sitic effects in circuits being rapidly switched. See *parasitic effects.*

equivalent series resistance [ESR] The effective resistance in series with an "ideal" capacitor caused by internal leads or the positions of internal elements.

equivalent sound absorption The area of perfectly absorbing surface that will absorb sound energy at the same rate as the given surface or object under the same conditions. The acoustical unit of equivalent absorption is the sabin.

equivalent stopping power 1. *Relative stopping power.* 2. *Stopping equivalent.*

erasable programmable read-only memory [EPROM] A nonvolatile semiconductor ROM memory that can be erased by exposure to ultraviolet (UV) light and rewritten electrically. The chip is covered with a quartz window permitting it to be exposed to UV light for erasure. The window is recovered with opaque material before the EPROM is reprogrammed. See also *EEPROM* and *OTO EPROM.*

erasable storage A storage whose data can be altered at any time.

erase 1. To remove recorded material from magnetic tape by passing the tape through a strong, constant magnetic field (DC erase) or through a high-frequency alternating magnetic field (AC erase). 2. To change all the binary digits in a digital computer memory to binary zeros. 3. To eliminate previously stored information in a charge-storage tube by charging or discharging all storage elements.

erase oscillator The oscillator in a magnetic recorder that provides the high-frequency signal needed to erase a recording on magnetic tape. The bias oscillator usually serves also as the erase oscillator.

erasing head A magnetic head that obliterates material previously recorded on magnetic tape.

ERC Abbreviation for *electrical rules check.*

E region The region of the ionosphere extending from about 60 to 90 mi (95 to 160 km) above the earth, between the D and F regions.

erg The absolute CGS unit of energy and work. It is the work done when a force of 1 dyn is applied through a distance of 1 cm. One foot-pound is equal to 13.56×10^6 ergs.

ergometer An instrument for measuring the amount of work performed by specific muscles in the body under controlled conditions.

ergonomics The science and technology related to the design and manufacture of tools, controls, equipment, and furniture best suited for long-term human use in homes, offices, factories, ships, aircraft, and vehicles. The term means "measurement of work." It considers all aspects of the environment such as lighting, temperature, humidity, and ambient noise as well as human physiological limitations and fatigue. Its objectives are to maximize human work performance safely. A well-designed workstation will include provisions for long-term comfort, protection against excessive noise or other potential dangers, and provisions for variations in operator size and weight. Tools and controls are designed to fit the hands and/or feet comfortably and will be made of appropriate materials in sizes, shapes, and colors that promote safety and efficient use. It is also called *human factors engineering.*

Erlang A unit of communication traffic density, equal to the average number of simultaneous calls originated during a specific hourly period.

ERP Abbreviation for *effective radiated power.*

error 1. The difference between the true value and a calculated or observed value. 2. *Malfunction.*

error amplifier An operational or differential amplifier that controls feedback in a closed-loop circuit or system. It produces an error voltage when the sensed output differs from the reference voltage. In switching power supplies, it adjusts the pulse-width modulator to correct the sensed output voltage. See *reference amplifier.*

error code A specific character entered into a disk, tape, or memory to indicate that a conscious error was made in the associated block of data. Machines reading the error code can be programmed to throw out the entire block automatically.

error-correcting code A code in which each data signal conforms to rules so that errors in received signals can be automatically detected and some or all of the errors corrected automatically.

error-detecting code *Self-checking code.*

error detection and correction [EDC] A process for storing digital data that has first been given a digital tag derived from that data. When the data is retrieved, the tag is used to check the data for correction.

error rate The ratio of the number of erroneous characters to the total number of characters received in a data-transmission system.

error-rate damping A type of damping in which servo control is accomplished by two voltages: one proportional to the error, and the other proportional to the rate at which the error changes. It is also called a *proportional plus derivative control.*

error signal A voltage or current proportional to the difference between the desired and the actual response in a *closed-loop system.*

error voltage A voltage, usually obtained from a tachometer whose output is proportional to the difference between the angular positions of the input and output shafts of a servosystem. This voltage acts on the system to produce a motion that tends to reduce the error in position. It is also called an *error signal.*

ERTS Abbreviation for *earth resources technology satellite.*

Esaki diode *Tunnel diode.*

escape velocity The minimum velocity that will enable an object to escape from the surface of a planet or other body without further propulsion. The escape velocity for the earth is 25,020 mi/h (40,266 km/h); for the moon, 5364 mi/h (8633 km/h).

ESCA Abbreviation for *electron spectroscopy for chemical analysis.*

E scope A radarscope that produces an E display.

escutcheon An ornamental plate around a dial, window, control knob, or other panel-mounted part.

ESD Abbreviation for *electrostatic discharge.*

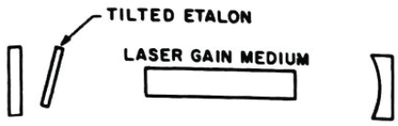
ESDI Abbreviation for *enhanced small-device interface.*

ESP Abbreviation for *earth-surface potential.*

ESU Abbreviation for *electrostatic unit.*

etalon An optical device consisting of two spaced, parallel, and partially silvered glass plates. When placed in the cavity of a laser, the etalon is tilted at an angle that pro-

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US PATENT NO. 6,557,540



Etalon in single-frequency laser.

vides enough reflection to prevent oscillation at all unwanted axial modes of the long cavity.

etch 1. The removal of copper lamination bonded to a circuit board substrate by acid etch with a subtractive mask and etch process that forms the conductors, lands, and pads on a printed circuit board. 2. The removal of semiconductor material, oxide, or thin metal films by acid or plasma (ion) bombardment such as nitride and oxide etch.

etchant An acid that removes unwanted materials such as metal or oxides from a substrate.

etched printed circuit A printed circuit formed by chemical etching or chemical and electrolytic removal of unwanted portions of a layer of conductive, typically copper foil material, bonded to an insulating base.

etching The act of removing unwanted portions of a metal or semiconductor by chemical or electrolytic action.

ETDMA Abbreviation for *enhanced time-division multiaccess.*

Ethernet A local area network (LAN) software standard that determines system operation. It is organized with software, circuit cards, and adapters in each computer or terminal in the network.

ETPC Abbreviation for *electrolytic tough pitch copper.*

ETSI Abbreviation for *European Telecommunications Standards Institute.*

Ettingshausen effect When a metal strip is placed with its plane perpendicular to a magnetic field and an electric current is sent longitudinally through the strip, corresponding points on opposite edges of the strip will have different temperatures.

ETV Abbreviation for *educational television.*

E unit A method of designating radar signal-to-noise ratio. E-1 is a 1 to 1 ratio, barely perceptible; E-2 is 2 to 1, weak; E-3 is 4 to 1, good; E-4 is 8 to 1, strong; E-5 is 16 to 1, very strong or saturating.

EUT Abbreviation for *equipment under test.*

eutectic The liquid alloy composition with the lowest freezing point. For lead-tin solder, the eutectic is 63% tin and 37% solder, giving a freezing point of 361°F.

eV Abbreviation for *electronvolt.*

evacuate To remove gases and vapors from an enclosure. Also called exhaust.

evacuation The removal of gases and vapors from the envelope of an electron tube during manufacture.

evanescent mode The mode of oscillation in which the amplitude diminishes along a waveguide without change of phase.

evaporant The material that is to be deposited as a thin film by evaporation.

evaporated dielectric film A film of dielectric material deposited by vacuum evaporation for passivation of components with active and passive films. It is also used as a capacitor dielectric in thin-film capacitors.

evaporation The process of vaporizing a material by heat in a vacuum to produce a thin film.

evaporative-cooled *Vaporization-cooled.*

EVC Abbreviation for *enhanced video connection standard.*

E vector A vector that represents the electric field of an electromagnetic wave. In free space it is perpendicular to the H vector and the direction of propagation.

even harmonic A harmonic that is an even multiple of the fundamental frequency.

even parity check A method of detecting when bits are dropped by adding 1 bit whenever a character is represented by an odd number of bit patterns. All characters are then represented by an even number of bits, and failure to do so is thus a parity error.

EVR Abbreviation for *electronic video recording.*

EW Abbreviation for *electronic warfare.*

E wave British term for *transverse magnetic wave* (TM wave).

exa- [abbreviated E] A prefix representing 10^{18}.

EXCEPT A logic operator that has the property that if P and Q are two statements, then the statement P EXCEPT Q is true only when P alone is true. It is false for the other three combinations (P false Q false, P false Q true, and P true Q true). The EXCEPT operator is equivalent to AND NOT.

EXCEPT gate A gate that produces an output pulse only for a pulse on one or more input lines and the absence of a pulse on one or more other lines.

excess electron An electron in excess of the number needed to complete the bond structure in a semiconductor, generally resulting from donor impurities.

excess-three code A number code in which the decimal digit n is represented by the 4-bit binary equivalent of $n + 3$, so decimal digits 0 through 9 become 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, and 1100, respectively.

excitation 1. The signal voltage that is applied to the control electrode of an electron tube. 2. Application of signal power to a transmitting antenna. 3. The transfer of a nuclear system from its ground state to an excited state by adding energy. 4. The application of voltage to field coils to produce a magnetic field, as required for the operation of an excited-field loudspeaker or a generator.

excitation winding The magnetic amplifier winding that applies a unidirectional magnetomotive force to the core.

excited-field loudspeaker *Electrodynamic loudspeaker.*

exciter 1. The part of a directional transmitting antenna system that is directly connected to the transmitter. 2. A crystal oscillator or self-excited oscillator that generates the carrier frequency of a transmitter. 3. A small auxiliary generator that provides field current for an AC generator. 4. A loop or probe that extends into a resonant cavity or waveguide. 5. *Exciter lamp.*

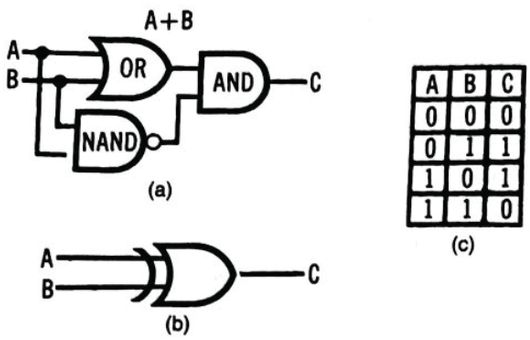
exciting current *Magnetizing current.*

exciton The combination of an electron and a hole in a semiconductor that is in an excited state. In attracting the electron, the hole acts as a positive charge.

exclusion principle *Pauli exclusion principle.*

EXCLUSIVE-OR gate A logic gate whose output is 1 if any one but not more than one of its inputs is 1. The output is 0 if more than one input is 1 or all inputs are 0. Also called XOR gate.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540



XOR

EXCLUSIVE OR gate: (*a*) logic symbol, (*b*) schematic symbol, and (*c*) truth table.

execute To perform the operations in the stored program of a computer.

executive routine A digital computer routine designed to process and control other routines.

exhaust *Evacuate.*

exhaust tube A glass or metal tube through which air from the envelope of an electron tube is evacuated.

exosphere A region of the atmosphere above the thermosphere, beginning at roughly 600 km, where the density is so low that an upward-traveling molecule makes no further collisions until it falls back to the base of the exosphere. At roughly 10,000 km the exosphere merges into the interplanetary medium. The exosphere overlaps the magnetosphere.

exothermic A condition of radiating heat or other energy. All radioactive processes are exothermic. It is also called *exoergic.*

expanded sweep A cathode-ray sweep in which the movement of the electron beam across the screen is speeded up during a selected portion of the sweep time.

expander The part of a compandor that is used at the receiving end of a circuit to return the compressed signal to its original form. It attenuates weak signals and amplifies strong signals.

expert systems Computer programs written on a basis of a database gathered from the practical experience of experts in specific fields or disciplines. Examples include medical diagnostic programs, weather prediction (hurricane and tornado) programs, and earthquake or volcano eruption programs. All are based on personal experience, empirical data, readings from test instruments, history, and other factors.

exploring coil A small coil used to measure a magnetic field or to detect changes produced in a magnetic field by a hidden object. The coil is connected to an indicating instrument either directly or through an amplifier. It is also called a magnetic test coil or a search coil.

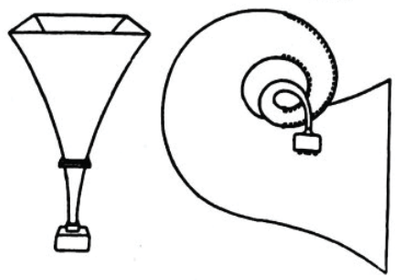
exponential absorption The removal of particles or photons from a beam at an exponential rate as the beam passes through matter.

exponential amplifier An amplifier capable of supplying an output signal proportional to the exponential of the input signal.

exponential antenna A television receiving antenna that has a series of active elements mounted parallel to each other, with element lengths adjusted so their ends form two natural logarithmic curves. The antenna provides high gain over the VHF and UHF television bands.

exponential decay Decay of radiation, charge, signal strength, or some other quantity at an exponential rate.

exponential horn A horn whose cross-sectional area increases exponentially with axial distance.



Exponential horns, straight and curled.

exponential transmission line A two-conductor transmission line whose characteristic impedance varies exponentially with electrical length along the line.

exposure dose A measure of X-ray or gamma radiation at a point, based on its ability to produce ionization. The unit of exposure dose is the roentgen.

exposure-dose rate The exposure dose per unit time. The unit of exposure-dose rate is the roentgen per unit time.

exposure meter An instrument that measures the intensity of light reflected from an object for the purpose of determining proper camera exposure. Modern exposure meters consist of a photovoltaic cell connected to an indicating meter.

extended binary-coded decimal interchange code [EBCDIC] A computer code in which 8 binary bits represent a single character, giving a possible maximum of 256 characters. It is the BCD code extended to 8 binary bits. EBCDIC-encoded messages are returned to the sending station for verification of data integrity.

extended data output [EDO] A reference to a *dynamic random access memory* [DRAM] format that offers faster speed, (approximately 60 ns) than the 70 to 80 ns of conventional DRAMs.

Extended Industry Standard Architecture [EISA] An extension for Intel 80386 microprocessors (and later processors) of the ISA bus for PC-compatible computers that provides compatibility with earlier ISA systems. See *Industry Standard Architecture.*

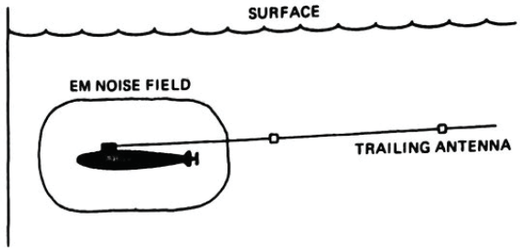
extragalactic radio source A discrete source of radio signals outside known galaxies or quasars. More than 10,000 such sources have been detected with radio telescopes, at frequencies ranging from 10 MHz to 100 GHz.

extra-high voltage [EHV] A voltage above 345 kV for electric power transmission.

extraordinary component The component of light that is plane-polarized and passes through a Nicol prism. The ordinary component is totally reflected by the prism.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

extraterrestrial noise Cosmic, solar, radio, and other electromagnetic noise from sources not related to the earth.
extremely high frequency [EHF] A Federal Communications Commission designation for a frequency in the band from 30 to 300 GHz, corresponding to a millimetric wave between 1 and 10 mm.
extremely low frequency [ELF] A frequency below 300 Hz in the radio spectrum, corresponding to a wavelength above 1000 km.
extrinsic properties The properties of a semiconductor as modified by impurities or imperfections within the crystal.
extrinsic semiconductor A semiconductor whose electrical properties are dependent on impurities added to the semiconductor crystal, in contrast to an intrinsic semiconductor whose properties are characteristic of an ideal pure crystal.



Extremely low frequency signals, in range of 30 to 100 Hz, reach a submerged nuclear submarine trailing long antenna.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

F

f Abbreviation for *femto-*.

f Symbol for *frequency.*

F 1. Symbol for *fuse.* 2. Abbreviation for *Fahrenheit.* 3. Abbreviation for *farad.*

°F Abbreviation for degree Fahrenheit.

