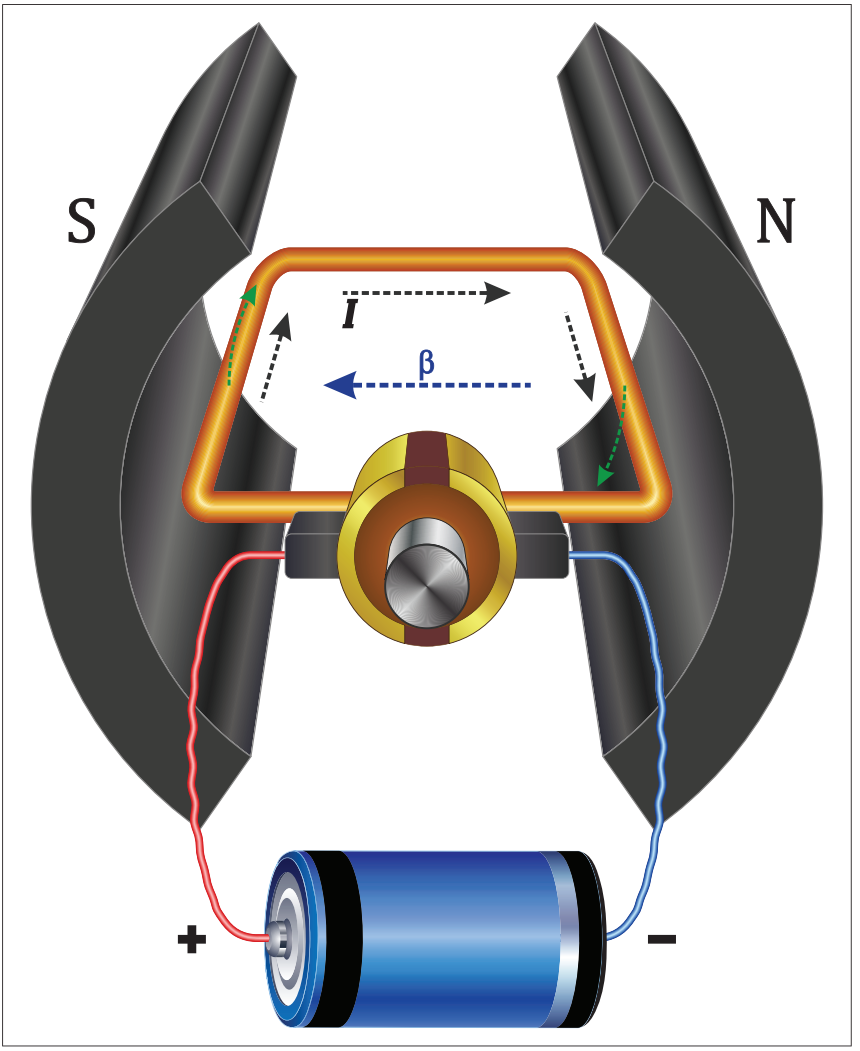
Electric Brake Retarder
The electric retarder is used on heavy truck and buses to provide noise-free braking to support the vehicle service brakes. Electromagnets are used to generate drag that is transmitted directly to the vehicle propeller shaft, creating a retarding force. Power for the electric retarder is supplied from the 12 or 24 V electrical system of the vehicle. The Caterpillar BrakeSaver is a hydraulic retarder that bolts directly to the rear of the engine crankshaft flange. When the brake is activated, engine oil is forced under pressure against the rotor vanes in the retarder, thereby slowing the rotor and providing braking power to the rear wheels.

Electric Circuit
An electric circuit consists of a power source, wiring, and load to use electrical energy.

Electric Device
A device that uses electricity to do work, such as motors, switches, relays, solenoids, and light bulbs.

Electric Motor
An electromagnet is created in a loop of wire that is placed between two electromagnetic poles. Motors work on the principle of magnetic repulsion. This magnetic repulsion takes place when a straight-loop wire conductor made up of an armature, commutator, and brushes is located in a magnetic field and current flows through that wire loop. This situation creates two separate magnetic fields. One produced by the magnet (poles of the magnetic field winding) and another produced by the current flowing through the conductor (armature/commutator/brushes)—the magnetic field of the magnet moving from the S-Pole to N-Pole and magnetic field of the conductor flowing around the conductor.

FIGURE E.3 Current flows from the negative (–) battery terminal through the brush and copper ring nearer the S-Pole through the conductor (armature) to the copper ring and brush nearer the N-Pole and back to the positive (+) battery terminal. This electrical flow causes the portion of the loop near the N-Pole to push downward and the S-Pole to push upward. When there is a strong field on one side of the conductor and a weak field on the other side, the conductor will move from the strong side to the weak side. A weaker magnetic field between N and S Poles on one side of the conductor is repulsed by the stronger magnetic field on the other side of the conductor. The armature then rotates.



Fouad A. Saad/Shutterstock.com.

Electric Parking Brake

Electric parking brake, or EPB, uses two different strategies: cable-pulling type that uses an electric motor to pull the parking brake cable instead of a lever-controlled cable and a design that uses an electric motor attached to the brake caliper arm to activate it, that is, controlled by the body control module. Some applications use an EPB that is activated when the vehicle stops and then goes off as soon as the gas pedal is pressed. It is generally controlled by a switch and deactivated either automatically or by pressing the same switch in the opposite direction and stepping on the service brakes. It can be tested using a factory-level bidirectional scan tool.

Electric Shock

The result of current passing through the tissue of the human body.

