ENCYCLOPEDIA ARTICLE

Electric vehicle

A ground vehicle propelled by a motor that is powered by electrical energy from rechargeable batteries or other source onboard the vehicle, or from an external source in, on, or above the roadway. Examples are the golf cart, industrial truck and tractor, automobile, delivery van and other on-highway truck, and trolley bus. In common usage, electric vehicle refers to an automotive vehicle in which the propulsion system converts electrical energy stored chemically in a battery into mechanical energy to move the vehicle. This is classed as a battery-only-powered electric vehicle. The other major class is the hybrid-electric vehicle, which has more than one power source. See also: Automobile; Bus; Truck

History

Construction of the first electric vehicle is credited to the French inventor and electrical engineer M. Gustave Trouvé, who demonstrated a motorized tricycle powered by lead-acid batteries in 1881. In the United States, Andrew L. Riker is credited with building the first electric vehicle (also a tricycle) in 1890, and by 1891 William Morrison had built the first electric four-wheeler. In France in 1899, a four-wheel electric vehicle driven by Camille Jenatzy became the first car to break 60 mi/h (96 km/h). By then, production of battery-powered vehicles for use as personal transportation, commercial trucks, and buses had already begun.

Electric vehicles, with their instant starting, quiet running, and ease of operation, peaked in their challenge to steam- and gasoline-powered cars in 1912. The limited performance, range, and speed of electric vehicles, plus the need for frequent battery charging, restricted their usefulness and dampened their popularity. By the 1920s, the piston-type internal combustion engine had prevailed as the dominant automotive powerplant. Most production and development work on electric vehicles ended during the 1930s. See also: Automotive engine; Engine; Internal combustion engine

In the 1960s, interest revived in electric vehicles as a result of concern with diminishing petroleum reserves, rising cost of crude oil production, and air pollution from the automotive engine that burned gasoline which was refined from crude oil. Over the years, a few electric vehicles had been constructed, usually by converting small light cars and trucks into electric vehicles by removing the engine and fuel tank and installing an electric motor, controls, and batteries. However, during that time no major automotive manufacturer brought out an electric vehicle. See also: Air pollution; Gasoline; Petroleum

The Clean Air Act of 1963 and its amendments established limits on emissions from new vehicles sold in the United States. In 1990, the California Air Resources Board decided to further reduce air pollution by mandating (but later rescinding) that 2% of each automaker's sales must have zero emissions in the 1998 model year. This demand for a zero-emission vehicle (ZEV) could be met only by the electric vehicle, which typically was powered by lead-acid batteries. Used in an electric vehicle, lead-acid batteries have two major weaknesses: relatively high weight for the amount of energy stored, and reduced capacity in cold weather.

To help develop a better battery for electric vehicles, the U.S. Advanced Battery Consortium was formed in 1991. The purpose of this partnership among United States automakers and the electric utility industry was to develop advanced batteries capable of providing future generations of electric vehicles with significantly increased range and performance.

In 1996 General Motors began limited marketing of the electric vehicle EV1 (**Fig. 1**). The EV1 was the first specifically designed electric car produced by a major automaker since before World War II. Other automakers also have developed and tested electric vehicles and vehicle conversions powered by lead-acid or advanced batteries.