F– *A–.*

F+ *A+.*

fA Abbreviation for *femtoampere.*

FAA Abbreviation for *Federal Aviation Administration.*

FACCH Abbreviation for *fast associated control channel.*

fab A slang (colloquial) term for the first part or "front end" of semiconductor manufacturing. See *front-end fabrication.*

face bond A bond that is made directly between the bonding pad of a face-down semiconductor chip and a mating contact on a mounting substrate.

faceplate The transparent or semitransparent glass front of a cathode-ray tube, through which the image is viewed or projected. The inner surface of the face is coated with fluorescent chemicals that emit light when hit by an electron beam. Also called face.

facsimile [fax] A system for transmitting and receiving text and/or graphics over the public telephone system. An electric signal representing the image of the *subject copy* is generated by optical scanning in a *scanner* and then is encoded before being transmitted by modem over the telephone lines to a compatible fax receiver or *recorder,* typically a machine capable of both transmitting and receiving. The speed of fax modems is typically 14.4 kb/s. The receiving fax machine decodes the signal and converts it into a format for operating a printer to print out a *facsimile copy* based on the received signal.

facsimile copy The printout of a fax machine on thermal or plain paper. See also *subject copy.*

facsimile machine A modern personal or business machine that combines the dual functions of fax scanning and transmission and receiving and printout in a single integrated unit. In a common scanning method, the *subject copy* is inserted in the machine so it passes around a drum rotating at constant angular velocity. An optical carriage with a photocell is mounted on a traverse drive belt that advances a distance equal to the height of a specified rectilinear area or horizontal strip across the width of the subject copy. The photocell generates a stream of pixels encountered in a helical-scan track. The output of the photocell or cells is converted by a *modem* for transmission over the public dial-up telephone line to a compatible fax machine that contains a mode for converting the data back to a signal that can be printed out on plain or thermal paper. Fax machines are typically assigned an exclusive telephone number so they can operate 24 hours a day without interfering with voice telephone service. Some machines can also serve as *scanners* or document digitizers for converting text and graphics to a digital format for processing or storage by computer, and some can also serve as office copying machines.

facsimile signal The picture signal produced by scanning the subject copy in a facsimile transmitter.

facsimile transmission The transmission of digital data produced by scanning fixed graphic material, including photographs, for reproduction in record form.

fade To change signal strength gradually.

fadeout A gradual and temporary loss of a received radio or television signal caused by magnetic storms, atmospheric disturbances, or other conditions along the transmission path. A blackout is a fadeout that can last several hours or more at a particular frequency.

fader A multiple-unit volume control for the gradual changeover from one microphone, audio channel, or television camera to another. In each changeover, the level is held essentially constant because one section of the fader increases signal level in its channel while the other fader section reduces signal level a corresponding amount.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

fading Variations in the field strength of a radio signal, usually gradual, that are caused by changes in the transmission medium.

fading margin An attenuation allowance made in radio system planning so that anticipated fading will still keep the signal above a specified minimum signal-to-noise ratio.

Fahnestock clip A spring-type terminal for making a temporary electrical connection.

Fahrenheit [F] A temperature scale in which the freezing point of water is 32° and the boiling point of water is 212° at normal atmospheric pressure. Absolute zero is –459.6°F. To change degrees Fahrenheit to degrees Celsius, subtract 32 and then multiply the result by ⅝. Fahrenheit and Celsius scales agree at one point: –40°F = –40°C. Multiply degrees Celsius by ⅝ and add 32 to get degrees Fahrenheit.

fail-safe control A control so designed that control-circuit failure cannot cause a dangerous condition under any circumstances.

fairlead A plastic, wood, or metal tube with a funnel-shaped end through which a trailing antenna is reeled on an aircraft.

fall time The time for the voltage at the trailing edge of a pulse to fall from 90 to 10% of the original negative or positive amplitude. It is the opposite of *rise time.*

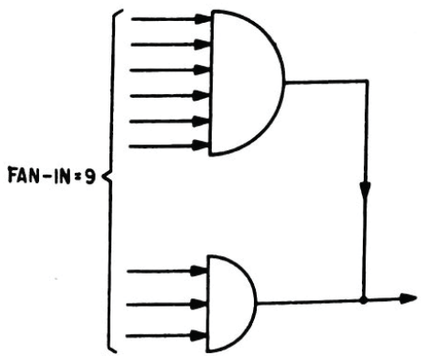
false echo A misleading extra echo indication on the plan-position indicator of a ship's radar set. On rivers, shore structures can cause false echoes. A target can also be hit by a side lobe of the beam, and the echo reflected back into the main beam path by a mast, stack, or tower.

fan beam 1. A radio beam having an elliptically shaped cross section in which the ratio of the major to minor axes usually exceeds 3 to 1. The beam is broad in the vertical plane and narrow in the horizontal plane. 2. A radar beam with a fan shape.

fan dipole See *dipole antenna.*

fan-in The number of inputs that can be connected to a digital logic gate.

fan-in circuit A circuit having many inputs feeding to a common point.



Fan-in circuit for logic gates.

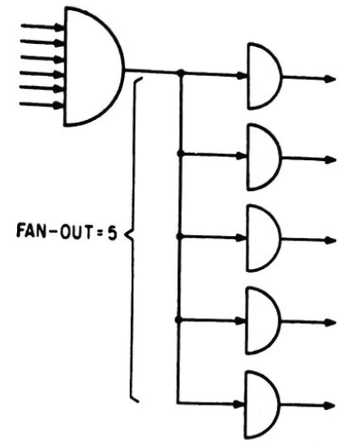
fan marker *Fan marker beacon.*

fan marker beacon A VHF radio facility with a vertically directed fan beam intersecting an airway to provide a fix. When used near an airport as part of an instrument landing system, it is called a boundary, middle, or outer marker beacon.

fanning beam A radio beam that is swept back and forth repeatedly over a limited arc.

fan-out The number of parallel compatible logic outputs that can be driven from an integrated circuit without exceeding the device specifications.

fan-out circuit A circuit with a single output point that feeds many branches.



Fan-out circuit with a fan-in circuit for logic gates.

farad [F] The SI unit of capacitance. A capacitor has a capacitance of 1 F when a voltage change of 1 V/s across it produces a current of 1 A. The farad is too large a unit for practical work, so two smaller units are generally used. The microfarad is equal to one-millionth of a farad, and the picofarad is equal to one-millionth of a microfarad.

faraday A unit of quantity of electricity equal to 96,500 C.

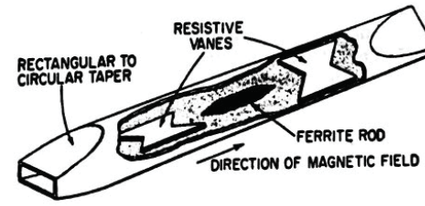
Faraday cage See *Faraday shield.*

Faraday dark space The relatively nonluminous region that separates the negative glow from the positive column in a cold-cathode glow-discharge tube.

Faraday effect When a plane-polarized beam of light passes through certain transparent substances in a direction parallel to the lines of a strong magnetic field, the plane of polarization is rotated a certain amount. The same effect governs the action of a ferrite rotator in a waveguide.

Faraday rotation The rotation of a signal's polarization caused by its passage through the ionized E and F layers of the upper atmosphere.

Faraday rotation isolator An isolator for circular waveguides that passes waves traveling in one direction but not



Faraday rotation isolator.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

in the other direction. A ferrite rod is positioned between resistive vanes to rotate the plane of polarization of the waves 45°. With appropriate rectangular-to-circular transitions, the isolator will work with rectangular waveguides.

Faraday rotator phase shifter A latching, reciprocal phase shifter that includes a Faraday rotator section and nonreciprocal quarter-wave plates at each end. It includes a square ferrite-filled waveguide. An axial coil is wound around the waveguide, and its magnetic field is completed outside the waveguide wall with ferrimagnetic yokes. Quarter-wave plates at each end convert energy in the rectangular enclosure either to right- or left-hand circularly polarized energy, depending on the direction of propagation. The energy phase is changed by a variable axial magnetic field supplied by the coil around the waveguide. See *phase shifter.*

Faraday shield 1. An electrostatic shield placed between the primary and secondary windings of a transformer to reduce coupling capacitance and common-mode noise. 2. An electrostatic shield made of open metal-wire mesh. 3. A plastic bag with both outer surfaces metallized to protect delicate, ESD-sensitive components from damage or destruction from ESD. The shield provides electrostatic shielding while passing electromagnetic waves. It need not be grounded. See *electrostatic shield.*

Faraday's law The voltage induced in a circuit is proportional to the rate at which the magnetic flux linkages of the circuit are changing. Also called law of electromagnetic induction.

faradic current An intermittent and nonsymmetrical alternating current similar to that obtained from the secondary winding of an induction coil.

far-end crosstalk Crosstalk that travels along the disturbed circuit in the same direction as desired signals in that circuit. When it occurs at carrier telephone repeater stations, the output signals of one repeater go out also over the output line for the other repeater.

far field The radiation field in the Fraunhofer region surrounding a transmitting antenna.

far region *Fraunhofer region.*

far zone *Fraunhofer region.*

fast Fourier transform [FFT] A Fourier transform method for calculating the frequency spectrum, in both magnitude and angle, for any function of time by means of special operating programs that speed machine computation of complex Fourier series.

fathometer *Depth sounder.*

fault 1. A defect such as an open circuit, short circuit, or inadvertent ground in a component, circuit, or transmission line. 2. A defect in a semiconductor device that can cause the device to fail during normal operation. It is usually the result of a processing defect.

fault mode current The current in a circuit under fault conditions, such as during arcbacks and load short-circuits.

fault simulation This term usually means computer simulation of processing defects in integrated-circuit fabrication. The circuit description is modified (faulted) to correspond to a processing defect, and the simulation is rerun to determine whether the test program would find this defect.

FAX (or **fax**) Abbreviation for *facsimile.*

fc Abbreviation for *footcandle.*

FC-AL Abbreviation for *fiber-channel arbitrated loop.*

FCC Abbreviation for *Federal Communications Commission.*

FDCC Abbreviation for *forward control channel.*

FDDI Abbreviation for *fiber distributed data interface.*

FDM Abbreviation for *frequency-division multiplex.*

FDMA Abbreviation for *frequency-division multiple-access.*

FDX Abbreviation for *full-duplex transmission.*

FEC Abbreviation for *forward error correction.*

FED Abbreviation for *field-emitter display.*

Federal Aviation Administration [FAA] An agency created by Congress in 1958, with full authority over both military and civilian airspace requirements.

Federal Communications Commission [FCC] A U.S. government agency responsible for the following: 1. The policy governing allocation of radiated emissions (frequencies). 2. Establishing owner eligibility for commercial radio and TV stations and their licensing. 3. The qualification and licensing of amateur and professional radio and radar operators and electronic technicians.

feed 1. To supply a signal to the input of a circuit, transmission line, or antenna. 2. That part of a radar antenna connected to or mounted on the end of the transmission line which radiates RF energy to the reflector or receives energy therefrom.

feedback The return of a portion of the output of a circuit or device to its input. With positive feedback, the signal fed back is in phase with the input and increases amplification but can cause oscillation. With negative feedback, the signal fed back is 180° out of phase with the input and decreases amplification but stabilizes circuit performance and tends to minimize noise and distortion.

feedback amplifier An amplifier with a passive network that returns a portion of the output signal to its input in a way that changes the performance characteristics of the amplifier.

feedback controller A circuit or element in a *closed-loop system* that controls the motor or other actuator in a closed loop system to correct an *error signal.*

feedback control loop A control loop circuit that senses any deviation from the desired output level and changes the drive waveforms of the power switch to compensate for those changes.

feedback control system *Closed loop control system.*

feedback oscillator An oscillating circuit with an amplifier whose output is fed back in phase with the input. Oscillation is maintained at a frequency determined by the values of the reactive components in the amplifier and the feedback circuits.

feedback path The transmission path from the loop output signal to the loop feedback signal in a feedback control loop.

feedback regulator A feedback control system that tries to maintain a prescribed relationship between certain system signals and other predetermined quantities. Some system signals in a regulator are adjustable reference signals. Under certain methods of operation, a feedback regulator can also be a servomechanism.

feedback resistor The resistor in parallel with an operational amplifier to couple output to input and act as a voltage control.

feedback signal *Primary feedback.*

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

feedback winding A winding that makes feedback connections in a magnetic amplifier.

feeder A transmission line between a transmitter and an antenna.

feed forward A method for improving line regulation by directly sensing the input voltage of a circuit.

feed-forward control Process control in which changes are detected at the process input, and an anticipating correction signal is applied before process output is affected.

feed-forward network An external distortion-reducing network for use with a class C amplifier in communication-satellite service. Signal samples are taken before and after the distorting amplifier to obtain an error signal. This error signal is processed and combined beyond the amplifier output, to provide an undistorted signal by cancellation of the common error terms.

feed line A wire or cable for connecting an antenna to the transmitter and receiver. See *transmission line.*

feedthrough A conductor that connects patterns on opposite sides of a printed-circuit board. It is also called a *via* connection.

feedthrough capacitor A feedthrough insulator that provides a desired value of capacitance between the feedthrough conductor and the metal chassis or panel through which the conductor is passing. It serves as a bypass in UHF circuits.

feedthrough insulator *Feedthrough terminal.*

feedthrough terminal An insulating sleeve with a coaxial conductor, made to mount in a hole formed in a metal panel, case, or firewall to pass electrical power or signals through a partition. It is also called a *feedthrough insulator.*

feet per second [ft/s] A unit for specifying the speed of sound through a medium. In air at standard sea-level conditions, the speed of sound is approximately 1080 ft/s (330 m/s), and 4800 ft/s (1460 m/s) in water.

female connector A connector that has one or more contacts set into recessed openings. Jacks, sockets, and wall outlets are examples of female connectors.

femto- [f] A prefix representing 10^{-13}, which is 0.000 000 000 000 001, or one-thousandth of a millionth of a millionth.

femtoampere [fA] A unit of current equal to 10^{-13} A.

femtosecond [fs] A unit of time equal to 10^{-13} second.

femtovolt [fV] A unit of voltage equal to 10^{-13} V.

femtowatt [fW] A unit of power equal to 10^{-13} W.

FEP An abbreviation for *fluorinated ethylene propylene.*

Fermat's principle An electromagnetic wave will take the path of least travel time when propagating between two points.

fernico An iron-nickel cobalt alloy whose coefficient of expansion is similar to that of glass, making it suitable for making glass-to-metal seals for power tubes and other vacuum chambers. See also *Kovar.*

ferric Containing a trivalent compound of iron.

ferric oxide [Fe_2O_3] A magnetic iron oxide (red) used as a coating on magnetic recording tapes.

ferrimagnetic limiter A power limiter that replaces TR tubes in microwave systems. It uses ferrimagnetic material that exhibits nonlinear properties, such as ferrite or garnet.

ferrimagnetic material A ferrite material that exhibits ferrimagnetism, such as yttrium-iron garnet polycrystalline materials.

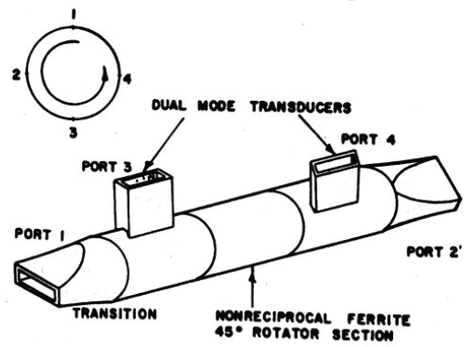
ferrimagnetism A type of magnetism in which the magnetic moments of neighboring ions tend to align antiparallel to each other. The moments are of different magnitudes, however, so there can be a large resultant magnetization. It is observed in the ferrites and similar compounds.

ferristor A miniature two-winding saturable reactor that operates at a high carrier frequency and can be connected as a coincidence gate, current discriminator, free-running multivibrator, oscillator, or ring counter.

ferrite A powdered, compressed, and sintered magnetic material that has high resistivity, consisting chiefly of ferric oxide combined with one or more other metals. The high resistance makes eddy current losses extremely low at high frequencies. Examples of ferrite compositions include nickel ferrite, nickel-cobalt ferrite, manganese-magnesium ferrite, yttrium-iron garnet, and single-crystal yttrium-iron garnet. It is also called ferrospinel.

ferrite bead A bead made of ferrite powder, placed on a connecting wire in a high-frequency circuit to introduce inductance for suppressing parasitic oscillations.

ferrite circulator A combination of two dual-mode transducers and a 45° ferrite rotator that control and switch microwave energy in a rectangular waveguide.