Electric Water Pump

An electrically operated centrifugal pump that circulates coolant through an ICE. The electric pump cannot compete with the flow of a mechanical pump at high RPM. One major factor is that the electric pump consumes a known quantity of electric power, about 200 W, no matter what the engine is doing. The mechanical pump consumes as much as 15–20 hp at high RPM.

Electrical Burn

A burn caused by the heat from electricity.

Electrical Fire

The result of excess current that heats and burns wire insulation.

Electrical Solvent

A solvent that is used to clean oil and grease from components before soldering. It can also be used to remove soldering flux from a component.

Electricity

Flow of electric current, which is the flow of free electrons from one atom to the next atom.

Electrodes
Metal plates that can donate and receive electrons.

Electro-Hydraulic Brake Assist Systems
The brake assist system that replaces a vacuum booster and its vacuum supply. The brake takeoff rocket takes the driving force applied brake demand and transforms this into an amplified brake pressure and does not depend on the vacuum. The brake booster rocket is intended to control along with an electronic stability control module which is often to blame for ABS, traction control, and stability control. It combines the functions of a brake booster, hydraulic brake cylinder, brake pressure modulator valve (BPMV), and therefore the electronic brake control module (EBCM) into one assembly. The brake fluid reservoir stores brake fluid, are often remote mounted, and uses a brake fluid level sensor, foot lever pushrod, and hydraulic brake cylinder, which is found in line with the pushrod. The EBCM controls all functions of braking including base brake operation, ABS, TCS (traction control system), ESC, automatic emergency braking (AEB), three-phase motor, and plunger to make hydraulic pressure.

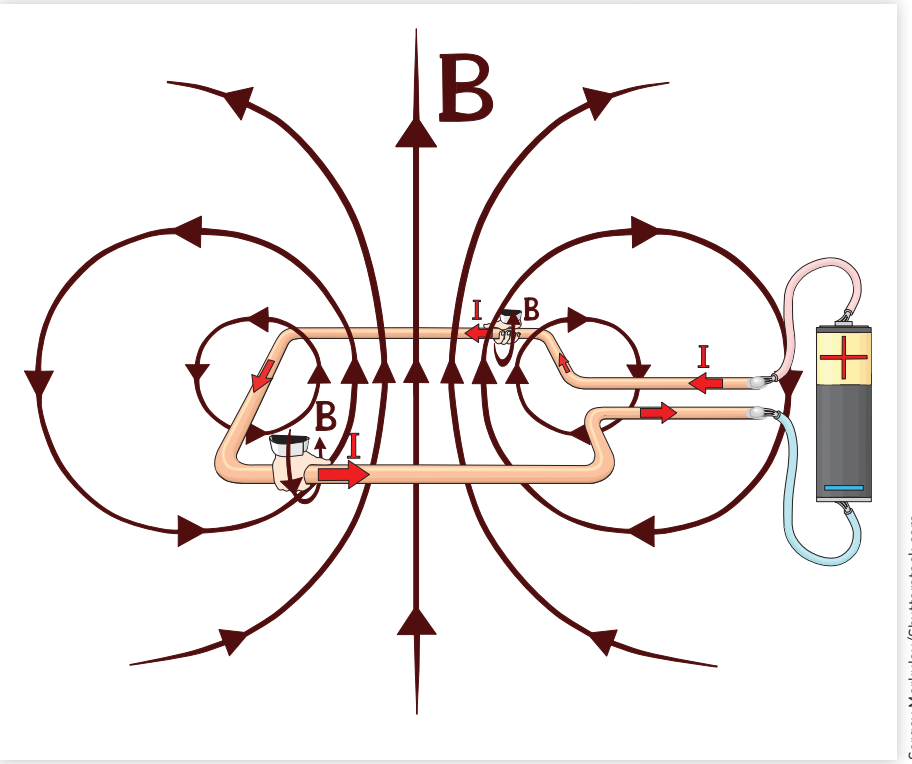
Electrolyte
Lead dioxide of the positive plates and the sponge lead of the negative plates are the active materials in the battery. These materials cannot become active until they are absorbed in electrolyte, which is composed of water and sulfuric acid.

Electromagnet
An electrically energized magnet. A metal core surrounded by a coil of wire that has current flowing through it, creating a magnetic field producing a magnet dependent on that magnetic field.

Electromagnetic Clutch
A device used to disengage a drive pulley from a belt to drive an engine accessory.

Electromagnetic Field
The electromagnetic field (EM field, or EMF) is a field produced by accelerating electric charges caused by electromagnetic induction When a magnetic field cuts across an electrical conductor, a voltage is induced in that conductor. See **Electromagnetic Induction** and **Magnetic Field**.

FIGURE E.4 EMF surrounding a wire loop as in a motor.



Sergey Merkulov/Shutterstock.com.

Electromagnetic Induction

Principal under which generators and alternators produce current. Michael Faraday's First Law of Electromagnetic Induction describes the induction of EMF (electromagnetic force) in a very conductor and also the Second Law quantifies the EMF produced within the conductor. First Law: A physicist stated that an EMF is induced in a very coil when the magnetic flux across the coil changes with time. Whenever a conductor is placed in a very varying flux, an EMF is induced. If the conductor circuit is closed, a current is induced, which is termed induced current. Second Law: The induced EMF in a very coil is capable of speed change of the magnetic flux. The magnetic flux is the product of the quantity of turns within the coil, and therefore, the magnetic flux is related to the coil. Currents are produced by changes within the flux. These currents are called the induced current because they are produced by a changing field. The EMF that generates this current is called an induced EMF.

Electromagnetic Solenoid

A cylindrical coil of wire acting as a magnet when carrying electric current. The polarity of the coil can be changed to create movement in the other direction.

