The Carburetor

The carburetor was invented by an Italian, Luigi De Cristoforis, in 1876. A carburetor was developed by Enrico Bernardi at the University of Padua in 1882, for his Motrice Pia, the first petrol combustion engine (one cylinder, 121.6 cc) prototyped on 5 August 1882.

A carburetor was among the early patents by Karl Benz as he developed internal combustion engines and their components.

Early carburetors were the surface carburetor type, in which air is charged with fuel by being passed over the surface of gasoline. Read more about early carburetors here.

In 1885, Wilhelm Maybach and Gottlieb Daimler developed a float carburetor for their engine based on the atomizer nozzle. The Daimler-Maybach carburetor was copied extensively, leading to patent lawsuits, but British courts rejected the Daimler company's claim of priority in favor of Edward Butler's 1884 spray carburetor used on his Petrol Cycle.

Hungarian engineers János Csonka and Donát Bánki patented a carburetor for a stationary engine in 1893.

Frederick William Lanchester of Birmingham, England, experimented with the wick carburetor in cars. In 1896, Frederick and his brother built the first gasoline-driven car in England: a single cylinder 5 hp (3.7 kW) internal combustion engine with chain drive. Unhappy with the performance and power, they re-built the engine the next year into a two-cylinder horizontally opposed version using his new wick carburetor design.

Carburetors were the usual method of fuel delivery for most US-made gasoline-fueled engines up until the late 1980s, when fuel injection became the preferred method. This change was dictated more by the requirements of catalytic converters than by any inherent inefficiency of carburation; a catalytic converter requires much more precise control over the fuel / air mixture, to closely control the amount of oxygen in the exhaust gases. In the U.S. market, the last carbureted cars were:

In Australia, some cars continued to use carburetors well into the 1990s; these included the Honda Civic (1993), the Ford Laser (1994), the Mazda 323 and Mitsubishi Magna sedans (1996), the Daihatsu Charade (1997), and the Suzuki Swift (1999). Low-cost commercial vans and 4WDs in Australia continued with carburetors even into the 2000s, the last being the Mitsubishi Express van in 2003. Elsewhere, certain Lada cars used carburetors until 2006. Many motorcycles still use carburetors for simplicity's sake, since a carburetor does not require an electrical system to function. Carburetors are also still found in small engines and in older or specialized automobiles, such as those designed for stock car racing, though NASCAR's 2011 Sprint Cup season was the last one with carbureted engines; electronic fuel injection was used beginning with the 2012 race season in Cup.

In Europe, carburetor-engined cars were being gradually phased out by the end of the 1980s in favor of fuel injection, which was already the established type of engine on more expensive vehicles including luxury and sports models. EEC legislation required all vehicles sold and produced in member countries to have a catalytic converter after December 1992; among the last carburetor-engined models produced in these countries were most of the Ford Fiesta MK2 range (1989) as well as cheaper versions of the Nissan Primera (1990) and Peugeot's 106 and 405 range - the French built 106 went into production just over a year before carburetor engines were outlawed in the EEC.

Principles

The carburetor works on Bernoulli's principle: the faster air moves, the lower its static pressure, and the higher its dynamic pressure. The throttle (accelerator) linkage does not directly control the flow of liquid fuel. Instead, it actuates carburetor mechanisms which meter the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the airstream.

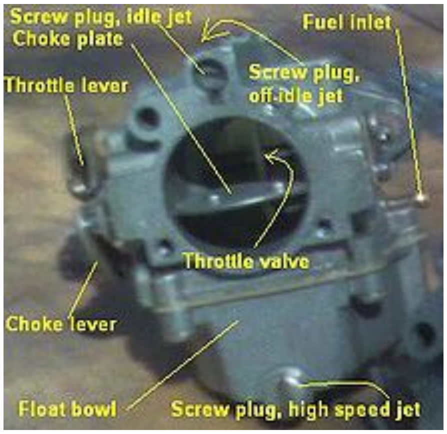
When carburetors are used in aircraft with piston engines, special designs and features are needed to prevent fuel starvation during inverted flight. Later engines used an early form of fuel injection known as a pressure carburetor.

Most production carbureted, as opposed to fuel-injected, engines have a single carburetor and a matching intake manifold that divides and transports the air fuel mixture to the intake valves, though some engines (like motorcycle engines) use multiple carburetors on split heads. Multiple carburetor engines were also common enhancements for modifying engines in the USA from the 1950s to mid-1960s, as well as during the following decade of high-performance muscle cars fueling different chambers of the engine's intake manifold.