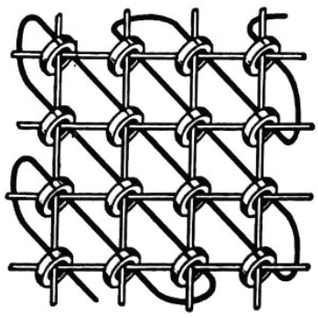
Ferrite circulator with four rectangular ports.

ferrite-core memory A magnetic memory consisting of read-in and read-out wires threaded through a matrix of tiny toroidal cores molded from a square-loop ferrite. Some cores of this type are only 0.018 in (0.5 mm) in diameter. It is also called a core memory and a core plane. It is now an obsolete technique.

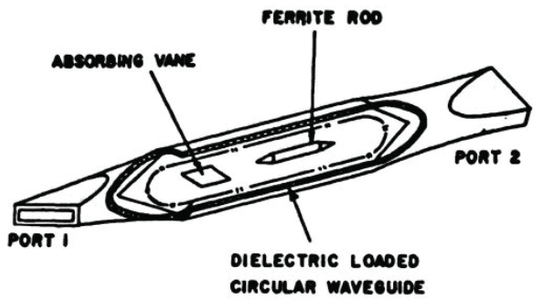
ferrite isolator An isolator that passes energy in one direction through a waveguide while making possible the absorption of energy from the opposite direction. A ferrite rod, centered on the axis of a short length of circular waveguide, is located between rectangular-waveguide end sections displaced 45° with respect to each other. A signal in the desired direction is rotated 45° by the ferrite rod to make it correct for the output waveguide. A backward signal is rotated 45° in the wrong direction, and its energy is absorbed by resistance cards.

ferrite limiter A passive low-power microwave limiter that has an insertion loss of less than 1 dB when it is operating in its linear range, with minimum phase distortion. The input signal is coupled to a single-crystal sample of

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US PATENT NO. 6,557,540



Ferrite-core memory construction. Technology is now obsolete.



Ferrite isolator.

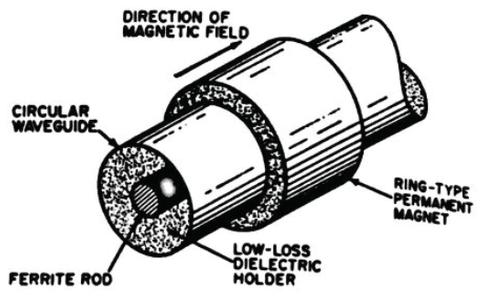
either yttrium-iron garnet or lithium ferrite, which is biased to resonance by a magnetic field. They are used to protect sensitive receivers from burnout and blocking by a strong interfering signal.

ferrite phase-differential circulator A combination microwave duplexer and load isolator that functions as a switching device between a high-power radar magnetron, a radar receiver, and a radar antenna. It consists of a T junction, a ferrite section, and a short-slot hybrid coupler with a dual adapter that connects a matched load and the antenna to the hybrid. The ferrite section consists of a double waveguide unit, with a wall between the two waveguide lines. Ferrite slabs are placed in the waveguide lines to produce the desired differential phase shift.

ferrite phase shifter A microwave radar component that alters the frequency phase of the signal passing through it. A matrix of phase shifters permits a phased-array radar beam to be electronically scanned. The most common are ferrite phase shifters enclosed in a waveguide. Alternatives are microstrip versions that include ferrimagnetic materials (ferrites and garnets or ceramic materials with magnetic properties. A phase shifter can be either *reciprocal* or *nonreciprocal.* The toroidal phase shifter is the most common nonreciprocal type; Reggia-Spenser and Faraday rotator phase shifters are the most popular reciprocal units.

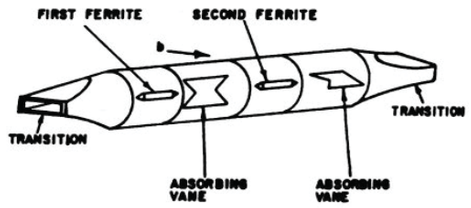
ferrite-rod antenna An antenna that consists of a coil wound on a rod of ferrite for radio receivers. The coil generally serves as the tuning inductance for the first stage of the receiver. It is also called a ferrod or loopstick antenna.

ferrite rotator A gyrator consisting of a ferrite cylinder surrounded by a ring-type permanent magnet, inserted in a waveguide to rotate the plane of polarization of the electromagnetic wave passing through the waveguide. The dimensions of the ferrite cylinder and the magnetization of the ferrite determine the amount of rotation.



Ferrite rotator in circular waveguide.

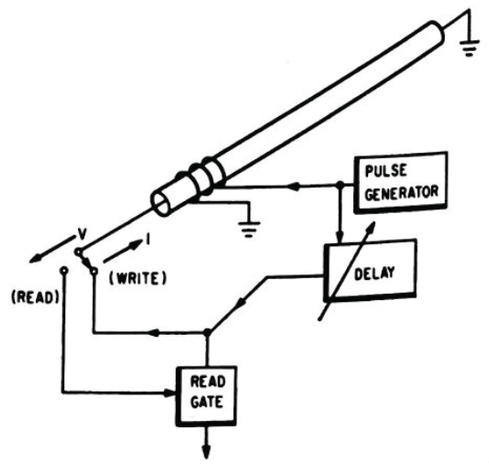
ferrite switch A ferrite device that blocks the flow of energy through a waveguide by rotating the electric field vector 90°. The switch is energized by sending direct current through its magnetizing coil. The rotated energy is then reflected from a reactive mismatch or absorbed in a resistive card.



Ferrite switch.

ferrite-tuned oscillator An oscillator with the resonant characteristic of a ferrite-loaded cavity that is changed by varying the ambient magnetic field, to permit electronic tuning. In one example, the tuning range is 500 to 1300 MHz.

ferroacoustic storage A delay-line storage medium consisting of a thin tube of magnetostrictive material, a central conductor passing through the tube, and an ultrasonic



Ferroacoustic-storage principle. At top is thin tube of magnetostrictive material with a central conductor wire.

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Goodheart-Willcox

automotive encyclopedia

fundamental principles, operation, construction, service, repair

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US PATENT NO. 6,557,540

INTRODUCTION

The automotive service field offers excellent career opportunities for anyone who is mechanically inclined and has the necessary educational background, including extensive training in the fundamentals of service and repair work.

The AUTOMOTIVE ENCYCLOPEDIA is a book of fundamentals. It covers construction details, principles of operation, latest mechanical advances and basic service procedures. This is the foundation on which a sound, thorough knowledge of auto mechanics is based. Once you learn these fundamentals, you can quickly acquire the know-how, through experience, that will enable you to diagnose trouble and perform the service or repair needed on any make of car.

The ENCYCLOPEDIA tells you how each system works. It explains what happens when you turn the ignition key or "step on the gas" or apply the brakes. It shows by clear illustration how the energy in fuel is converted into power, and how that power is transmitted to the driving wheels of the car.

This book helps you explore the sciences involved in vehicle operation: the fundamentals of electricity, hydraulics, pneumatics, internal combustion and exhaust emission control. It also gives basic information on hand tools, fasteners, measuring instruments, service equipment and meters.

The purpose of the AUTOMOTIVE ENCYCLOPEDIA is to provide instruction in auto mechanics as recommended by the Standards for Automotive Service Instruction in Schools, prepared by the Automotive Service Industry -- Vocational Educational Conference. It is intended, too, as a guide for car owners and prospective car owners who want to learn more about the mechanical features of their cars.

William K. Toboldt

Larry Johnson

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

CONTENTS

AUTOMOTIVE TOOLS 7

FASTENING DEVICES 31

MEASURING INSTRUMENTS 39

ENGINE FUNDAMENTALS 45

ENGINE CONSTRUCTION 55

ENGINE PISTON RINGS AND PINS 67

ENGINE CRANKSHAFTS AND CAMSHAFTS 73

ENGINE BEARINGS, VALVES 81

ENGINE PERFORMANCE 93

ENGINE LUBRICATION 101

ENGINE COOLING SYSTEMS 111

OTHER ENGINES 127

ENGINE RECONDITIONING 147

PISTON RING AND PIN FITTING 163

CRANKSHAFT, CAMSHAFT AND CONNECTING ROD SERVICE 169

VALVE SERVICE 181

ENGINE TROUBLESHOOTING 197

ENGINE TUNE-UP 213

AUTO SHOP SAFETY 225

AUTOMOTIVE FUELS 229

PRINCIPLES OF CARBURETION 237

MANUAL AND AUTOMATIC CHOKES 259

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Contents

ENGINE MANIFOLDS 265
AIR CLEANERS 271
CARBURETOR ADJUSTMENT, SERVICE 275
FUEL SUPPLY SYSTEMS 283
FUEL INJECTION 301
EXHAUST SYSTEMS 321
EMISSION CONTROL 327
FUNDAMENTALS OF ELECTRICITY, MAGNETISM 341
GENERATORS AND ALTERNATORS 351
GENERATOR AND ALTERNATOR, TESTING AND SERVICING 359
GENERATOR AND ALTERNATOR, REGULATORS AND RELAYS 369
STARTING MOTOR FUNDAMENTALS 387
ENGINE IGNITION 401
LIGHTS, LIGHTING CIRCUITS, WIRING AND HORNS 435
STORAGE BATTERIES 446
SPEEDOMETERS 458
SPEED CONTROL SYSTEMS 463
WINDSHIELD WIPERS, WASHERS 470
METERS, TESTERS AND ANALYZERS 477
SPRING SUSPENSION AND STEERING 483
WHEEL ALIGNMENT 497
WHEEL ALIGNMENT CORRECTION 505
AUTOMOTIVE BRAKES 515
CLUTCHES 553
TRANSMISSION FUNDAMENTALS 563

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

FLUID COUPLING TRANSMISSIONS 579

TORQUE CONVERTER TRANSMISSIONS 587

DRIVE LINE, UNIVERSAL JOINTS, DIFFERENTIALS 601

DRIVE LINE SERVICE 617

AUTOMOBILE AIR CONDITIONING 625

TIRES, TIRE SERVICE 645

BODY REPAIRING, REFINISHING 655

HYDRAULICS AND PNEUMATICS 689

BUILT-IN SAFETY SYSTEMS 699

CAREER OPPORTUNITIES 707

DICTIONARY OF AUTOMOTIVE TERMS 711

MECHANICAL, TUNE-UP SPECIFICATIONS 720

INDEX 783

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

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PRINCIPLES OF CARBURETION

The purpose of the fuel supply system, Fig. 21-1, is to provide a combustible mixture of fuel and air to the engine cylinders. The ratio of fuel to air must always be in the correct proportion regardless of the speed and load on the engine.

Major elements of the fuel supply system include: fuel tank and cap, fuel system emission controls, fuel lines, fuel pump, fuel filter, carburetor, air cleaner and manifold. In addition, there is the fuel gauge, which indicates the amount of fuel in the tank.

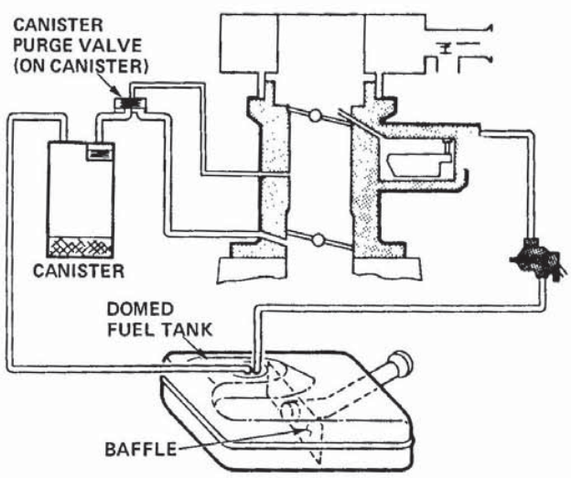


Fig. 21-1. Details of fuel system on late model car.

PURPOSE OF CARBURETOR

The purpose of the carburetor is to prepare and supply a mixture of fuel vapor and air, in proper proportion for efficient combustion, to the engine cylinders.

Because of varying conditions of temperature, engine speed and load on the engine, perfect carburetion is difficult to attain. When an internal combustion engine is started, it is cold and an air-fuel mixture containing a larger proportion of fuel is required. When the engine reaches operating temperatures, better vaporization of the fuel is attained and, as a result, the initial mixture of fuel and air is too "rich." This mixture contains more fuel than is normally required. It is not efficient and the engine will not operate satisfactorily, particularly at idling speed.

Still another difficulty must be overcome by the carburetor. When the engine is idling or operating at low speed, a richer mixture is required than when operating at medium speed and power. Then, when maximum power is required, the amount of fuel in relation to air must be increased. Similarly, during periods of acceleration, a richer mixture is needed.

A problem encountered in designing carburetors results from the fact that the rate of air flow through the carburetor changes in a ratio of more than 100 to 1. This is a direct result of the changes of engine speed. At low speed, the flow of air through the carburetor is at a minimum. At maximum engine speed, it will be at least 100 as great.

Variations in types and characteristics of fuels also complicate the carburetor design operation. Gasoline is a blend of various parts or fractions of crude petroleum. As a result, some fractions contained in commercial gasoline will boil or vaporize at 100 deg. F, others have boiling points ranging up to 400 deg. F.

Depending on the temperature of various parts of the intake manifold, some cylinders may receive a mixture with some portions of the fuel completely vaporized, while other portions of the fuel may be in liquid form. In addition, some cylinders will receive fuel having greater antiknock qualities than others. Consider, too, that when the engine and manifold are cold, the problem is still more difficult.

AIR-FUEL RATIO

For normal operating conditions, the best economy is obtained by a mixture of 1 part by weight of gasoline to between 16 to 17 parts of air. For quick acceleration and maximum power, a richer mixture of about 1 part of gasoline to 12 to 13 parts of air is needed. For idling, a somewhat richer-than-normal mixture is required. When starting a cold engine, an extremely rich mixture is needed. (See the chapter on MANUAL AND AUTOMATIC CHOKES.)

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

EVAPORATION

All substances, whether solid, liquid or gas, are made of molecules. In solids such as steel and copper, the particles are so close together they seem to have no motion. In liquids, the molecules are not held together so tightly. They can move with respect to each other and, as a result, liquids flow. In gases, such as air, there is even less tendency for the molecules to hold together, so they move quite freely.

When molecules of a liquid move from the liquid into the air, the liquid is said to evaporate. As this continues, the liquid disappears from its container and forms vapor in the air.

Rapidity of evaporation varies with a number of factors. These factors, include temperature, the pressure above the liquid, the amount of liquid that has already evaporated into the air and the volatility of the liquid.

The term volatility refers to the ease with which a liquid vaporizes. For example, alcohol and benzene are more volatile than water because they evaporate more easily. A highly volatile liquid evaporates rapidly. A liquid of low volatility evaporates slowly.

At higher temperatures, molecules move faster. As a result, the rate of vaporization is increased. Furthermore, when there is little pressure above the liquid, the molecules can escape from the liquid more easily. If evaporation takes place in a closed chamber, the evaporation of the liquid will soon stop because the closed space above the liquid becomes filled with escaped molecules of the liquid. When this occurs, the space above the liquid is said to be saturated.