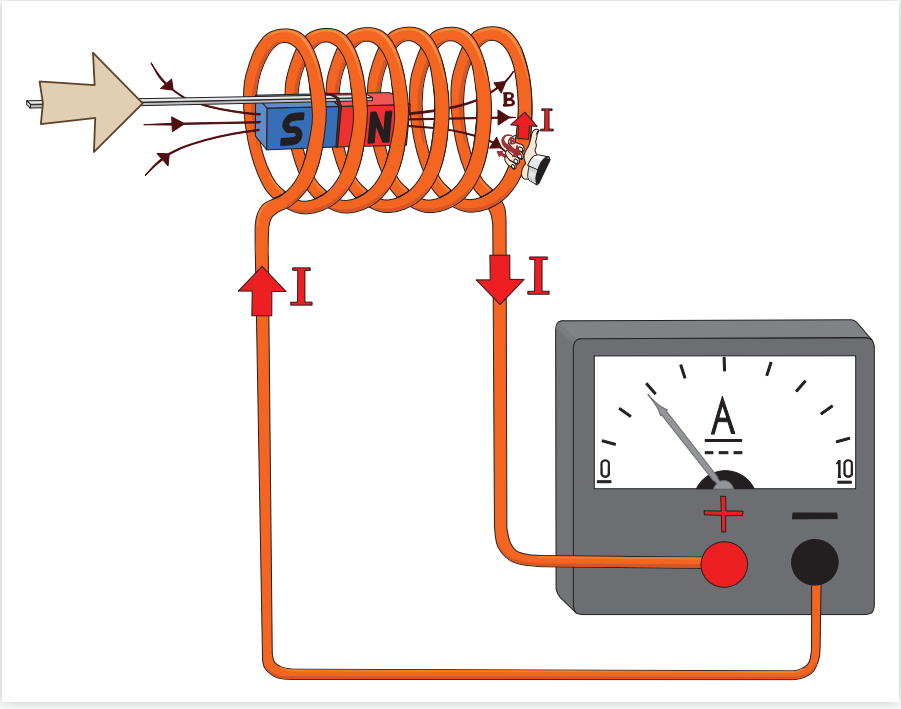
Electromagnetics

The study of the relationship of magnetic energy to electrical energy.

Electromagnetism

A magnetic field or magnetic flux that is created by current flow through a conductor. Magnetism can also be formed electrically. It was discovered that current-carrying conductors were surrounded by a magnetic field. Current flowing through a conductor such as copper wire creates a magnetic field around the wire. This effect can be observed by passing a compass lengthwise over a copper wire through which current is flowing from positive to negative. The needle will deflect from its North-South orientation when this occurs. Current flow through a wire creates a magnetic field around the wire. The greater the current flow the stronger the magnetic field. This type of magnetism created in the space around a conductor by the current flowing through is called electromagnetism.

FIGURE E.5 The principle of electromagnetic induction shown with a galvanometer reading induced current.



Sergey Merkulov/Shutterstock.com.

Electron
A negative-charged particle 1/1800 the mass of a proton.

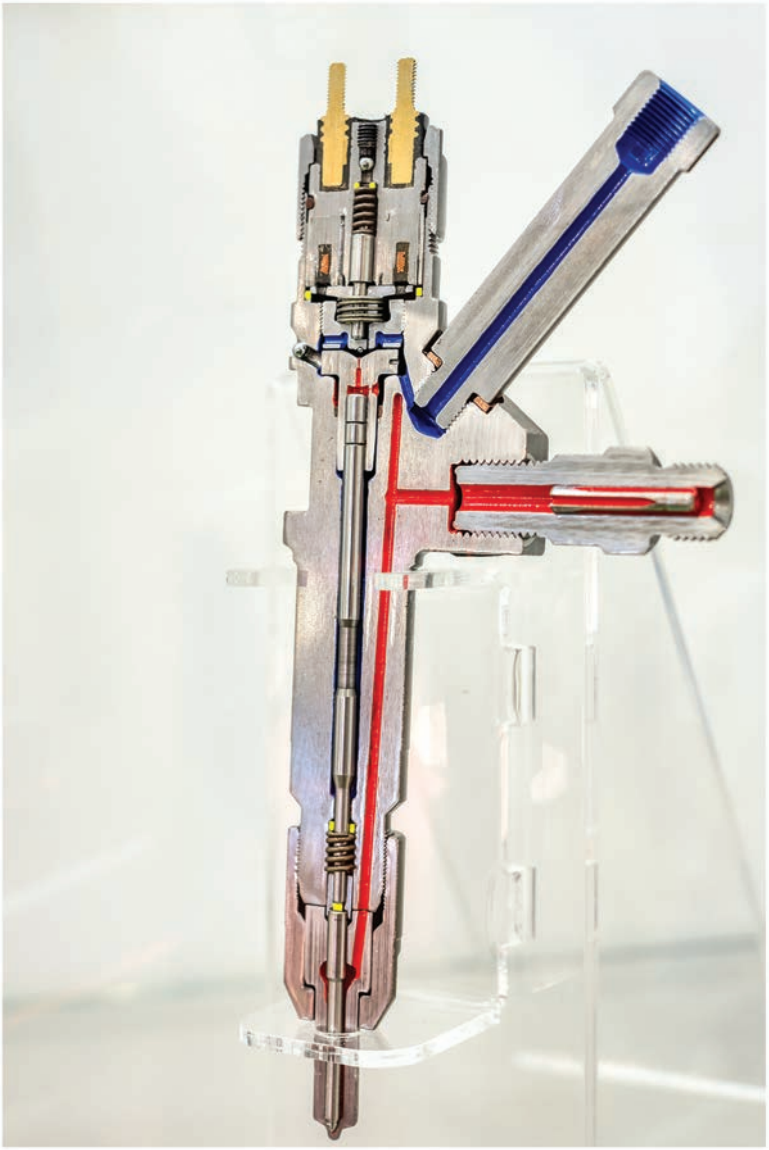
Electron Flow Theory
Electrons leave the negative (–) terminal of the battery, flow through the circuit, and then reenter the positive (+) terminal.