Older engines used updraft carburetors, where the air enters from below the carburetor and exits through the top. This had the advantage of never flooding the engine, as any liquid fuel droplets would fall out of the carburetor instead of into the intake manifold; it also lent itself to use of an oil bath air cleaner, where a pool of oil below a mesh element below the carburetor is sucked up into the mesh and the air is drawn through the oil-covered mesh; this was an effective system in a time when paper air filters did not exist.

Beginning in the late 1930s, downdraft carburetors were the most popular type for automotive use in the United States. In Europe, the sidedraft carburetors replaced downdraft as free space in the engine bay decreased and the use of the SU-type carburetor (and similar units from other manufacturers) increased. Some small propeller-driven aircraft engines still use the updraft carburetor design.

Outboard motor carburetors are typically sidedraft, because they must be stacked one on top of the other in order to feed the cylinders in a vertically oriented cylinder block.



1979 Evinrude Type I marine sidedraft carburetor

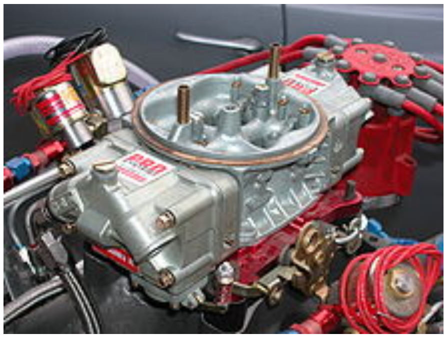
The main disadvantage of basing a carburetor's operation on Bernoulli's Principle is that, being a fluid dynamic device, the pressure reduction in a Venturi tends to be proportional to the square of the intake air speed. The fuel jets are much smaller and limited mainly by viscosity, so that the fuel flow tends to be proportional to the pressure difference. So jets sized for full power tend to starve the engine at lower speed and part throttle. Most commonly this has been corrected by using multiple jets. In SU and other movable jet carburetors, it was corrected by varying the jet size. For cold starting, a different principle was used in multi-jet carburetors. A flow resisting valve called a choke, similar to the throttle valve, was placed upstream of the main jet to reduce the intake pressure and suck additional fuel out of the jets.

Operation

Fixed-Venturi
: in which the varying air velocity in the Venturi alters the fuel flow; this architecture is employed in most carburetors found on cars.

Variable-Venturi
: in which the fuel jet opening is varied by the slide (which simultaneously alters air flow). In "constant depression" carburetors, this is done by a vacuum operated piston connected to a tapered needle which slides inside the fuel jet. A simpler version exists, most commonly found on small motorcycles and dirt bikes, where the slide and needle is directly controlled by the throttle position. The most common variable Venturi (constant depression) type carburetor is the sidedraft SU carburetor and similar models from Hitachi, Zenith-Stromberg and other makers. The UK location of the SU and Zenith-Stromberg companies helped these carburetors rise to a position of domination in the UK car market, though such carburetors were also very widely used on Volvos and other non-UK makes. Other similar designs have been used on some European and a few Japanese automobiles. These carburetors are also referred to as "constant velocity" or "constant vacuum" carburetors. An interesting variation was Ford's VV (Variable Venturi) carburetor, which was essentially a fixed Venturi carburetor with one side of the Venturi

hinged and movable to give a narrow throat at low rpm and a wider throat at high rpm. This was designed to provide good mixing and airflow over a range of engine speeds, though the VV carburetor proved problematic in service.


A high performance 4-barrel carburetor

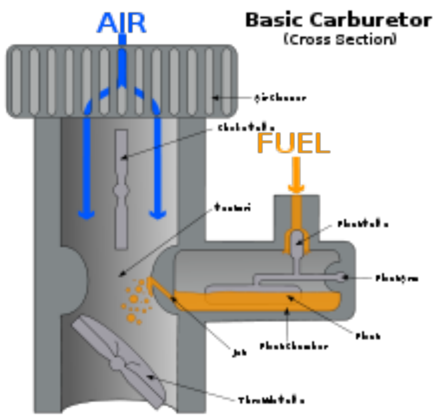
Under all engine operating conditions, the carburetor must:

This job would be simple if air and gasoline (petrol) were ideal fluids; in practice, however, their deviations from ideal behavior due to viscosity, fluid drag, inertia, etc. require a great deal of complexity to compensate for exceptionally high or low engine speeds. A carburetor must provide the proper fuel/air mixture across a wide range of ambient temperatures, atmospheric pressures, engine speeds and loads, and centrifugal forces:

In addition, modern carburetors are required to do this while maintaining low rates of exhaust emissions.