If a liquid is broken up into tiny particles or globules, it will vaporize more easily. Breaking a liquid into tiny particles is known as vaporization. Spray guns of the type used for spraying insecticides or paint will vaporize a liquid. For example, if gasoline is placed in an ordinary spray gun, Fig. 21-2, the fuel will be broken into a fine mist that will change into vapor almost instantly.



Fig. 21-2. Fuel leaving jet in a carburetor is vaporized like a spray from a conventional spray gun.

PRINCIPLES OF CARBURETOR OPERATION

Both air and gasoline are drawn through a carburetor and into the engine combustion chambers by suction created by the pistons moving downward in the cylinders. As the piston moves down, a partial vacuum is created in the cylinder and combustion chamber. The difference between this low pressure within the cylinder and the atmospheric pressure outside of the carburetor causes air and fuel to flow into the cylinder from the carburetor.

Directly related to this air flow into the carburetor is the principle or method whereby the moving air draws fuel from the carburetor jet and fuel supply. It is called the venturi principle, a means by which the suction within the carburetor is increased. Actually, a venturi is an hour-glass shaped constriction placed in a carburetor, so that incoming air must pass through it on its way to the intake manifold and engine cylinders, Fig. 21-3.

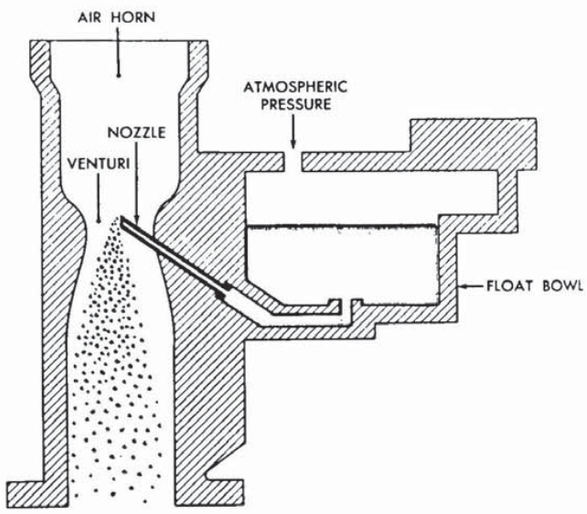


Fig. 21-3. Simplified carburetor consisting only of air horn, venturi, float bowl and nozzle.

A venturi is simply a specially designed section of a pipe line or tube where the area of the tube is reduced. This reduction in area increases the speed of the air that is passing through the tube. The same volume of air or fluid flows through all sections of the tube. Therefore, if the area of the tube is decreased, the velocity of the air or fluid must increase as it passes through the restricted area.

The venturi not only increases the velocity of the flow of air which passes through it, but it also produces a vacuum at its point of maximum restriction, Fig. 21-4. The outlet of a fuel jet is placed at that point, so that fuel is drawn from the jet and immediately mixes with the passing air.

This mixing of the fuel with air is known as vaporization, and it closely resembles the action of the familiar spray gun used for spraying insecticides, Fig. 21-2.

Some carburetors have as many as three venturies, Fig. 21-15 and Fig. 21-37. This design permits a more accurate metering of the flow of air and fuel for different conditions of engine operation. It improves the efficiency of combustion, which has become increasingly important in reducing exhaust emissions.

Remember that the difference between the pressure at the open carburetor jet at the venturi and surface pressure on the fuel in the float bowl, Fig. 21-3, causes the fuel to flow.

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US PATENT NO. 6,557,540

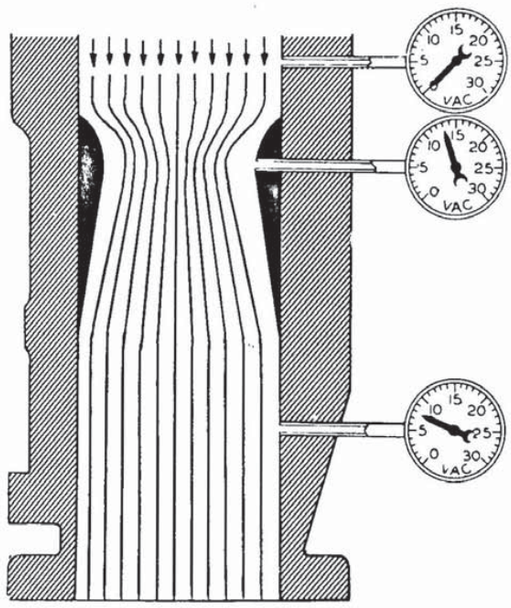


Fig. 21-4. Note how vacuum varies through different sections of carburetor.

CARBURETOR CIRCUITS

In order to supply an air-fuel mixture suitable for all the different operating conditions of low to high speeds, and light loads to full loads, a carburetor must be provided with additional circuits and controls. These circuits include: float system, idle system, main metering system, accelerating system and high speed system. Under controls, there are: the throttle, anti-percolator, fast idle, unloader, anti-icing, hot idle compensator and anti-stall dashpot.

THROTTLE

One of the important controls on a carburetor is the throttle valve, or valves. The throttle valve is a device for varying the amount of air-fuel mixture that enters the intake manifold. This control is necessary so the speed of the vehicle can be changed.

The throttle valve, Fig. 21-5, is simply a round disk mounted on a shaft, so that it can be tilted at various angles in the carburetor throttle valve body. It is connected by means of suitable linkage to the accelerator pedal in the driving compartment of the vehicle. Depressing the pedal opens the throttle valve, permitting an increased amount of air-fuel mixture to reach the manifold.

FLOAT CIRCUIT

Fuel in the carburetor must be maintained at a specified level for correct fuel metering under all operating conditions. This is the function of the float circuit, Fig. 21-6. Maintenance of the desired fuel level is accomplished by the float or pontoon when its attached lever forces the needle valve closed and shuts off the flow of fuel.

Then, as soon as fuel is withdrawn from the float bowl, the float drops, the needle valve opens and fuel again flows into the bowl. In that way the fuel level is maintained at the opening of the main discharge nozzle.

The float level must be set with a high degree of accuracy. If the level is too low, insufficient fuel will be supplied to the system and engine performance will suffer. On the other hand, if the level is too high, excessive fuel will flow from the nozzle.

Under conditions of a high fuel level in the float bowl, excessive fuel consumption results and carbon will accumulate in the combustion chambers of the engine. In actual operation, the float and needle valve maintain a position that permits the fuel coming into the float bowl to balance the fuel issuing from the carburetor jets.

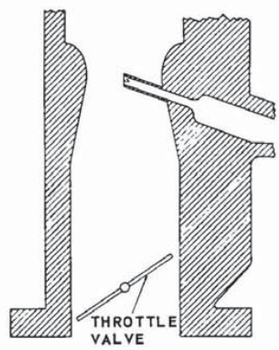


Fig. 21-5. Illustrating position of throttle valve or plate.

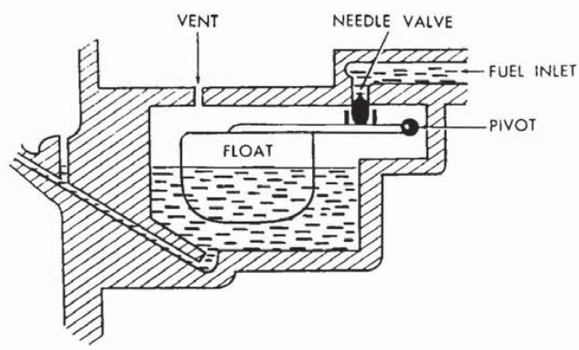


Fig. 21-6. Typical carburetor float system.

LOW-SPEED CIRCUIT

The idle system or low-speed circuit, Fig. 21-7, is designed to supply the proper amount of mixture for the engine at idle and extremely low speeds. It operates from idle speed to approximately 25 mph. Above that speed, the idle system gradually passes out of operation and fuel is supplied by the main metering system.

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US PATENT NO. 6,557,540

When the throttle valve is almost closed, there will be very little air passing through the venturi. Consequently, there will be very little vacuum to draw fuel from the fuel nozzle.

However, on the manifold side of the throttle valve, the vacuum will be at a maximum as long as the throttle is in the closed position. A fuel discharge port is located immediately below the closed position of the throttle, Fig. 21-7. It is supplied by fuel from the float bowl. Atmospheric pressure in the float bowl will force fuel from the idle discharge port as long as there is some degree of vacuum of the port.

When the throttle valve is opened, vacuum at the discharge port decreases. It continues to decrease as the valve opens further until there is no flow of fuel from that port. An adjustable needle valve is provided, so that the amount of fuel discharged from the idle port can be governed.

Immediately above the venturi is another port, Fig. 21-7, which is designed to permit air to bleed into the idle circuit as long as the idle circuit is operating. The air mixes with fuel to help atomize it before the fuel leaves the idle discharge port.

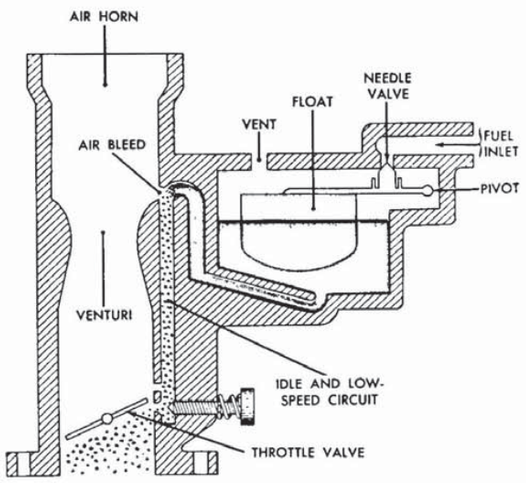


Fig. 21-7. Details of carburetor idle system.

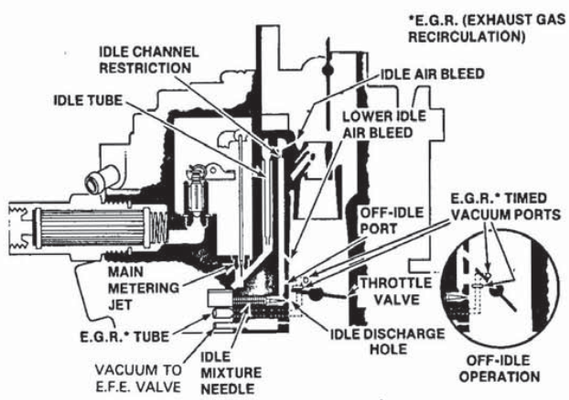


Fig. 21-8. Note location of idle discharge ports on this Rochester M2ME carburetor.

OFF IDLE OPERATION

In addition to the basic idle system, some carburetors (Rochester 2GC and M2ME) are provided with an off idle system. As the throttle valves are opened during acceleration, more fuel is supplied by the off idle discharge port, Fig. 21-8.

The off idle port gradually is exposed to manifold vacuum and supplies the additional fuel needed for the increase in engine speed. Improved fuel control is achieved by an adjustable off idle air bleed screw. The adjustment screw, which regulates air passing from a separate channel into the idle channel, is factory adjusted.

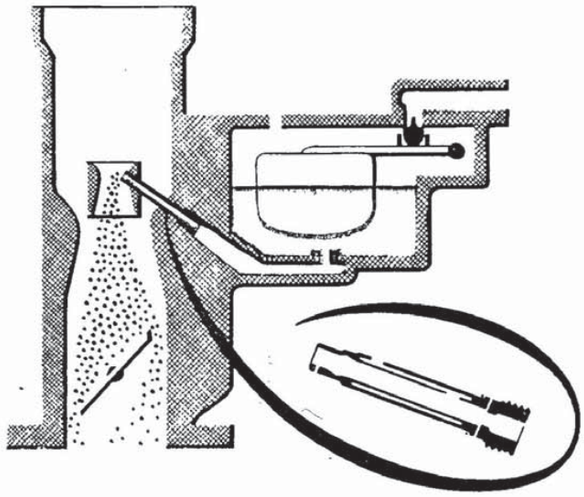


Fig. 21-9. Main or high-speed system.

AIR FLOW IS RESTRICTED

When the throttle is opened a little, the flow of air is still too restricted for the venturi to discharge fuel from the main jet or nozzle, Fig. 21-5. However, with the increased movement of air through the carburetor, more fuel must be supplied in order to maintain the correct proportions of air and fuel.

To supply additional fuel during this stage of low-speed operation, another port is included in the idle circuit. This hole is positioned slightly above the closed position of the throttle valve, Fig. 21-7. As soon as the valve is opened a small amount, the port will be uncovered, intake manifold vacuum will act on it and the additional fuel needed will be obtained.

Another type of idling system is used on Zenith carburetors on many industrial engines. In this system, air mixes with the fuel in proportions determined by the position of an idle-adjusting needle valve. The tube of the idling jet projects down into a well filled with fuel when the engine is at rest. As more air is admitted by means of the needle valve adjustment, less fuel will flow.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

MAIN CIRCUIT

As the throttle is opened, the flow of fuel from the idle ports gradually decreases in volume. However, vacuum at the venturi gradually increases, so fuel starts to flow from the main or high-speed system. The main system consists essentially of the main nozzle or jet, which is centered in the venturi, Fig. 21-9, and supplies fuel from partly open to fully open throttle positions.

Remember, as the rate of flow of the air through the carburetor increases, the flow of the fuel also increases at a much faster rate. This results from the fact that the density of the fuel does not change, while that of the air does. So the mixture in a simple carburetor will be much too rich under wide-open throttle valve conditions. In fact, with a simple carburetor, the correct mixture of air and fuel would be provided at only one position of the throttle valve. So provision must be made to supply the correct ratio of air to fuel for all positions of the throttle valve.

POWER ENRICHMENT SYSTEM

To supplement the main metering system, some carburetors are provided with a power enrichment system, Fig. 21-10. Power enrichment is designed to provide proper mixtures

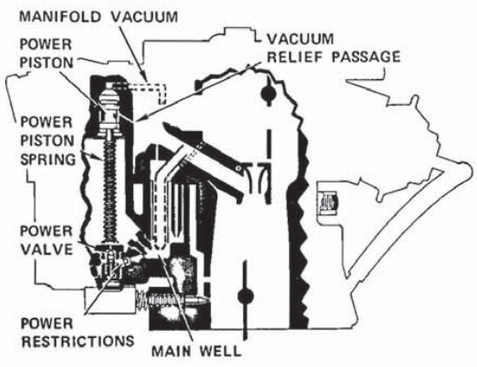


Fig. 21-10. Details of a Rochester power enrichment system.

when more power is desired, or for extreme high-speed driving. The system consists of a vacuum-operated power piston in the air horn and a power valve located in the bottom of the float bowl. The power piston cylinder is exposed to engine manifold vacuum at all times through a connecting vacuum passage from the base of the carburetor.

During idle and part throttle operation, the relatively high vacuum holds the power piston against spring pressure, and the power valve remains closed. The increase in engine load lowers the manifold vacuum. When it has dropped sufficiently, the power piston spring overcomes the upward pull of vacuum. Under spring pressure, the power piston moves downward. This opens the power valve to allow additional fuel to flow through calibrated restrictions into the main well.

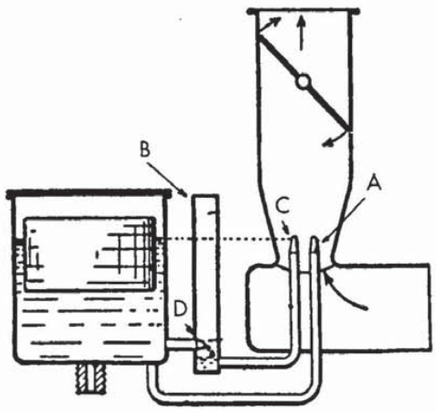


Fig. 21-11. Main nozzle A secures fuel directly from float chamber. Compensating nozzle C receives fuel from standpipe B. Fuel supplied by nozzle C depends on size of metering orifice D which delivers fuel to standpipe B.

COMPENSATION OR DOUBLE NOZZLE PRINCIPLE

One method of controlling the mixture of fuel and air is to provide, in addition to the main nozzle, another nozzle with a constant rate of discharge. In combination, the two nozzles give a substantially constant mixture.