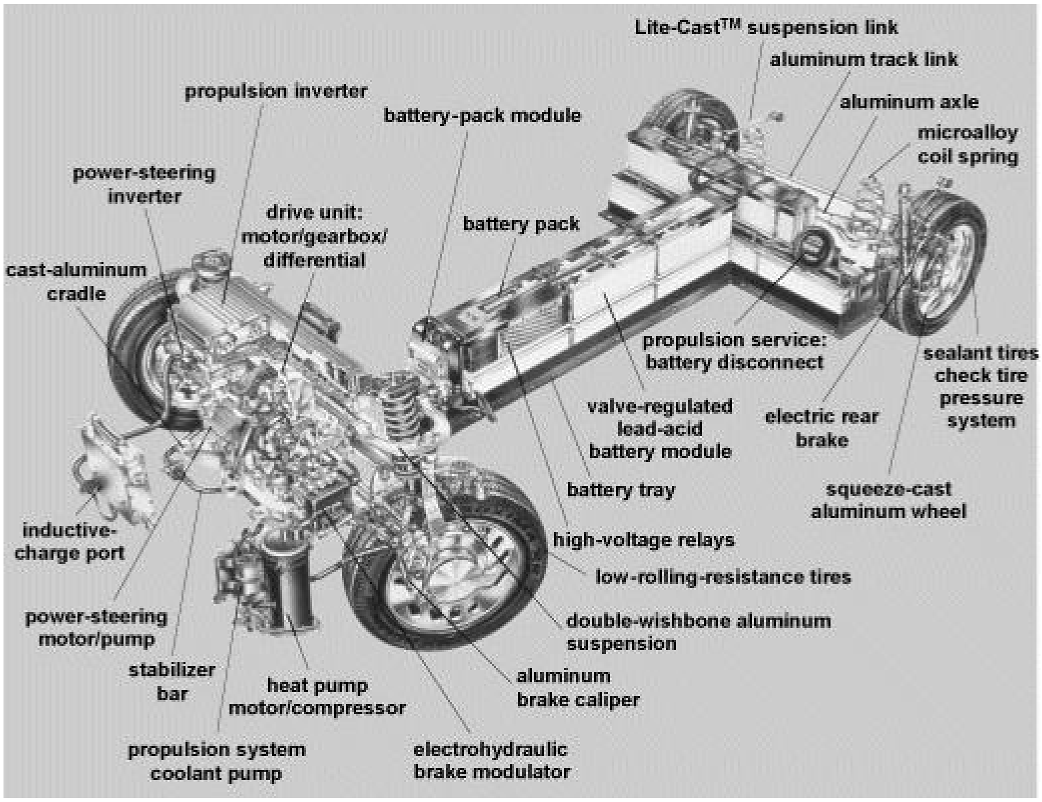

Fig. 1 EV1, a two-seat electric vehicle powered by lead-acid batteries. (*General Motors Corp.*)

Battery-only power

The General Motors EV1 is a battery-only-powered vehicle containing 26 lead-acid batteries which are assembled into a T-shaped pack that provides a nominal voltage of 312 volts (**Fig. 2**). These batteries differ from 12-V automotive batteries primarily in duty cycle. In the electric vehicle, the batteries must supply all the energy needs. Except for regenerative braking, there is no onboard charging. The batteries provide the power to propel the vehicle, and to power the lights and all accessories such as air conditioning and radio. As a result, electric-vehicle batteries go through much deeper discharge cycles than an automotive battery, which seldom is discharged more than 5% of its rated capacity. See also: Battery