Electronic Device
A solid-state non-mechanical component that is manufactured from semiconductor material, which allows a device to alter the flow of electricity. These devices include diodes, transistors, sensors, and computers. For more terms in electronics, see **J1213_2_198810** [7].

Electronic Fuel Injectors (Diesel)
Diesel engines need from 50 to 1,000 times the pressure utilized in gasoline fuel systems because the injection period is shorter, about 300 ms in duration, and precise metering of fuel is required. The form of the speed of the discharge curve or injection rate must match engine speed and cargo conditions. Robert Bosch, Delphi, and Siemens all manufacture electronically controlled high common rail injectors. There are several generations of injectors to realize the goals of emission compliance, noise reduction, fuel economy improvement, and engine performance. They are designed with the following:

- Injection pressure independent of engine speed
- High injection pressure
- Flexible beginning and ending of injection (timing)
- Multiple injections
- Small, consistent injection quantities for pilot and post-injection sequences
- Rapid nozzle valve opening velocities
- Low injection rate during a period of ignition delay
- Ability to produce maximum injection rates
- Rapid increase in injection rate after the start of combustion
- Rapid decrease to injection rate at end of injection, along with high nozzle valve closing velocity

FIGURE E.6 Bosch piezoelectric high-pressure common rail diesel fuel injector.



Nordroden/Shutterstock.com.

Electronic Fuel Injectors (Gasoline Fueled)

An electronic fuel injector may be a common actuator found in the gasoline fuel spark-ignited ICE since 1981 and on the current-model diesel system. It was started in 1967 by Robert Bosch. The fuel injectors are electronically controlled by an engine management computer. The control module can vary the quantity of time the injectors are held open, thereby controlling the number of fuel supplied to the engine. The beginning of injection and also the injected fuel quantity are adjusted by electrically triggered injectors. The control module not only injects the fuel but also the proportion of injected fuel. An electronic fuel injector operates at a variable frequency and responds to a modulated pulse width output generated by the control module. The control module changes the injector pulse width with regard to the number of fuel needed by the engine. The longer the heart beat width the longer the injector stays open and therefore the more fuel provided.

FIGURE E.7 An electronically controlled gasoline-fueled engine fuel injector.

Stason4ik/Shutterstock.com.

Electronic Ignition

A general term used to describe any of various types of ignition systems that use electronic instead of mechanical components such as contact points.

Electronic Ignition Module

Computerized module that switches off and on the ignition coil ground to create an ignition spark.

Electronic Listening Device

A tool that allows a technician to hear noises inside of a component accurately. It amplifies sounds so it can be heard through a speaker or headphones. The trade name is Chassis Ears. For more information on this, see **J3152_202005** [5].

Electrostatic Field

The area around an electrically charged body resulting from the difference in voltage between two points or surfaces.

Element

An atom or group of atoms that have exactly the same positive charge in their nuclei. Examples of elements include hydrogen (H) and oxygen (O).

Embittered Ethylene Glycol

Ethylene glycol antifreeze mixtures containing an embittering agent denatonium benzoate which is used to discourage accidental or deliberate consumption.

EMD (Engine Manufacturer Diagnostic)

Systems developed in 2007 as new medium and heavy diesel emission standard for 2007. Prior to 2007, legislated standards for OBD systems were required for medium-duty vehicles and engines with a gross vehicle weight of up to 14,000 lb. Some form of OBD is always used by heavy-duty diesel engine OEMs for electronically controlled engines since 1985 with the introduction of DDEC (Detroit Diesel Electronic Control) I. Introduction of particulate filters, EGR and SCR (selective catalytic reduction) systems added a level of complexity requiring monitoring to make sure they were functioning properly similar to OBD II. EMD standard was less comprehensive than OBD II, so HD-OBD was developed in 2010. Like OBD II, EMD continuously monitors circuit continuity and performs functional monitoring of the injection system, EGR, SCR, and particulate filter. MIL was added along with the useful life or durability requirement.

Emergency Flasher System

A system that consists of a switch, flasher unit, four turn signal lamps, and related wiring. The emergency light switch is normally mounted on the steering column. It is usually a push-pull switch. Also called a hazard warning system.

EMF (Electromotive Force)

Electrical force, or pressure, that pushes free electrons and develops current. It is also called voltage or potential difference.

EMI (Electromagnetic Interference)

An undesirable electronic signal that takes place when an induced voltage enters another system wiring.

Emission Gases

Gases and particles left over from incomplete combustion of an ICE. The primary emissions of concern are hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and oxides of nitrogen (NOx). For more information on this, see **J1145_201109** [3].

Emulsion

A fine dispersion of miniscule droplets of one liquid in another liquid that is not soluble or capable of being mixed in any ratio without separation of the two liquid phases.

Emulsion Tube (Carburetor)

The emulsion tube mixes air and fuel in a carburetor.

Enable Criteria

The OBD II engine management computer requires internal software to keep track of when each diagnostic monitor should run. The different OEMs use different names for this controller, such as the diagnostic executive or the task manager. Each monitor has enabling criteria. Enabling criteria are a set of conditions that must be met before the task manager will allow the monitor to run. For more information on this, see **J1930DA _202105** [1].