In Fig. 21-11, the main nozzle is supplied with fuel directly from the float chamber. The compensating nozzle, which has a constant rate of discharge, is supplied from a standpipe that receives its fuel from the float chamber. The upper end of the standpipe is open to the atmosphere.

Fuel enters the standpipe through a metered opening. Since the fuel in the float chamber is at a constant level, the flow to the standpipe will be constant. In addition, the rate at which fuel can be drawn from the compensating nozzle also will be constant. At high engine speed, the compensating nozzle delivers less fuel than at low engine speed. In this way, it compensates for the natural tendency of the main nozzle to deliver a mixture that is too rich at high speed.

Also at high engine speed, and when the compensating nozzle is delivering smaller amounts of fuel (due to reduced vacuum), the level of the fuel in the standpipe will rise until its level is equal to that in the float chamber. Then, as suction on the compensating nozzle draws fuel from it, the fuel level in the standpipe will be lowered. If the throttle valve is maintained at the same opening for a sufficient length of time, all the fuel will be drawn from the standpipe. Then the compensating nozzle will be supplied directly from the compensating jet or submerged metering orifice.

AIR BLEED PRINCIPLE

The use of air bleeds is another method of compensating for the increased richness of the mixture caused by increased air velocity through the carburetor throat. Fig. 21-12 shows

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

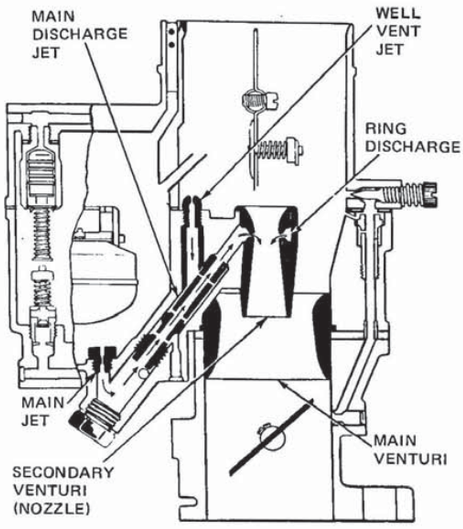


Fig. 21-12. Illustrating air bleed principle used on Model 228 Zenith carburetor.

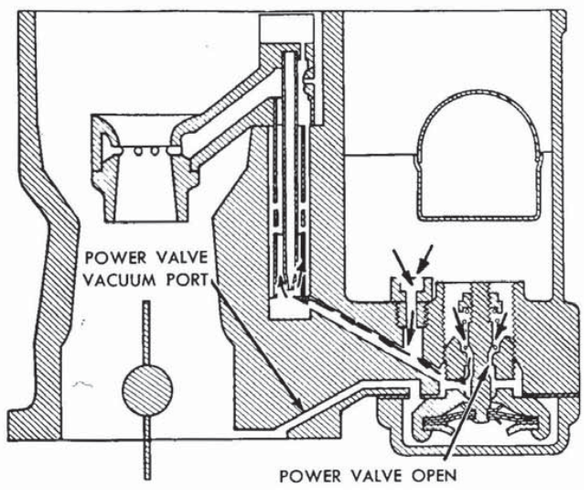


Fig. 21-13. Motorcraft 2150 carburetor power valve, or economizer valve, which supplies additional fuel needed for wide open throttle.

the air bleed system used on a Zenith carburetor. In this case, the high-speed system of the carburetor consists of a primary venturi, a secondary venturi, a main jet, a well jet and a discharge jet.

The main jet controls the fuel mixture from about one-fourth to about three-fourths throttle valve opening. The mixture is controlled by a small amount of air admitted through the well vent or high speed bleeder. The air bleed holes are located in the upper section of the discharge jet at a point below the level of the fuel in the jet.

Introduction of air at that point reduces the surface tension of the fuel and helps fuel flow at low pressures. This bleed also restricts fuel flow through the main jets under high vacuum conditions. In combination, these two factors control the air-fuel ratio and offset the tendency toward increased richness of mixture that occurs when a plain nozzle is subjected to increased air velocity.

FULL POWER CIRCUIT

With its air bleed maintaining the air-fuel ratio at a constant rate, the main circuit provides economical operation for all speeds, from low speed up to but not including wide-open throttle. However, for maximum speed and power, additional fuel must be supplied. There are several ways that this additional fuel is provided for maximum power. These methods include the economizer valve or power jet, and the metering rod.

POWER VALVE

The power valve, or economizer valve, depends upon manifold vacuum for its operation. It is connected to a vacuum port on the engine side of the throttle valve, Fig. 21-13. By design, when full throttle operation is approached, engine vacuum acting on the diaphragm or plunger of the power valve will permit the required amount of fuel to pass through the main nozzle.

Another type of power valve is shown in Fig. 21-14. In this design, the power jet valve is controlled by a vacuum-actuated piston assembly, operating in accordance with throttle valve opening. With the throttle closed (high manifold vacuum), atmospheric pressure in the float chamber moves the vacuum-controlled piston assembly to the top of its cylinder against the tension of a spring. This closes the power valve. When the throttle valve is opened to a point where additional fuel is required, manifold vacuum has decreased sufficiently so that

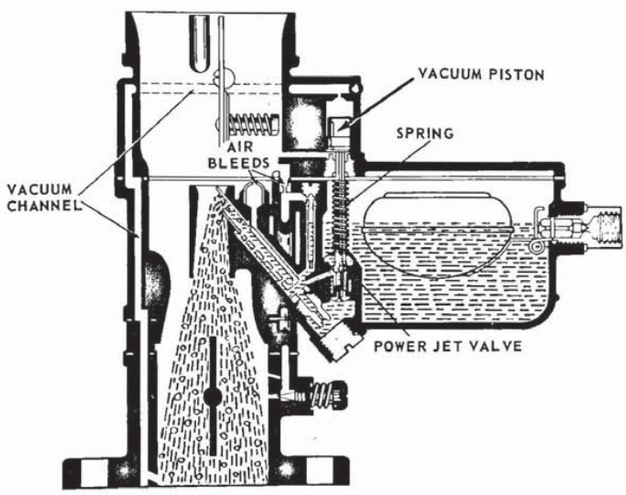


Fig. 21-14. Another type of power jet valve is controlled by vacuum piston.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

the spring moves the piston down, opening the power jet to feed additional fuel into the high-speed circuit.

Mechanical means are also used on some carburetors for supplying the additional fuel needed for high-speed operation. In this design, the power jet is opened by the accelerator pump when the pump is at the bottom, or end, of its stroke.

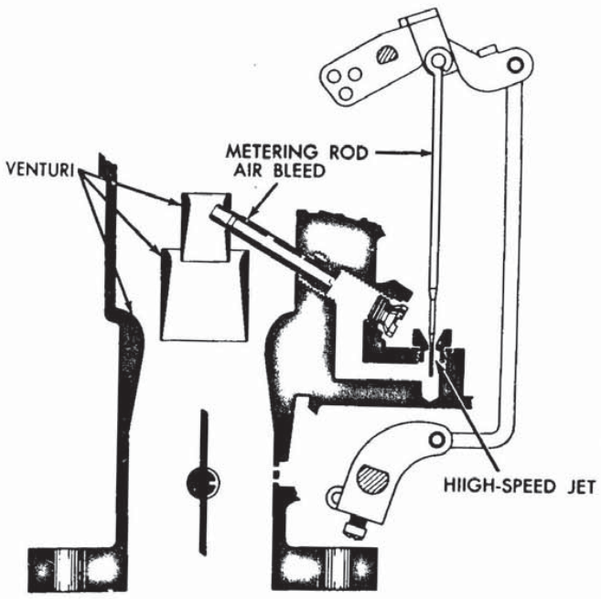


Fig. 21-15. Metering rod varies amount of fuel flowing from a jet.

METERING ROD

Instead of using a power jet, some carburetors accomplish the same results by employing a metering rod that varies the size of the high-speed jet openings. In this design, Fig. 21-15, fuel from the float bowl is metered to the high-speed circuit through the calibrated orifice provided by the high-speed jet and the metering rod within it. From this point, the fuel is conducted to the nozzle extending into the venturi.

As the throttle valve is opened, its linkage raises the metering rod in the jet. The rod has several steps, or tapers, on the lower end. As it is raised in the jet, it makes the effective size of the fuel orifice greater, permitting more fuel to flow through the circuit. Obviously, metering rod position must be carefully synchronized with every throttle position so that the correct air-fuel ratio is maintained throughout all engine speeds.

Metering rods are also operated by means of a vacuum controlled piston as shown in Fig. 21-16.

VACUUM STEP-UP

The vacuum step-up circuit, Fig. 21-17, operates much like the power jet. It consists of a step-up piston fastened to a step-up rod. When high vacuum develops in the intake manifold (part throttle operation), atmospheric pressure holds the step-up piston down against spring pressure. This, in turn, holds the step-up rod down in the step-up jet, closing the jet.

With low vacuum in the intake manifold (wide-open throttle), the difference in pressure above and below the piston is small. Consequently, the piston is moved up by spring pressure and the rod is raised out of its jet. In this way, additional fuel is supplied for maximum power.

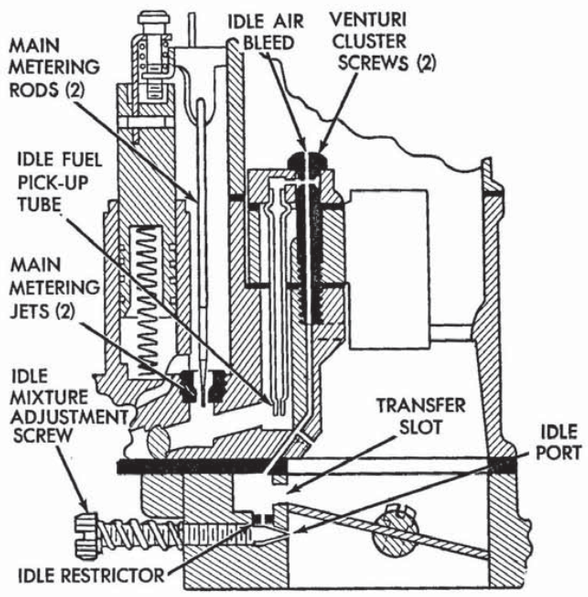


Fig. 21-16. Metering rods (2) are operated by a vacuum piston on a Carter BBD carburetor.

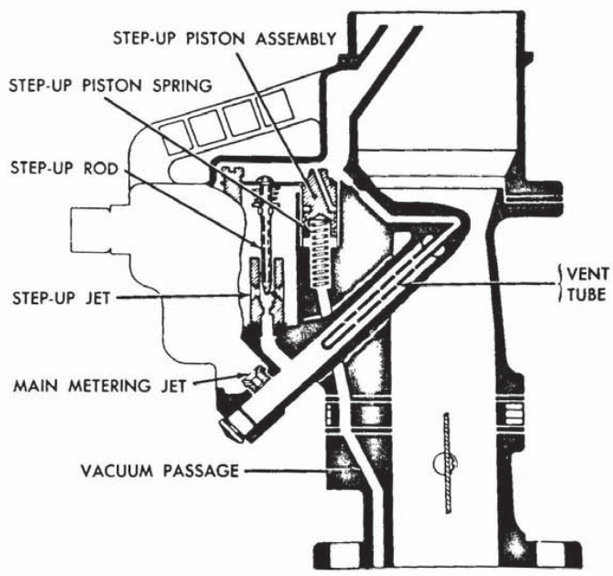


Fig. 21-17. Details of vacuum step-up circuit designed to supply additional fuel needed for full power operation.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

ACCELERATING PUMP

When a throttle valve is opened quickly to produce rapid acceleration of the engine, the carburetor fuel mixture tends to become too lean and a "flat spot" occurs. This results from the fact that the fuel is of greater weight than air. Consequently, when the accelerator is opened suddenly the flow of fuel will lag behind the flow of the air.

To supply the additional fuel needed to overcome this condition, a small accelerating pump is incorporated in the design of the carburetor, Fig. 21-18. This pump is operated by the throttle linkage. In some designs, the strokes of the pump can be adjusted to any one of three positions. The longest stroke provides the maximum amount of fuel, so this is the setting usually used during cold weather.

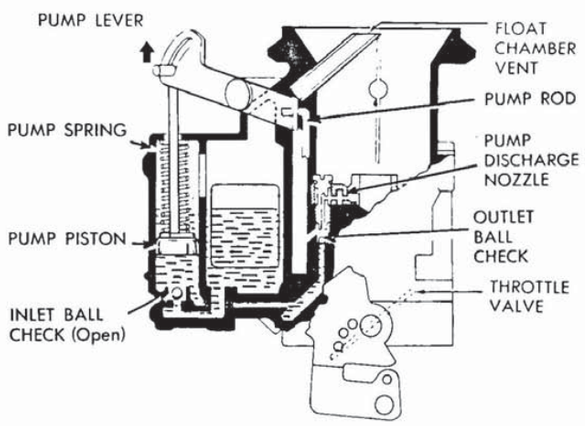


Fig. 21-18. Accelerator pump supplies additional fuel for rapid acceleration.

The accelerating pump circuit generally consists of:

1. A pump cylinder.
2. A plunger, mechanically actuated by a lever mounted on throttle shaft, or vacuum-operated by intake manifold vacuum.
3. An intake check valve located in bottom of pump cylinder to control passage of fuel from bowl to pump cylinder.
4. A discharge or outlet check valve.
5. An accelerating jet to meter fuel used.

When the throttle is opened, the pump plunger moves downward in its cylinder. In the mechanically-operated design, the downward movement is obtained by direct linkage with the throttle. In the vacuum-actuated design, a sudden throttle opening will cause the manifold vacuum to drop, allowing the accelerating pump spring to force the pump plunger down in the cylinder.

In either case, the downward travel of the plunger forces the fuel past the discharge check valve of the acelerating jet.

Fuel is supplied to the pump cylinder through the intake check valve at the bottom. This valve permits a supply of fuel to reach the cylinder, but closes on the down stroke of the plunger to prevent fuel in the cylinder from being pushed back into the float bowl.

ANTI-PERCOLATOR

During extremely hot weather, there is a tendency for the fuel to vaporize in the fuel line, the fuel pump or within the carburetor. When this condition occurs in the carburetor, it is known as "percolation."

To overcome percolation when it occurs, special provisions

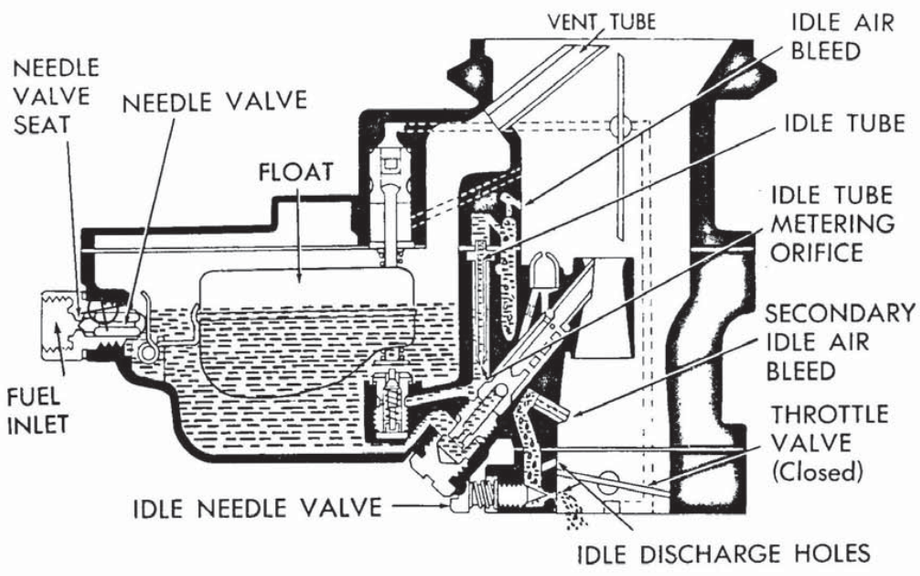


Fig. 21-19. Vent tube from float bowl to air horn prevents vapor lock and equalizes effect of a clogged air filter. This illustration also shows a typical idling system.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

are made. One method is to provide a passageway or vent tube between the top of the float bowl chamber and the upper part of the air horn, Fig. 21-19. By this means, any vapor developing in the float bowl chamber will be drawn into the air stream in the air horn. From there, it will pass through the carburetor and into the intake manifold.