To function correctly under all these conditions, most carburetors contain a complex set of mechanisms to support several different operating modes, called *circuits*.

Basics



Cross-sectional schematic of a downdraft carburetor

A carburetor basically consists of an open pipe through which the air passes into the inlet manifold of the engine. The pipe is in the form of a Venturi: it narrows in section and then widens again, causing the airflow to increase in speed in the narrowest part. Below the Venturi is a butterfly valve called the throttle valve — a rotating disc that can be turned end-on to the airflow, so as to hardly restrict the flow at all, or can be rotated so that it (almost) completely blocks the flow of air. This valve controls the flow of air through the carburetor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed. The throttle is connected, usually through a cable or a mechanical linkage of rods and joints or rarely by pneumatic link, to the accelerator pedal on a car or the equivalent control on other vehicles or equipment.

Fuel is introduced into the air stream through small holes at the narrowest part of the Venturi and at other places where pressure will be lowered when not running on full throttle. Fuel flow is adjusted by means of precisely calibrated orifices, referred to as *jets*, in the fuel path.

Off-idle circuit

As the throttle is opened up slightly from the fully closed position, the throttle plate uncovers additional fuel delivery holes behind the throttle plate where there is a low pressure area created by the throttle plate blocking air flow; these allow more fuel to flow as well as compensating for the reduced vacuum that occurs when the throttle is opened, thus smoothing the transition to metering fuel flow through the regular open throttle circuit.

Main open-throttle circuit

As the throttle is progressively opened, the manifold vacuum is lessened since there is less restriction on the airflow, reducing the flow through the idle and off-idle circuits. This is where the Venturi shape of the carburetor throat comes into play, due to Bernoulli's principle (i.e., as the velocity increases, pressure falls). The Venturi raises the air velocity, and this high speed and thus low pressure sucks fuel into the airstream through a nozzle or nozzles located in the center of the Venturi. Sometimes one or more additional *booster Venturis* are placed coaxially within the primary Venturi to increase the effect.

As the throttle is closed, the airflow through the Venturi drops until the lowered pressure is insufficient to maintain this fuel flow, and the idle circuit takes over again, as described above.

Bernoulli's principle, which is a function of the velocity of the fluid, is a dominant effect for large openings and large flow rates, but since fluid flow at small scales and low speeds (low Reynolds number) is dominated by viscosity, Bernoulli's principle is ineffective at idle or slow running and in the very small carburetors of the smallest model engines. Small model engines have flow restrictions ahead of the jets to reduce the pressure enough to suck the fuel into the air flow. Similarly the idle and slow running jets of large carburetors are placed after the throttle valve where the pressure is reduced partly by viscous drag, rather than by Bernoulli's principle. The most common rich mixture device for starting cold engines was the choke, which works on the same principle.

Power valve

For open throttle operation a richer mixture will produce more power, prevent pre-ignition detonation, and keep the engine cooler. This is usually addressed with a spring-loaded "power valve", which is held shut by engine vacuum. As the throttle opens up, the vacuum decreases and the spring opens the valve to let more fuel into the main circuit. On two-stroke engines, the operation of the power valve is the reverse of normal — it is normally "on" and at a set rpm it is turned "off". It is activated at high rpm to extend the engine's rev range, capitalizing on a two-stroke's tendency to rev higher momentarily when the mixture is lean.

Alternative to employing a power valve, the carburetor may utilize a *metering rod* or *step-up rod* system to enrich the fuel mixture under high-demand conditions. Such systems were originated by Carter Carburetor in the 1950s for the primary two Venturis of their four barrel carburetors, and step-up rods were widely used on most 1-, 2-, and 4-barrel Carter carburetors through the end of production in the 1980s. The step-up rods are tapered at the bottom end, which extends into the main metering jets. The tops of the rods are connected to a vacuum piston and/or a mechanical linkage which lifts the rods out of the main jets when the throttle is opened (mechanical linkage) and/or when manifold vacuum drops (vacuum piston). When the step-up rod is lowered into the main jet, it restricts the fuel flow. When the step-up rod is raised out of the jet, more fuel can flow through it. In this manner, the amount of fuel delivered is tailored to the transient demands of the engine. Some 4-barrel carburetors use metering rods only on the primary two Venturis, but some use them on both primary and secondary circuits, as in the Rochester Quadrajet.