Endplay

The total amount of axial play in an automotive component like an engine crankshaft or automatic transmission input or output shaft. Endplay can be measured using a dial indicator or feeler gauges.

Energy

Energy is the capacity or the ability to perform work, which is force times distance.

Energy-Absorbing Steering Column Operation

To reduce the effects of a frontal impact on a driver, most manufacturers incorporate energy-absorbing features into their steering columns. Steering columns can collapse on impact from either the steering gear end or the steering wheel. Most vehicles use a polyacetal resin or other component inside the steering

column, steering coupler, and/or column housing that separates or bends when stresses from the steering gear are strong enough. This allows the steering shaft assembly to slide inside the pipe assembly.

Engine Mapping

Operating a vehicle on a chassis dynamometer and manually adjusting the variable factors such as speed, load, and spark timing to determine the optimum output settings for the best drivability, economy, and emission control, which is programmed into the engine management computer.

Engine Speed Sensor

The RPM, or revolutions per minute, signal that comes from the primary signal in the ignition module or crankshaft position (CKP) sensor.

Engine Support Fixture

A support tool used to hold the engine when removing the transaxle in a front-wheel-drive (FWD) vehicle.

Enrichment

The act of adding fuel to the air-fuel mix to create a richer mixture.

EP (Extreme Pressure) Additive

Additive used in gear oil, cutting oil, or grease used to decrease wear of the gears or other components exposed to very high pressures.

EPA (Environmental Protection Agency)

US federal government agency that oversees the enforcement of laws related to the environment such as the Federal Clean Air Act. These laws include exhaust gas emission gas amounts and CAFE (Corporate Average Fuel Economy).

EPHS (Electrically Powered Hydraulic Steering)

This system used on HEVs replaces the customary drive belts and pulleys that drive an influence steering pump during a conventional rack-and-pinion mechanism with a brushless motor. This system still uses a pump, but it is driven by an electrical motor to scale back power drawn from the engine. An electronic controller regulates pump speed to vary pressure and flow. This provides steering efforts tailored for various driving situations. The pump is run at low speed or shut off to supply energy savings during straight-ahead driving. An EPHS system is claimed to use only 20% of the engine power employed by a

typical belt-driven pump and improves fuel mileage by approximately 10%. The engine still contributes power to the mechanism through electrical demand on the alternator of the vehicle, but it is greatly reduced from that of hydraulic steering mechanism systems.

EPROM (Erasable Programmable Read-Only Memory)

Compared to the PROM (programmable read-only memory), the data in an erasable PROM can be erased and the memory reprogrammed with new data by a qualified technician. To erase the existing information, the tape covering a window on the EPROM chip is removed and the EPROM is exposed to ultraviolet light. New information is then loaded using an EPROM burner. Like ROM and PROM, an EPROM chip retains the data in its memory even when power is removed. This computer reprogramming is usually called "reflashing." For more information on this, see **J1930DA_202105** [1].

Equivalent Resistance

The total resistance of a series-parallel circuit found by calculating the resistance of each parallel section and then adding the series resistances to these values.

ERFS (Electronic Returnless Fuel System)

Fuel pressure at the rail is sensed by a pressure transducer, which sends a low-level signal to a controller. The controller contains logic to calculate an indication to the pump power driver. The power driver contains a high-current transistor that controls the pump speed using pulse-width modulation (PWM).

Ergonomics

The scientific process of fitting a job to a person.

ESC (Electronic Spark Control)

A computer system equipped with a piezoelectric knock sensor that can retard spark advance, if necessary, to eliminate spark knock. For more information on this, see **J1930DA_202105** [1].

ESD (Electrostatic Discharge)

An electrostatic charge can build up on the surface of a human body. If the body touches something the charge can be discharged to the other surface.

ESI (Electronic Service Information)

An Internet information service that contains vehicle service information and provided by all OEMs and a group of aftermarket companies like ALLDATA, ShopKey Pro, etc.

EST (Electronic Service Tools)

Problems within the engine control system can be identified and diagnosed using a variety of both OBD and EST, also called scan tools. External ESTs can be generic (working with multiple OEM systems) or proprietary, designed to work with specific OEM electronics. OBD II or HD-OBD illuminates a check engine light, MIL (malfunction indicator lamp), or service engine soon light when the vehicle is performing outside required emissions standards. Connecting a scan tool to the DLC (data link connector) allows DTCs (diagnostic trouble codes) to be downloaded. Some systems used dash or ECM-mounted lights that flashed a fault code to identify a problem area. Digital multimeters (DMM) and Digital Storage Oscilloscopes (DSO) are also considered ESTs.

FIGURE E.8 Electronic service scan tool.

guruXOX/Shutterstock.com.

EST (Electronic Spark Timing)

The control of spark timing advance by computer.

ETBE (Ethyl Tertiary Butyl Ether)

An octane enhancer for gasoline, ETBE is added to gasoline up to grades of roughly 13%. It is also a fuel oxygenate that is manufactured by reacting isobutylene with ethanol, which ends in high octane and low volatility. This additive offers equal or greater clean air quality benefits over ethanol, while it is technically and logistically less perplexing with regard to the formulation. It is made by the acidic etherification of isobutylene with ethanol at a temperature of 30–110°C and a pressure of 0-8 to 1.3 MPa.

Ethanol (Grain Alcohol)

An octane enhancer added, at a rate of up to 10%, to gasoline that increases the octane number of the fuel by 2.5 to 3.0 points. Ethanol could be a fuel oxygenate because it contains oxygen.