Venting the float bowl in this manner has the added advantage that it will equalize the effect of a clogged air filter. A clogged filter will cause a somewhat greater vacuum at the venturi and consequent increased flow of fuel. Venting the float bowl into the carburetor air horn relieves this condition.

Another method vents the float bowl chamber directly into the atmosphere, Fig. 21-16. In this carburetor design, the vent is provided with a cap to prevent dust and dirt from entering the float bowl chamber.

Still another design incorporates a special valve that vents the main discharge nozzle to the atmosphere. Linkage is arranged so that closing of the throttle valve will open an anti-percolator valve. Another method designed to accomplish the same thing provides a vent for the passages to the discharge nozzle without the use of a valve.

With the coming of evaporative emission controls, venting of fuel vapors to the atmosphere was discontinued. See Chapter 29.

FAST IDLE

To prevent an engine from stalling before it reaches operating temperature, it must be operated at a faster-than-normal speed. This is done by preventing engine speed from dropping below a predetermined rpm. To accomplish this, the choke shaft is linked to a cam on the outside of the carburetor, Fig. 21-20. The linkage is arranged so that as long as the choke is in a partially closed position, the high spot on the cam comes under the fast idle speed adjusting screw. In this way, the throttle valve will be held open a sufficient amount to prevent stalling.

After the engine reaches operating temperature, opening of the choke valve will move the cam from under the fast idle speed adjusting screw, and the engine will idle at normal speed.

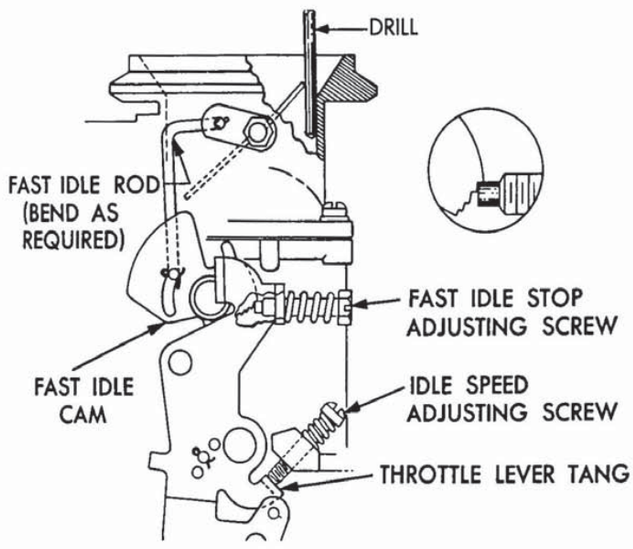


Fig. 21-20. Showing fast idle and choke linkage, together with fast idle adjustment and idle speed adjustment.

CARBURETOR UNLOADER

When an engine does not start immediately, prolonged cranking will result in a flooded condition. The air-fuel mixture in the manifold and engine is so rich that it is no longer a vapor. Consequently, the spark plugs cannot fire it. To overcome this condition, linkage is provided on the carburetor which will hold the choke valve open when the accelerator is pushed to the floor, Fig. 21-21. Then, as the engine is cranked again, air will enter the manifold and cylinders to clear excessive gasoline from the system. This is accomplished by special linkage between the throttle and choke levers, Fig. 21-21.

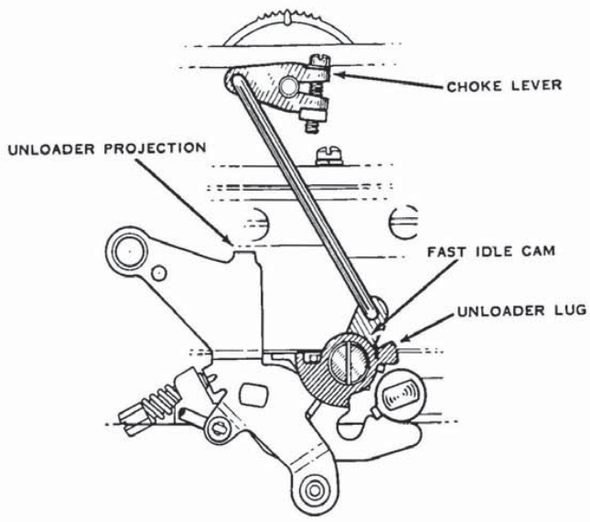


Fig. 21-21. Showing relationship of unloader lug or cam, unloader projection, choke lever and fast idle cam.

ANTI-ICING

When fuel is evaporated, it absorbs heat from the surrounding air and metal parts of the carburetor. When the humidity of the air is high and temperatures are at approximately the freezing point, the evaporation of fuel in the carburetor often causes "icing." The ice forms around the closed position of the throttle plate, and the idle port becomes closed with ice. This, in turn, will cause the engine to stall at low speeds.

To overcome this icing condition, some carburetors are provided with special passages that carry hot exhaust gases around the carburetor, heating the area surrounding the

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

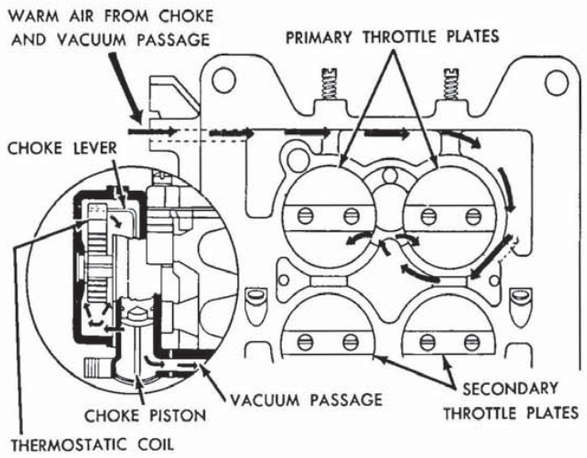


Fig. 21-22. Showing path of warm air from choke passing around throttle valves to prevent formation of ice.

throttle plate, Fig. 21-22.

Another method of overcoming this difficulty is to provide a water jacket for the carburetor. This water jacket, of course, is connected to the cooling system of the vehicle.

HOT IDLE COMPENSATOR

During long periods of idling with an extremely hot engine, the fuel in the carburetor bowl becomes hot enough to form vapors. These vapors enter the carburetor bores by way of the inside bowl vents, mixing with the idle air and causing an extremely rich mixture. This will result in loss of engine rpm and, eventually, in stalling. To overcome this condition (on Carter AFB carburetors, for example), a hot idle compensator valve is placed in the secondary side of the carburetor. This is calibrated to permit additional air to enter the manifold below the secondary throttle valve, where it mixes with the fuel vapors to provide a more combustible mixture.

On Rochester 4GC carburetors, the hot idle compensator is placed on the secondary side of the float bowl and permits additional air to enter the primary bores under extreme hot idle conditions, Fig. 21-23.

ANTI-STALL DASHPOT

Most older cars with automatic transmissions have an anti-stall dashpot connected to the carburetor linkage, Fig. 21-24. The purpose of this dashpot is to prevent the throttle valve from closing too fast. Too rapid closing often causes the engine to stall. Installation of the dashpot prevents the throttle from being closed too quickly, thereby avoiding stalls.

This condition would not occur with a manual transmission since the momentum of the vehicle would continue to drive the engine through the stall period.

Also, to insure easy starting, some engines have special carburetor linkage designed to automatically hold the throttle valve slightly open during cranking.

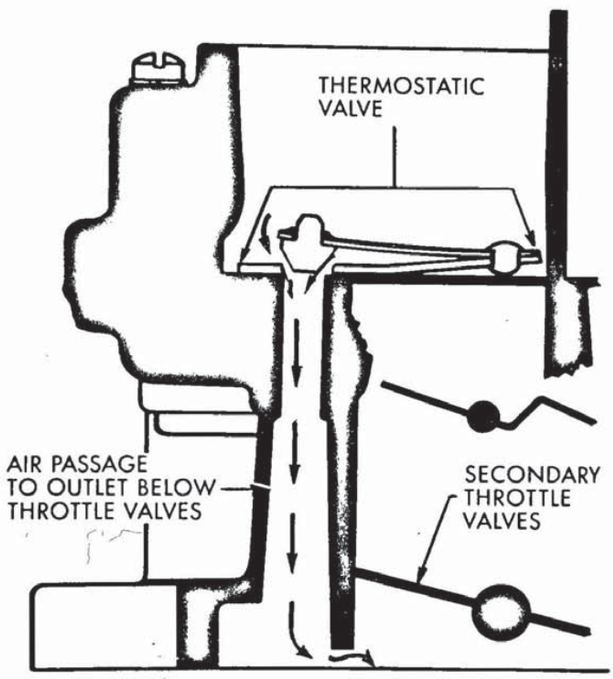


Fig. 21-23. Hot idle compensator permits additional air to enter primary bores of carburetor under extreme hot idle conditions.

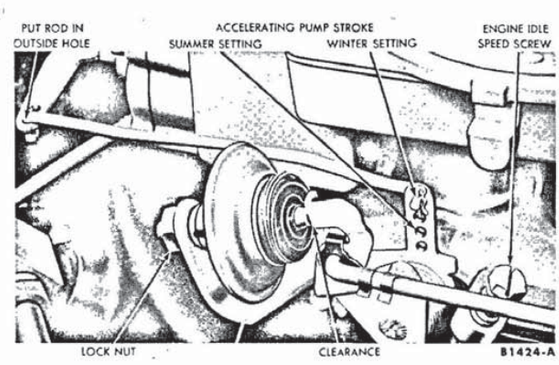


Fig. 21-24. Showing anti-stall dashpot mounted on side of Ford carburetor. Some carburetors have anti-stall dashpot built into carburetor. Note provision for adjustment of accelerator pump.

VACUUM ADVANCE

Vacuum from the carburetor is used to control the spark advance on the Ford Loadomatic distributor. By design, vacuum is transmitted to the distributor diaphragm from three interconnected passages in the carburetor, Fig. 21-25. All manifold vacuum to the distributor passes through the spark control valve.

Under normal load conditions, the spark valve is held open against spring pressure by a combination of atmospheric

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

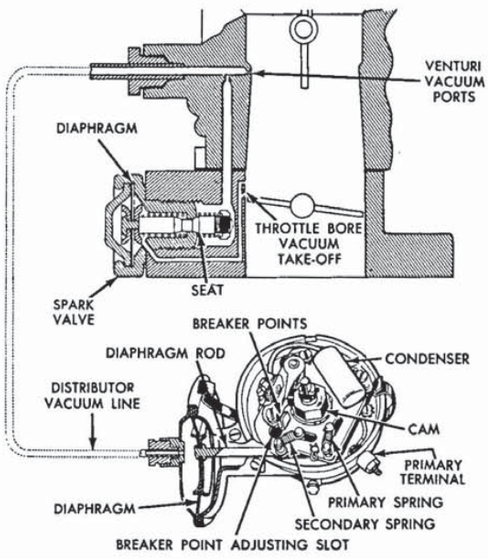


Fig. 21-25. Method of using vacuum at venturi and at throttle valve to control spark advance.

pressure and manifold vacuum. When accelerating, manifold vacuum drops and spring pressure closes the spark valve which shuts off the vacuum and prevents excessive spark advance. Venturi vacuum prevents full retard. When manifold vacuum increases, the spark valve will again allow a higher vacuum to advance the distributor.

GOVERNORS

Governors are used principally on industrial engines and commercial vehicles so that economical and safe speeds are not exceeded. One type of Holley unit, Fig. 21-26, is inserted between the carburetor and the intake manifold, where it is actuated by the pressure differential acting against the governor diaphragm. The differential is provided by vacuum below the governor throttle plates and atmospheric pressure above the plates.

At low engine rpm, the governor control valve weight is held away from its seat by the tension of the valve weight spring. During this period, the valve is wide open to allow outside air to flow to the governor so that no governing action occurs. As engine speed increases, the differential between atmospheric pressure and engine vacuum decreases, causing the governor diaphragm to exert a pull on the governor lever. This turns the throttle shaft and partly closes the throttle.

Another method of limiting the speed of an engine is by means of a velocity type governor. In this design; the unit is inserted adjacent to the throttle. As the gas goes through the manifold, its velocity acts on a spring-loaded floating obstruction in the form of a ball or disk attached to the throttle As engine speed increases, the gas flowing through the manifold tends to carry the obstruction along with it. Since this disk or ball is attached to the throttle plate of the carburetor, its movement closes the throttle against the tension of a spring. In this way, the speed of the engine is controlled.

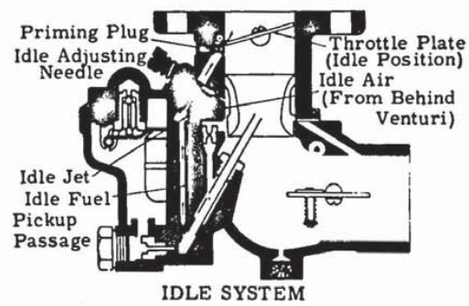


Fig. 21-27. Sectional view of updraft carburetor. Air enters at right and passes upward through venturi and past throttle plate.

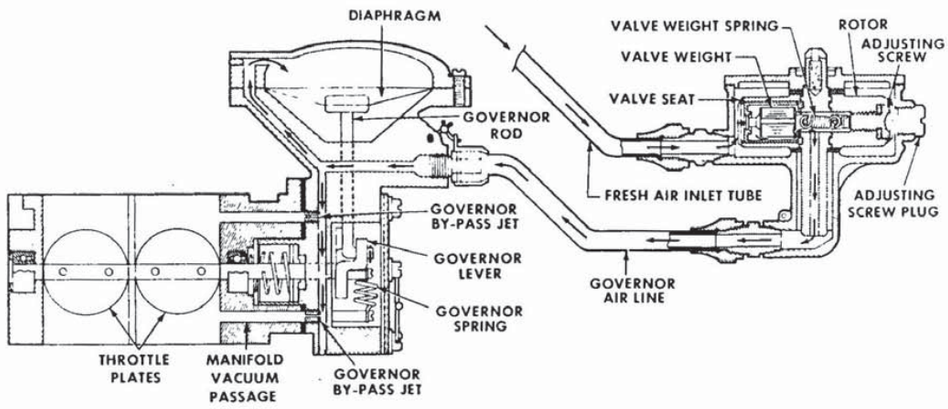


Fig. 21-26. This Holley governor uses vacuum below governor throttle plates and atmosphere above to control speed of vehicle.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

TYPES OF CARBURETORS

While there are many variations in the design and construction of carburetors, there are three basic types:

1. Updraft.
2. Downdraft.
3. Sidedraft.

The direction of the air flow at the carburetor outlet to the manifold determines the classification.

The updraft carburetor, Fig. 21-27, is placed low on the side of the engine. It is supplied with fuel by gravity feed. However, the fuel mixture must be lifted from the carburetor, through the manifold and into the engine. Air velocities must be high; a requirement that can be attained only by using carburetors and manifold passages of small diameter. As a result, power output is limited.