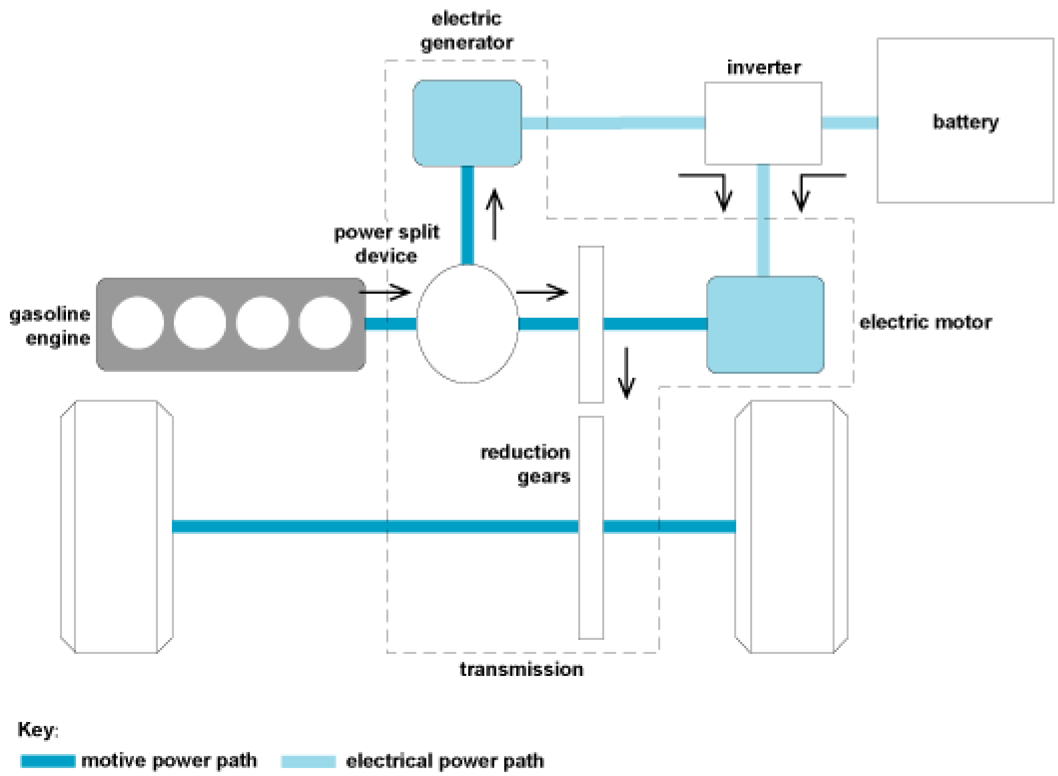

Fig. 2 Power flows through a hybrid vehicle which uses a gasoline engine to propel the vehicle and drive a generator that can operate the electric motor directly or charge the batteries, as necessary. (*Toyota Motor Sales, U.S.A., Inc.*)

Because of the increased duty cycle, electric-vehicle batteries can deliver 85% of their charge without damaging the batteries or shortening their useful life. Ideally, this could provide the EV1 and similar electric vehicles with a useful range of 70 mi (113 km) of city driving or 90 mi (145 km) of highway driving. A top speed of 80 mi/h (130 km/h) may be possible, but at a sacrifice in range, which also is shortened by hilly terrain and use of any electrical equipment on the vehicle.

In addition to lead-acid batteries, other batteries are used in electric vehicles. These include the newer nickel-metal hydride battery and the lithium-ion battery.

Hybrid power

A hybrid electric vehicle has more than one source of power. These sources can be different types of energy storage devices, power converters, and inverters. The first hybrid vehicle is credited to an Italian, Count Felix Carli. In 1894, Carli constructed an electric-powered tricycle that had a system of rubber springs which could release a short burst of additional power when needed.

Although power losses occur each time that energy is converted from one form to another, hybrid drive can be more efficient than a conventional automotive engine. However, having two or more power sources can increase the complexity, cost, and weight of a hybrid vehicle, as well as its manufacturing, safety, emissions, maintenance, and service problems. See also: Automotive engine

Internal combustion engine

Since the 1890s, major hybrid-vehicle research and development work has focused on adding a small internal combustion engine to an electric vehicle. Typically, the battery-powered motor drives the wheels, while the engine, usually running at constant speed, drives a generator that charges the batteries. Operating the engine at constant speed reduces fuel consumption and produces cleaner exhaust gas than if the engine were larger, operating at variable speed, and providing the sole source of vehicle power.

In some hybrid vehicles, engine power is split (**Fig. 2**). Part of the engine power propels the vehicle, while part drives the generator which can operate the motor directly or charge the batteries, as necessary. Reportedly, engine exhaust emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen are about 10% that of a conventional gasoline-engine vehicle. In addition, fuel efficiency is doubled.

Fuel cell

In this electrochemical device, the reaction between a fuel, such as hydrogen, and an oxidant, such as oxygen or air, converts the chemical energy of the fuel directly into electrical energy. The fuel cell is not a battery and does not store energy, although the fuel cell also has two electrodes separated by an electrolyte. As long as fuel is supplied to one electrode of the fuel cell and oxygen or air to the other, a voltage is produced between the electrodes. When an external circuit connects the electrodes, electrons will flow through the external circuit. Since fuel-cell voltage is less than 1 V, stacks of fuel cells are connected together to provide the needed electrical energy.

When fuel cells are the primary power source in a hybrid vehicle, batteries provide secondary power. Fuel cells do not provide immediate output during a cold start. Until the fuel cells reach operating temperature, which may take about 5 min, a battery pack supplies the power for initial startup and vehicle movement.
See also: Fuel cell; Hydrogen