Ethylene Glycol

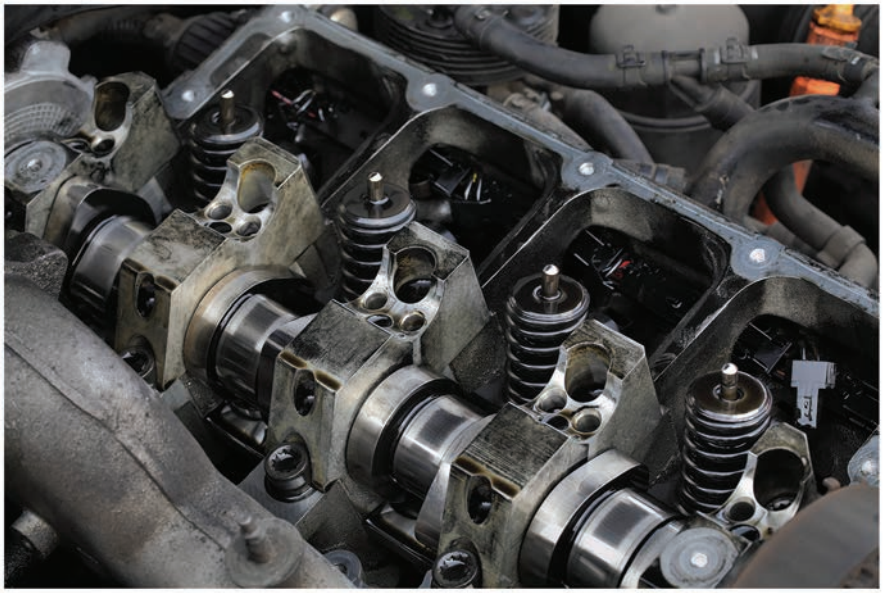
A permanent antifreeze as the upper boiling points provided advantages for summertime use as well as during worse weather conditions. The main additives are corrosion inhibitors to safeguard the engine metal, buffers to regulate pH, and colorants to spot the various types. Ethanediol is widely used in automotive applications, but there are also less-toxic alternatives made with humectants available with the newer organic hybrid antifreeze. Antifreeze oxidizes into five organic acids (formic, oxalic, glycolic, glyoxylic acid, and acetic acid). (Glyoxylic acid or oxoacetic acid is a chemical compound that is both an aldehyde and a carboxylic acid.) Inhibited antifreeze mixes are available with additives that can buffer the pH and preserve the alkalinity of the solution to prevent the oxidation of the antifreeze and formation of those acids. Nitrites, silicates, theodin, borates, and azoles may additionally be accustomed to prevent a corrosive attack on metal. It is poisonous to humans and other animals and may be handled carefully and disposed of properly. Its sweet taste can result in accidental ingestion.

EUI (Electronic Unit Injector)

The EUI System was first used by Detroit Diesel Corporation (DDC) in 1985 for its DDEC (Detroit Diesel Electronic Control) system. The EUI system was a full-authority engine management system with a mechanically actuated EUIs. EUIs were computer controlled by an electronic control module (ECM) and operated by a separate engine-mounted injector driver unit called an electronic

distributor unit (EDU) injector drivers that activated the electric solenoids on the individual injectors. These were later incorporated into the ECM. When the injector camshaft lobe comes around, it begins to push down the injector tappet and plunger. Control is restricted to the hard limit window created by the cam profile.

FIGURE E.9 EUI that is camshaft activated and electronically controlled.



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EV (Electric Vehicle)

A vehicle that uses one or more electric motors for propulsion. It is powered by a collector system, autonomously using a lithium-ion battery that can be charged with an external charging mechanism. EV batteries can charge from the power grid at home or by using a street recharging point, which is generated from a variety of domestic resources, such as coal, hydroelectricity, nuclear, etc. Home/grid power such as photovoltaic solar panels, microhydro, or wind may also be used and promoted due to sustainability concerns. Using the correct charging equipment it takes about 2–3 h for a full charge, but faster charging can be done. Charging time is limited by the kilowatt capacity of the grid connection. A normal household outlet delivers 1.5 kW in the USA, Canada, and Japan with 120 V supply and 3 kW in countries with 240 V supply. For more information on this, see **J1715_202105** [4].

FIGURE E.10 EV that is powered only by a battery being plugged into a charging station (left) and a Tesla battery EV (right).

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Courtesy of John F. Kershaw Ed.D.

EVA (Electronic Vibration Analyzer)

An electronic tool used to measure and diagnose vehicle vibrations. For more information on this, see **J3152_202005** [5].

Evaporative (EVAP) Emission Control System

A control system used to prevent fuel vapors in the tank from entering the atmosphere as HC emissions. Evaporative emissions systems capture, control, and eliminate gasoline vapors. The vapors are captured within the charcoal canister and, under certain driving conditions, routed through purge solenoid into the air intake where they are burned within the engine. EVAP purge happens when the engine management computer applies a duty-cycle voltage to the purge control solenoid during closed-loop operation and at cruising speeds. EVAP purge does not happen when the vehicle is in an open-loop operation, at idle, decelerating, or at wide-open throttle. For more information on this, see **J1145_201109** [3].

EV Battery Charging Connectors

The charging power is often connected to the car in two ways. The primary could be a direct electrical connection SAE J1772 conductive coupling connector, which uses the most lead into a weatherproof socket through special high-capacity cables with connectors to safeguard the user from high voltages. This standard for plug-in vehicle charging is the SAE J1772 conductive connector (IEC 62196 Type 1) in the USA. In the European Union (EU) they use the VDE-AR-E 2623-2-2 (IEC 62196 Type 2) for deployment, which, without a latch, means unnecessary extra power requirements for the locking mechanism. For more information on this, see **J1715_202105** and **J1772_201710_EV J Plug** [4, 11].