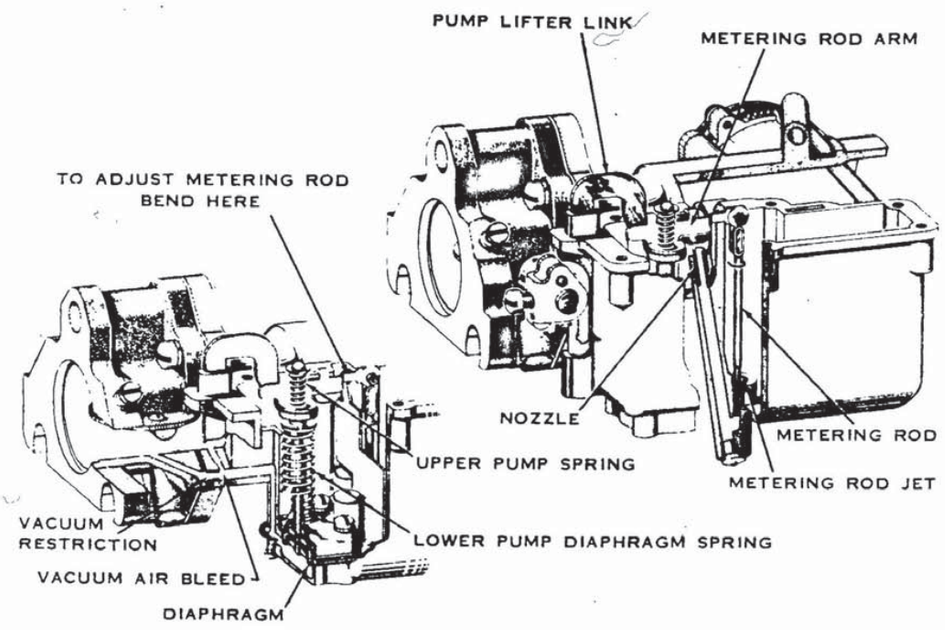


Fig. 21-28. Typical sidedraft, or crossdraft, carburetor.

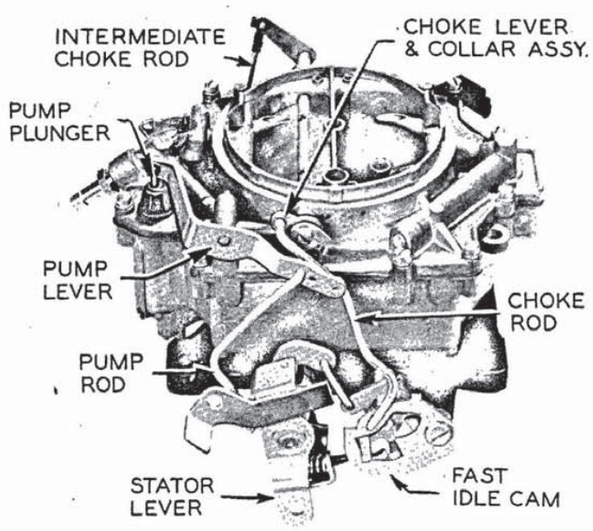


Fig. 21-29. Typical single-barrel, downdraft carburetor.

The sidedraft, or crossdraft, carburetor shown in Fig. 21-28 is used where there is little space over the engine. The air cleaner naturally is positioned lower in a sidedraft carburetor installation. Another application of this carburetor is where the vaporized mixture is heated by water in the engine water jacket.

U.S. passenger car engines are equipped almost exclusively with the downdraft carburetor, Figs. 21-14 and 21-29. In this design, the air-fuel mixture will reach the engine even though the air velocity is low. The carburetor throat and manifold can be made larger, by design. This, in turn, increases the size of the air-fuel intake system, making high speeds and high specific output possible.

SINGLE-BARREL CARBURETOR

While there are three basic types of carburetors, they also may be classed by number of throats, or barrels. A single-barrel carburetor, Fig. 21-29, has one outlet to the intake manifold. It is designed to take care of all the requirements of the engine for all operating conditions. Such carburetors are used extensively on engines having six cylinders or less.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

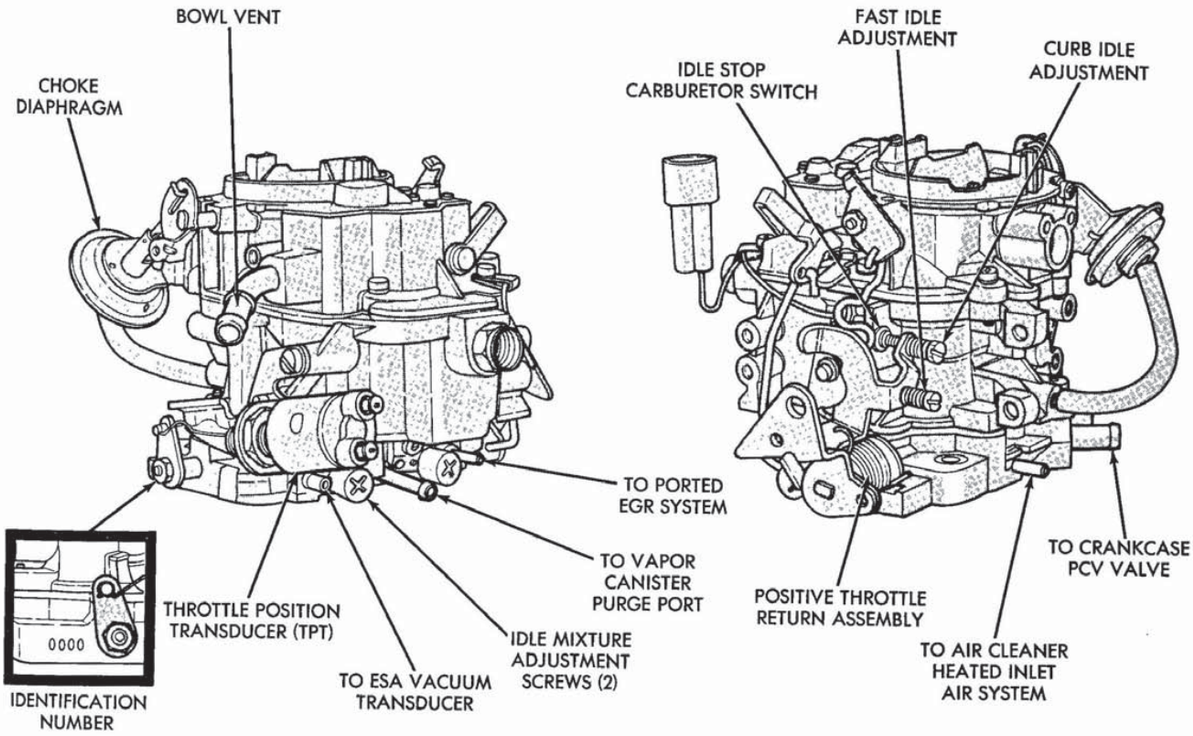


Fig. 21-30. Two views of Holley 2280 dual venturi carburetor as installed on Chrysler 318 cu. in. (5.2 litre) V-8 engine. This carburetor has four basic metering systems: idle system provides mixture for idle and low speed; accelerator pump system pumps additional fuel for acceleration; main metering system meters an economical mixture for normal cruising conditions; power enrichment system which combines a mechanical and vacuum operated power valve to provide additional fuel for maximum power.

TWO-BARREL CARBURETOR

Carburetors with two outlets to the intake manifold are known as two-barrel or two-throat carburetors, Fig. 21-30. Basically, these units are two carburetors in one, with two complete idling systems, two high-speed systems, two power systems, two accelerating systems, two throttle valves, two choke valves, but only one float system.

With a two-barrel carburetor, each barrel or mixing tube supplies alternate cylinders in the firing order. In a conventional six cylinder engine, one barrel supplies cylinders 1, 3 and 2, while the other barrel supplies cylinders 5, 6 and 4.

FOUR-BARREL CARBURETOR

In the four-barrel carburetor, Fig. 21-31, generally used on V-8 engines, there are four openings to the intake manifold within the single unit. Some systems, such as the float system, may be common to all four barrels. In some four-barrel carburetor designs, half of the carburetor operates as a two-barrel unit during light load and cruising speeds, while the other half of the carburetor is supplemental for top speed and full-throttle operation. The two barrels supplying fuel for light load operation are known as the primary side, while the supplementary two barrels are known as the secondary side.

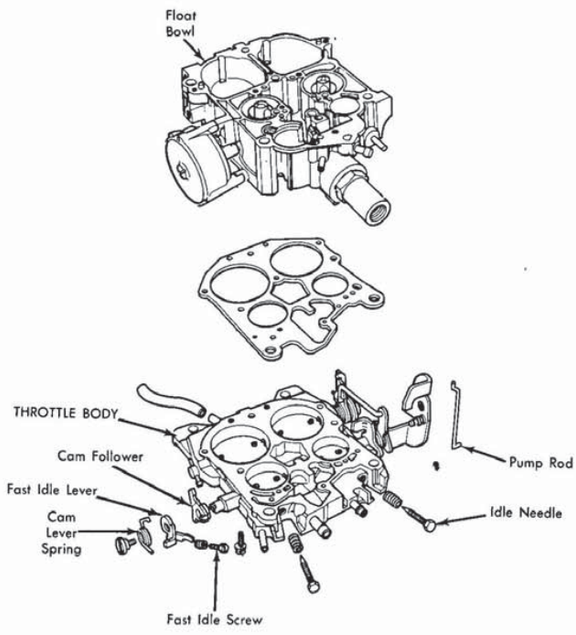


Fig. 21-31. Four-barrel carburetor. Note four openings to manifold.

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US PATENT NO. 6,557,540

When two barrels of a four-barrel carburetor supply fuel to the engine throughout the entire speed range, a portion of the idle system fuel is routed to the secondary barrels for satisfactory fuel distribution. Also in this design, the secondary throttle plates remain closed at lower engine speeds. As engine speed increases, the throttle plates of the secondary barrels are opened.

In some designs, the secondary throttle plates are operated mechanically through linkage. On other models, the secondary throttle plates are controlled automatically by a vacuum-operated diaphragm. In general, the secondary throttle plates will start to open when the primary plates are open 50 deg.

In a four-barrel carburetor on a V-8 engine, primary and secondary barrels form a pair to supply cylinders 1-7-4-6, while the other primary and secondary barrels will supply fuel to cylinders 3-5-2-8. However, this applies only to an engine having a firing order of 1-8-4-3-6-5-7-2.

In general, manifolding for both two-barrel and four-barrel carburetors is designed as follows: One half of the carburetor supplies fuel to the end cylinders on one side of the engine and two center cylinders on the other side. The other half of the carburetor supplies fuel to the remaining cylinders.

MULTIPLE CARBURETORS

Maximum engine performance requires perfect distribution of large quantities of the air-fuel mixture. One way to attain this is by using several carburetors. One installation on a V-8 engine uses three two-barrel carburetors.

In this installation (Chevrolet), the center carburetor is known as the primary, Fig. 21-32. It takes care of all engine requirements up to 60 deg. opening of the throttle. Above that, the secondary carburetors come into operation to supply the additional fuel required for maximum performance.

The primary carburetor is a complete unit, containing all the usual carburetor systems (float, idle, choke, port throttle, power and accelerator pump). The front and rear carburetors do not include idle, part throttle or choke systems.

A combined mechanical and vacuum linkage is used to operate the throttle valves. The primary carburetor throttle valves are operated mechanically. When they are opened 60 deg., a vacuum slider valve causes vacuum to act on a diaphragm which, in turn, operates the throttle valves on the secondary carburetors.

AUTOLITE 4300 CARBURETOR

The Autolite model 4300 4-V carburetor, Fig. 21-33, is a three-piece, separately cast design consisting of the air horn, main body and throttle body.

A cast-in center fuel inlet has provision for a supplementary fuel inlet system. The fuel bowl is vented by an internal balance vent; and a mechanical atmospheric vent operates during idle.

The idle bypass system is designed to provide a more consistent idle, and a hot idle compensator, Fig. 21-33, is used to help idle stability.

These adjustments for idle air and idle fuel must be made at the same time. Opening the idle air screw to increase engine rpm leans the air-fuel mixture. Consequently, the idle fuel mixture must also be adjusted to provide the correct air-fuel mixture for smooth engine idle.

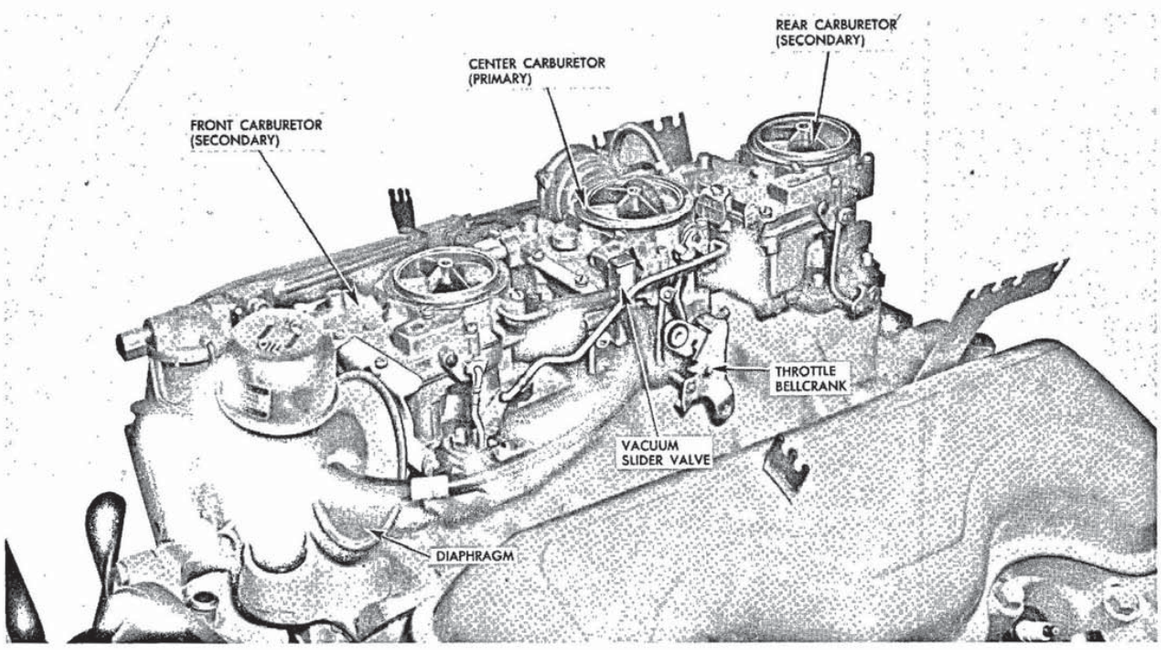


Fig. 21-32. Showing installation of three two-barrel carburetors on a Chevrolet V-8 engine.

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US PATENT NO. 6,557,540

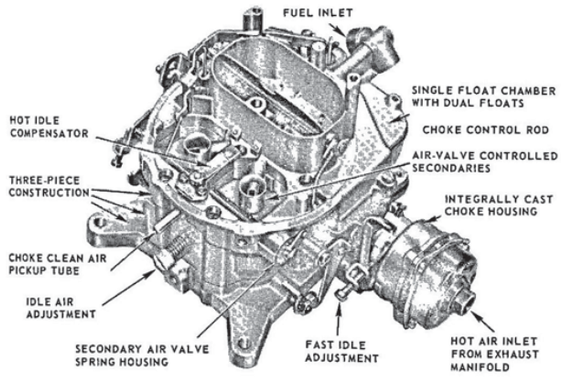


Fig. 21-33. Details of Autolite 4300 4-V carburetor. Note idle air adjustment.

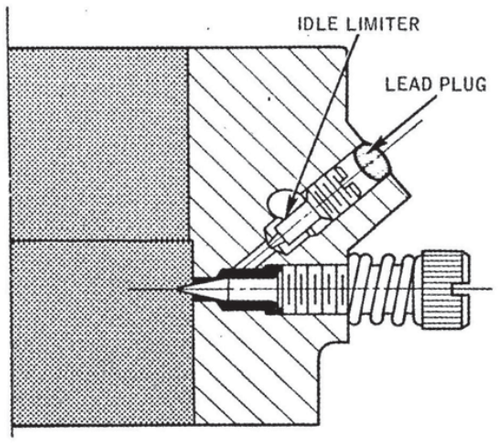


Fig. 21-35. Details of idle fuel limiter on Carter model YF carburetor.

Starting with 1968 models, most carburetors have been modified or recalibrated to provide leaner air-fuel mixtures to conform to the Federal regulations governing exhaust emissions.