Accelerator pump

Liquid gasoline, being denser than air, is slower than air to react to a force applied to it. When the throttle is rapidly opened, airflow through the carburetor increases immediately, faster than the fuel flow rate can increase. This transient oversupply of air causes a lean mixture, which makes the engine misfire (or "stumble")—an effect opposite what was demanded by opening the throttle. This is remedied by the use of a small piston or diaphragm pump which, when actuated by the throttle linkage, forces a small amount of gasoline through a jet into the carburetor throat. This extra shot of fuel counteracts the transient lean condition on throttle tip-in. Most accelerator pumps are adjustable for volume and/or duration by some means. Eventually the seals around the moving parts of the pump wear such that pump output is reduced; this reduction of the accelerator pump shot causes stumbling under acceleration until the seals on the pump are renewed.

The accelerator pump is also used to *prime* the engine with fuel prior to a cold start. Excessive priming, like an improperly adjusted choke, can cause *flooding*. This is when too much fuel and not enough air are present to support combustion. For this reason, most carburetors are equipped with an *unloader* mechanism: The accelerator is held at wide open throttle while the engine is cranked, the unloader holds the choke open and admits extra air, and eventually the excess fuel is cleared out and the engine starts.

Choke

When the engine is cold, fuel vaporizes less readily and tends to condense on the walls of the intake manifold, starving the cylinders of fuel and making the engine difficult to start; thus, a *richer mixture* (more fuel to air) is required to start and run the engine until it warms up. A richer mixture is also easier to ignite.

To provide the extra fuel, a *choke* is typically used; this is a device that restricts the flow of air at the entrance to the carburetor, before the Venturi. With this restriction in place, extra vacuum is developed in the carburetor barrel, which pulls extra fuel through the main metering system to supplement the fuel being pulled from the idle and off-idle circuits. This provides the rich mixture required to sustain operation at low engine temperatures.

In addition, the choke can be connected to a cam (the *fast idle cam*) or other such device which prevents the throttle plate from closing fully while the choke is in operation. This causes the engine to idle at a higher speed. Fast idle serves as a way to help the engine warm up quickly, and give a more stable idle while cold by increasing airflow throughout the intake system which helps to better atomize the cold fuel.

In many carbureted cars, the choke is controlled by a cable connected to a pull-knob on the dashboard operated by the driver. In some carbureted cars it is automatically controlled by a thermostat employing a bimetallic spring, which is exposed to engine heat, or to an electric heating element. This heat may be transferred to the choke thermostat via simple convection, via engine coolant, or via air heated by the exhaust. More recent designs use the engine heat only indirectly: A sensor detects engine heat and varies electrical current to a small heating element, which acts upon the bimetallic spring to control its tension, thereby controlling the choke. A *choke unloader* is a linkage arrangement that forces the choke open against its spring when the vehicle's accelerator is moved to the end of its travel. This provision allows a "flooded" engine to be cleared out so that it will start.

Some carburetors do not have a choke but instead use a mixture enrichment circuit, or *enrichment*. Typically used on small engines, notably motorcycles, enrichments work by opening a secondary fuel circuit below the throttle valves. This circuit works exactly like the idle circuit, and when engaged it simply supplies extra fuel when the throttle is closed.

Classic British motorcycles, with side-draft slide throttle carburetors, used another type of "cold start device", called a "tickler". This is simply a spring-loaded rod that, when depressed, manually pushes the float down and allows excess fuel to fill the float bowl and flood the intake tract. If the "tickler" is held down too long it also floods the outside of the carburetor and the crankcase below, and is therefore a fire hazard.

Other elements

The interactions between each circuit may also be affected by various mechanical or air pressure connections and also by temperature sensitive and electrical components. These are introduced for reasons such as response, fuel efficiency or automobile emissions control. Various air bleeds (often chosen from a precisely calibrated range, similarly to the jets) allow air into various portions of the fuel passages to enhance fuel delivery and vaporization. Extra refinements may be included in the carburetor/manifold combination, such as some form of heating to aid fuel vaporization such as an early fuel evaporator.

Feedback Carburetor Models by Brand

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
American Motors	Carter BBD				
Chrysler	Carter BBD	Holley 6145	Holley 6520		
Ford	Carter YFA	Motorcraft 2700 VV	Motorcraft 7200 VV	Holley 6520	Holley 6500
General Motors	Holley 6510-C	Rochester 2SE and E2SE	Rochester E2ME	Rochester Quadrajet	
Honda	PGM-CARB				
Nissan	DFP384				