FIGURE E.11 EV battery charging coupling.

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EV Charging Station

An EV charging station is also called EV (BEV) charging station, electric recharging point, charging point, charge point. The hookup to charge an EV is named the EVSE (electric vehicle service equipment) and must be installed by an electrician. The EVSE supplies electric energy for the recharging of PEV (plug-in electric vehicles), also referred to as BEV (battery electric vehicle) and PHEV (plug-in hybrid electric vehicles). Some EVs have on-board converters which will infix to a typical electric outlet or a high-capacity appliance outlet. Others either require or can use a charging station that has electrical conversion, monitoring, or safety functionality. These stations are used when traveling, and plenty of support for faster charging at higher voltages and currents than are available from residential EVSEs. Public charging stations are on-street facilities provided by electric utility companies or located at retail shopping centers and operated by many private companies. Charging stations provide one or a spread of heavy-duty or special connectors that conform to the range of competing standards. Common rapid charging standards include Combined Charging System and Tesla Supercharger. For more information on this, see **J1715_202105** [4].

FIGURE E.12 EV charging stations.

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EV Charging Time

The charging time depends on the battery capacity and also the charging power. It is calculated using the formula: Charging Time [h] = Battery Capacity [kWh]/ Charging Power [kW]. The battery capacity of a completely charged EV from EV OEMs like Nissan is about 20 kWh, providing it with an electrical autonomy of about 100 miles. Tesla released their Model S with battery capacities of 40, 60, and 85 kWh, with the latter having an estimated range of roughly 480 km. As of January 2018, Tesla has two models, 75 and 100 kWh. PHEVs with a capacity of roughly 3 to 5 kWh for an electrical autonomy of 20–40 km but the backup ICE guarantees the complete autonomy of a traditional ICE vehicle. The vehicle should be charged every two or three days. In general, drivers connect their vehicles each night, thus starting day after day with a full charge. For normal charging (up to 7.4 kW), the OEMs have built a battery charger into the car. A charging cable is employed to attach it to the electrical network to produce 120 or 240 V AC. For quicker charging (22 kW, even 43 kW, and more), OEMs have chosen two solutions:

- Use the built-in charger of the vehicle, designed to charge from 3 to 43 kW at 240 V single phase or 400 V three phase (SAE Level 2).
- Use an external charger, which converts AC into DC (SAE Level 3).and charges the vehicle at 50 kW (e.g., Nissan Leaf) or more (e.g., 120–135 kW Tesla Model S).

TABLE E.1 BEV charging times.

Charging time 100 km of BEV range	Power supply	Power (kW)	Voltage (V AC)	Max. current (Amps)
6–8 h	Single phase	3.3	230	16
3–4 h	Single phase	7.4	230	32
2–3 h	Three phase	11	400	16
1–2 h	Three phase	22	400	32
20–30 min	Three phase	43	400	63
20–30 min	Direct current	50	400–500	100–125
10 min	Direct current	120	300–500	300–350

For more information on this, see **J1715_202105** [4].

EV Paddle Connector

A paddle that is inserted into a slot is one winding of a transformer while the winding is part of the vehicle. The paddle completes a magnetic circuit which provides power to the battery pack. The inductive approach removes the chance of electrocution because there are not any exposed conductors. Inductive charging can reduce vehicle weight by moving more charging componentry off the vehicle. For more information on this, see **J1715_202105** and **J1715_202105** [4].

Exhaust ATS (Aftertreatment System)

Exhaust system treatment of emissions from combustion is used by OEMs to comply with federal and state emission regulations. The systems include EGR (exhaust gas recirculation), injection rate shaping from electronically controlled high-pressure systems, and less turbulent combustion chamber designs. Some of these strategies reduce the engine efficiency and were inadequate to achieve the required 90% or higher reduction for particulate emissions needed for 2007 when Tier 2 Bin 5 emission standards were implemented. Later more rigorous reductions in NOx (oxides of nitrogen) emissions were phased in beginning in 2004 and fully implemented by 2010. This action required moving the emission-reduction technologies to the exhaust system to maintain engine efficiency while meeting these very stringent emission values.

In 2010, ATSs used additional components to lower NOx and PM (particulate matter) emissions. The selective catalytic reduction (SCR) system injects a reductant such as ammonia or urea, also known as DEF (diesel exhaust fluid), which increases the nitrogen. SCR systems convert NOx into gaseous nitrogen and water. A DOC (diesel oxidation catalyst) was added to provide additional

burning of the HC (hydrocarbon) and CO (carbon monoxide). A DOC converts nitric oxide into nitrogen dioxide through oxidation. Heat is released from this process. SAE Journal Article 02-13-03-0016 states: "With ever tightening emission standards, the automotive industry is continuously seeking novel ways to improve the aftertreatment system (ATS). Exhaust treatment systems using diesel emission fluid (DEF), in conjunction with selective catalytic reduction (SCR) and diesel oxidation converters (DOC), have been gaining popularity in the heavy equipment industry. Spraying DEF (mixture of urea and water) into the exhaust flow can convert harmful NOx gases into N_2 and H_2O. Design of ATSs focuses on high evaporation rate and uniform mixing of ammonia at the entrance to the SCR catalyst.