Three types of fuel cell under development for electric vehicles are the hydrogen-fueled, the methanol-fueled, and the gasoline-fueled. (1) A hydrogen-fueled cell runs on hydrogen gas stored in pressure tanks carried by the vehicle. Range of the vehicle is determined by the amount of compressed hydrogen that the tanks can hold. When hydrogen is used as the fuel, fuel cell operation produces no significant amounts of unwanted emissions. Water vapor and electricity are the only products. However, widespread use of hydrogen as a near-term vehicle fuel is unlikely because there exists no infrastructure of hydrogen refueling stations which are in place and accessible to the public. (2) To provide the fuel cell with hydrogen gas while avoiding the problems of hydrogen refueling, a methanol-to-hydrogen reformer onboard the vehicle can produce hydrogen gas from liquid methanol. Installed on production models, this would allow motorists to refuel vehicles in the conventional manner at existing service stations through any pump which dispensed methanol. However, use of a reformer to obtain hydrogen lowers vehicle efficiency and creates some emissions of carbon dioxide. (3) A gasoline-to-hydrogen reformer on the vehicle can extract hydrogen gas from gasoline. The hydrogen is then delivered to the fuel cell stack (**Fig. 3**). Use of gasoline could move fuel cell technology years closer to production in automotive vehicles, while reportedly improving fuel efficiency by 50% and emissions by 90%.
See also: Methanol

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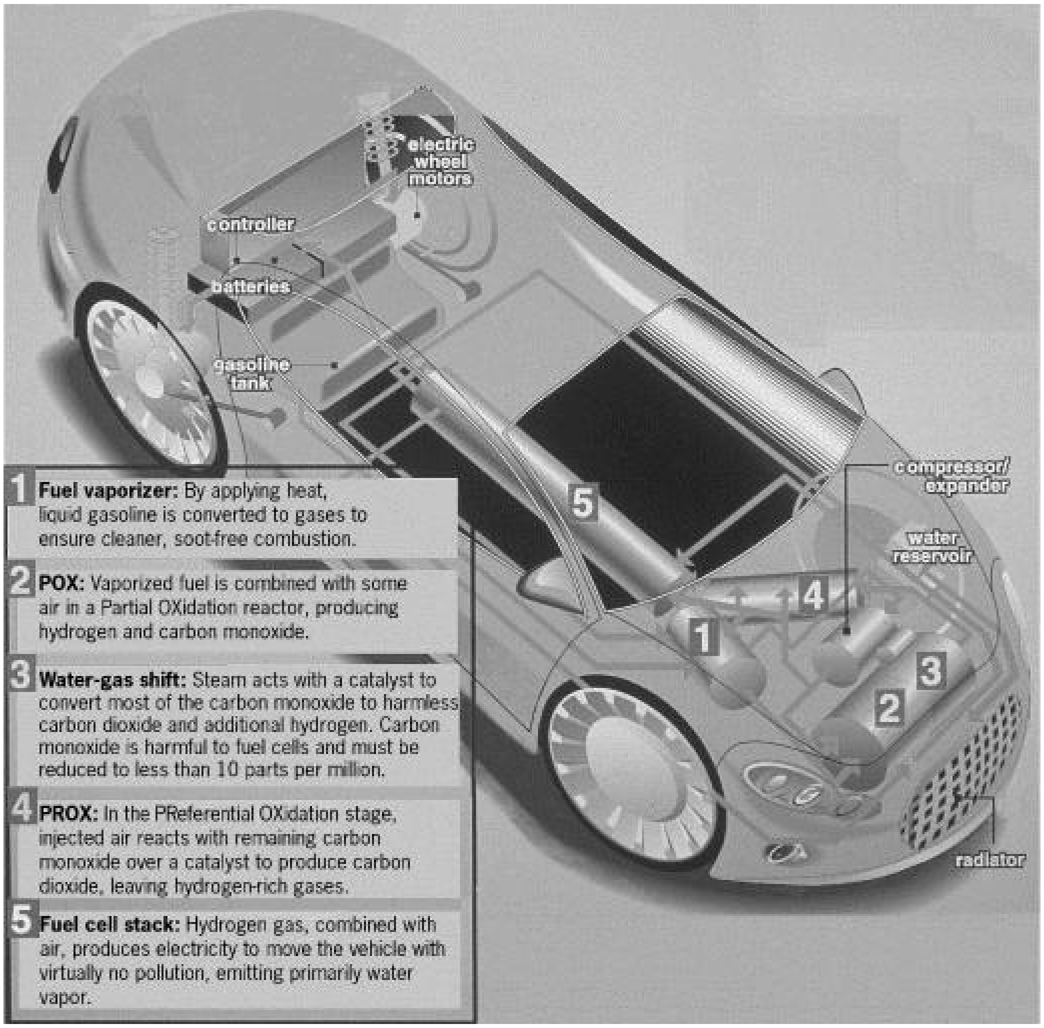

Fig. 3 Layout and five-step process that produces electricity from gasoline, which powers the fuel cells. (*Chrysler Corp.*)

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