This study applied support vector regressor (SVR), a machine learning (ML) method to a database of computational fluid dynamics (CFD) simulations to develop a highly efficient mixer with high heat exchange characteristics. Over 500 mixer designs were evaluated using CFD and were then used to train the SVR model. The trained ML model was then used as a surrogate to the CFD and coupled with the genetic algorithm (GA), an optimization technique, to further refine the design parameters. The optimal design obtained from this methodology showed a remarkable performance improvement compared to the baseline." [9]

Exhaust Brake

The engine exhaust brake operates by choking or restricting exhaust flow: the retarding stroke of the piston is therefore the exhaust stroke. Exhaust brakes are managed electrically and actuated pneumatically. Some engines use both an internal engine compression brake and an exhaust brake enabling both the upward strokes of the piston to be retarding strokes. This increases the engine braking capacity by a significant amount.

Exhaust Gas Analyzer

A testing device that uses a gas sniffing probe that is inserted in the engine exhaust that measures the chemical content in an engine exhaust. Most current units measure five types of gases: oxygen, hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and oxides of nitrogen (NOx).

Exhaust Gas Sensor (Oxygen Sensor)

A sensor that measures the oxygen content in the engine exhaust system as a means of checking combustion efficiency. It is located in the exhaust manifold or the exhaust pipe(s). Also called an O_2 sensor, or oxygen sensor.

Exhaust Manifold

A multiple port series of pipes that collects the exhaust gases from multiple cylinders and collects these gases into a collector or single pipe that goes to a series of output pipes to a muffler. Manifold means many. SAE J2515_201712 provides automotive engineers and designers with a basic understanding of the appearance considerations and availability of thermal material for manifold use. For more information on this, see **J2515_201712** [10].

Exhaust Pipe Bending

There are three methods of bending exhaust pipes: program card, pattern, and custom. Program cards are provided by the pipe bender manufacturer and contain all the information necessary to duplicate the exhaust pipes found on most vehicles. The number of the program card is found by looking up the make, model, year, and engine in the card catalog. There are separate cards for each pipe in the exhaust system. The program card lists the length and diameter of the pipe, the distance between the center of the bends, and the rotation and depth of the bends in degrees. There may also be remarks that describe bending instructions for peculiar applications. Using this information, the technician can make a pipe identical to the one which was originally installed by the vehicle manufacture; Pattern bending means measuring and comparing the old exhaust pipe to make a new one. This may be necessary when making a pipe for an older or low-production vehicle for which no program card exists; Custom bending is necessary when there is no program card or existing pipe. Applications for which customizing may be necessary include installing other than the original exhaust pipe.

Exhaust System

A system that channels the spent or exhaust gases coming out of the exhaust valve of an internal combustion engine (ICE) to guide these exhaust gases away from the ICE-controlled combustion. The system conveys spent gases from the ICE and includes one or more exhaust pipes. The role of the automotive exhaust systems is to rid the ICE of spent gases, i.e., what gases are left from the burning of the hydrocarbon fuel, oxygen, and nitrogen. The ICE has the ability to draw in fresh-air charge for combustion and relies on the exhaust system to remove what has been spent. The air that goes in must come out for good engine breathing. Exhaust gases must be removed with as little resistance as possible. The cylinders will not fill with the maximum air (high mass efficiency) if combustion gas pressure builds up in the exhaust system. This means that the cylinders cannot be swept clear of exhaust gases before the next combustion cycle. Exhaust systems that do not remove exhaust gases efficiently may have backpressure.

Exhaust System Hangers

O-ring or fabric devices that attach to brackets mounted on the underside of the vehicle to support the exhaust system. Some are welded to the exhaust system. Hangers can also be made of reinforced fabric, that is, in relation to both brackets on the underside of the vehicle which are bolted or clamped to the exhaust system. Hangers must be flexible enough to allow the exhaust system to expand as it gets hot and move with the engine torque. These hangers will also isolate the vehicle from vibrations in the exhaust system. When installing exhaust system components, make sure you take the necessary steps to properly position them. A hanger should be used to support the exhaust system and not pull components into place. Hangers that are used this way will be under constant stress and will most likely break.

Expansion Tank

A coolant-holding tank that provides cooling system expansion, that is, space for the coolant to expand up to a half gallon more coolant. If an expansion tank is overfilled, it will discharge the coolant at operating temperature. The radiator pressure relieving cap is moved to the expansion tank. The expansion tanks need to be located above the cylinder heads so the additional coolant can flow back into the main cooling system when the engine cools down. When the engine reaches operating temperature, the pressure valve in the cap closes and seals the system. The pressure in the cooling system increases up to the cap pressure to prevent the coolant from boiling. To get the proper expansion tank volume, you need to add together the drawdown capacity requirement and the thermal expansion requirement to get an additional 18% of the total volume required for the expansion tank. Coolant systems are designed to operate with about 13 quarts of coolant in the system. For example, a 13 quart system is calculated as follows: Drawdown = 12% of 13 quarts = 1.56 quarts. Thermal Expansion = 6% of 13 quarts = 0.78 quarts. 1.56 + 0.78 = 2.34 quart expansion tank required.

$$\begin{aligned}\text{Expansion tank size} = {} & 0.12 \times \text{Cooling system capacity} \\ & + 0.06 \times \text{Cooling system capacity}\end{aligned} \quad \textbf{(E.1)}$$

FIGURE E.13 ICE cooling system expansion tank.

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Extended Core Spark Plug

The insulator core and electrodes of this spark plug extend farther into the combustion chamber than they do on other types.

External Combustion Engine

The steam engine is an external combustion engine because the working fluid is separated from the combustion products. The Rankine cycle is used to analyze this combustion process. The term steam engine refers to the railway steam locomotives that is a heat engine performing mechanical work with steam as the working fluid. The steam engine uses the force generated by the steam pressure to push a piston back and forth inside a cylinder and this piston, which is connected to a rod and crank, generating the rotational force to turn the wheels of a steam locomotive.

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