These leaner mixtures result primarily from better control of the idle mixture, and from better combustion during periods of deceleration. In some cases the idle mixture screws have a finer pitch, making for more accurate control of the air-fuel ratio.

On Autolite carburetors, idle mixture adjustments are provided with an idler limiter device, Fig. 21-34, which sets a limit on enrichment of the idle mixture. Holley and single-venturi Carter carburetors contain a preset fixed mixture restriction in idle fuel passages that accomplishes the same thing, Fig. 21-35.

In the case of the Monojet carburetor used on six cylinder Chevrolet, Buick, Pontiac and Oldsmobile engines with automatic transmissions, an idle stop solenoid is used to stop engine "dieseling" after the ignition is turned off.

Idle rpm with exhaust emission control carburetors is slightly higher than normal and, in every case, must be accurately set to specified value. On the Monojet, Fig. 21-36, the idle speed is adjusted with the transmission in "drive"

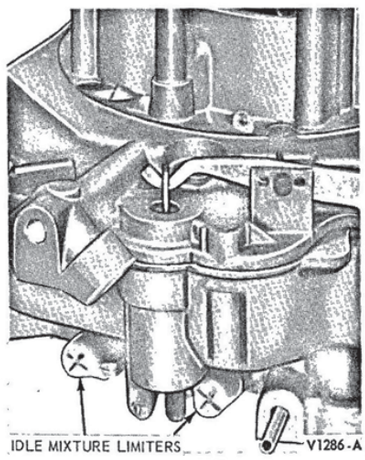


Fig. 21-34. Note idle mixture limiters on Autolite carburetor.

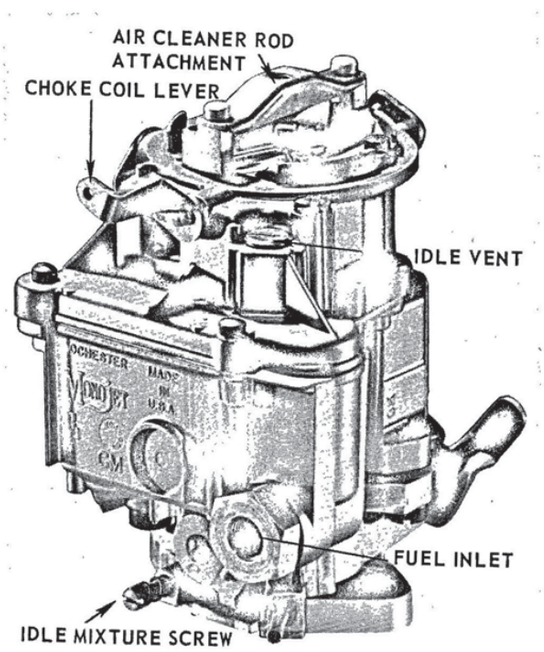


Fig. 21-36. Rochester Monojet carburetor is used on six cylinder Buick, Chevrolet, Oldsmobile and Pontiac engines.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

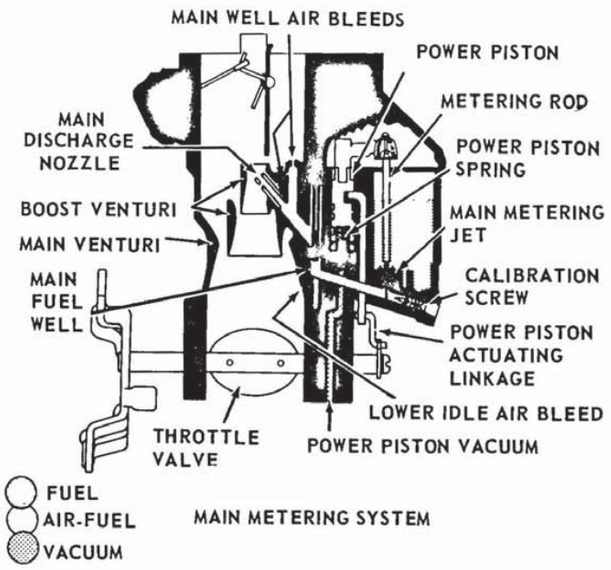


Fig. 21-37. Details of main metering system on Monojet carburetor.

position. When the owner is about to turn off the ignition, he places the transmission in "park" or "neutral." With the load off the engine, idle speed will rise to the 700 rpm range. With the engine running at that speed, plus higher operating temperatures and slightly retarded spark, "dieseling" may occur. The idle stop solenoid eliminates the possibility by closing the throttle valve when the ignition key is turned off.

The main metering system of the Monojet carburetor, Fig. 21-37, feeds fuel whenever air flow through the venturi is great enough to maintain fuel flow through the main discharge nozzle. The triple venturi stack-up is particularly sensitive to air flow. This means finer and more stable metering control from light to heavy loads, an important factor in the control of exhaust emissions.

The main metering system consists of the metering jet, a mechanical and vacuum-operated metering rod, main fuel well, main well air bleeds, fuel discharge nozzle and the triple venturi.

Power enrichment in the Monojet is obtained by the movement of a spring-loaded vacuum piston that senses changes in manifold vacuum. The amount of enrichment is controlled by the clearance between the groove in the power piston and the diameter of the power piston drive rod.

CARTER THERMO-QUAD CARBURETOR

One method of controlling hydrocarbon end carbon monoxide is to reduce the heat transfer to the fuel. The Carter Thermo-Quad carburetor installed on some Chrysler, Dodge and Plymouth engines has a float bowl made of molded phenolic resin which acts as an effective heat insulator, Fig. 21-38. A reduction of 20 deg. F over all-metal carburetors is claimed. The Thermo-Quad carburetor and others of the

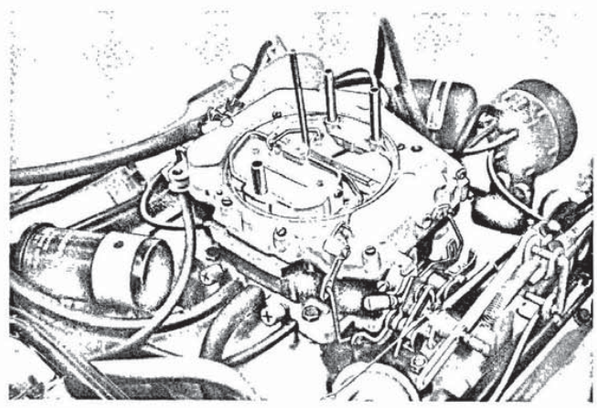


Fig. 21-38. Float bowl of this Carter Thermo-Quad carburetor is made of molded phenolic resin to reduce heat transfer.

Chrysler line form a part of the proportional exhaust gas recirculation (EGR) system, Fig. 21-39. The system includes a recirculation control valve and a vacuum sensor to insure proper flow of exhaust gas is proportional to vacuum sensed in the carburetor.

In this EGR system, a slot type port in the carburetor throttle body is exposed to an increasing percentage of manifold vacuum as the throttle valve opens. This throttle bore port is connected through an external nipple direct to the EGR valve. The flow rate is dependent on the manifold vacuum, throttle position and exhaust back pressure.

Recycling of exhaust gases is eliminated at wide-open throttle. This is done by calibrating the valve opening point above manifold vacuum available when the throttle valves are wide open, since port vacuum cannot exceed manifold vacuum. Elimination of wide-open throttle recycle provides maximum performance.

ROCHESTER 2GV CARBURETOR

The current Rochester 2GV carburetor has many features designed to reduce exhaust gas emissions. This carburetor uses calibrated cluster design that places the main well tubes, idle tubes, mixture passages, air bleeds and pump jets in a compact assembly. The cluster is removable for cleaning and inspection purposes.

The venturi cluster fits on a flat portion of the carburetor bowl in front of the main venturi with a gasket underneath. The idle and main well tubes are permanently installed in the cluster body by means of a precision press fit.

The main nozzles and idle tubes are suspended in the main wells of the float bowl. Removable plastic main well inserts surround the main fuel nozzles to insulate the nozzles and prevent percolation. The plastic inserts also provide smooth fuel flow through the main metering system during hot engine operation.

Rochester 2GC-2GE carburetors have similar construction. A sectional drawing in Fig. 21-40 shows the major parts of these carburetors.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

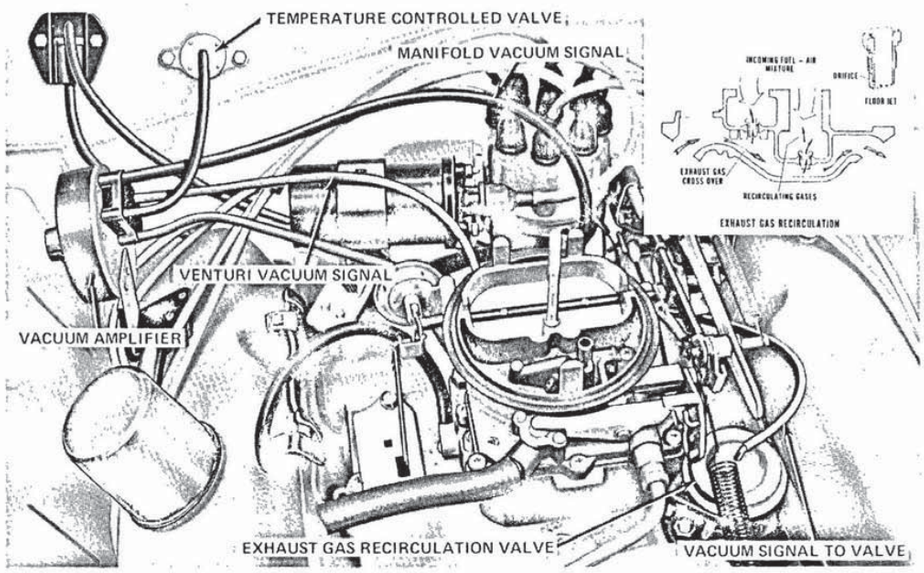


Fig. 21-39. Note details of proportional exhaust gas recirculation system installed on late model Chrysler Corp. engines.

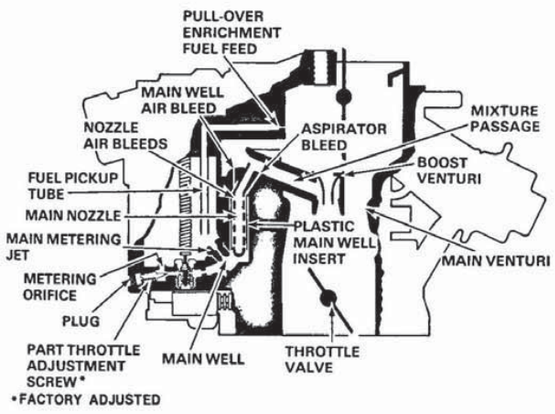


Fig. 21-40. Details of major parts of Rochester 2GC-2GE carburetors.

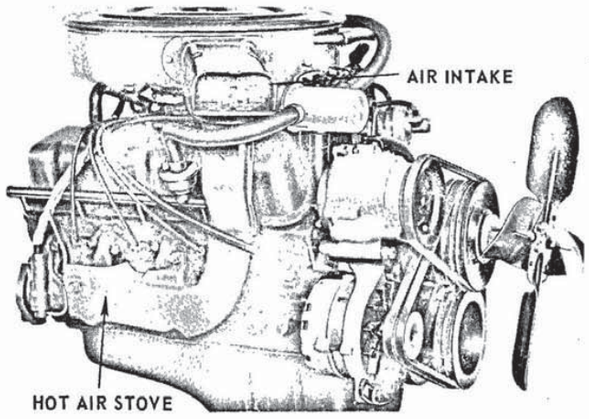


Fig. 21-41. Thermostatically controlled heated air intake is provided on modern carburetors. Ford 302 cu. in. V-8 is shown.

HOT AIR INTAKE – RAM AIR

Many of the carburetors designed for exhaust emission control have thermostatically controlled air intake systems. Hot air intake provides advantages ranging from improved cold start-up through warm-up and, more particularly, in more complete combustion and reduced exhaust by-products. The warm air is obtained from a heat stove on the exhaust manifold. See Ford design in Fig. 21-41. (Also see the chapters on AIR CLEANERS and EMISSION CONTROL.)

The Ford carburetor heated air intake system is equipped with a vacuum override control that opens the upper valve for direct air intake of unheated air for maximum air volume at full throttle opening. The override operates only when maximum air volume is needed for rapid acceleration. When high air volume is no longer needed, the override releases and the selector valve returns to the position indicated by underhood temperatures.

By placing carburetor intake air scoops at the front of the vehicle, full advantage is taken of air motion due to the speed of the car. This provides a ramming effect to the air entering the carburetor, and a degree of supercharging is obtained. Some Oldsmobiles with 400 cu. in. (6.6 litre), 10.5 to 1 compression ratio V-8 engines have scoops with 13 in. x 2 in. openings to feed ram air to the twin snorkels of the air cleaner.

FORD'S VARIABLE VENTURI CARBURETOR

Ford's Motorcraft model 2700 variable venturi carburetor, Figs. 21-42 and 21-43, varies the area of the venturi as a function of speed and load. Most other carburetors have

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

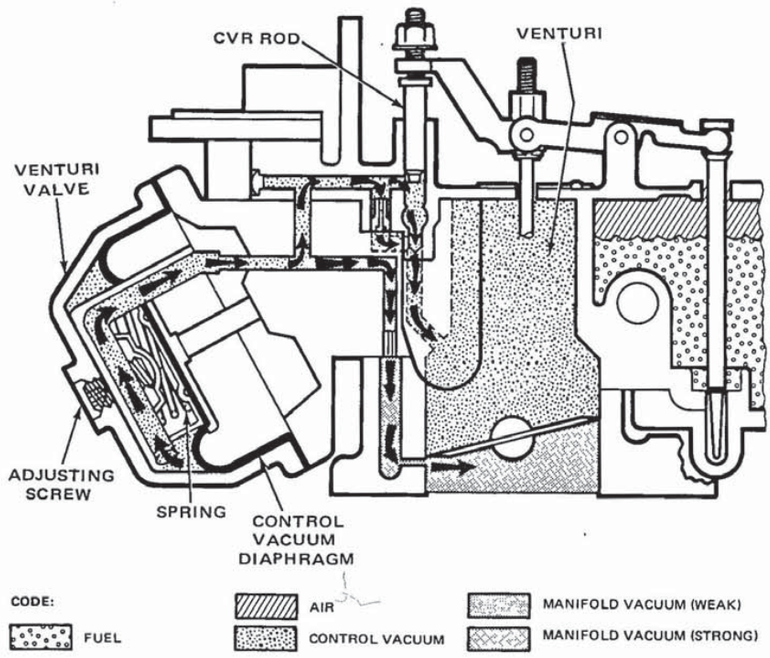


Fig. 21-42. In Ford's variable venturi carburetor, the venturi valve position is controlled by spring pressure and control vacuum. The spring pressure tends to close the valve. Control vacuum acts through a rubber diaphragm to open the valve. Control vacuum is vacuum below the venturi valve and above the throttle valves. See arrows in diagram.

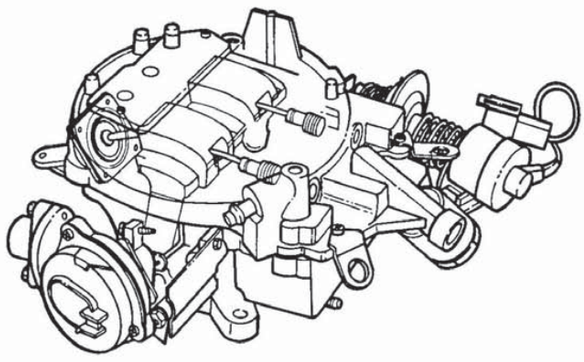


Fig. 21-43. Ford's Motorcraft variable venturi carburetor.

venturis that are fixed. In this design, changing the size of the venturi maintains sufficient air velocity and pressure drop to the main metering system. This is accomplished by means of tapered metering rods attached to the venturi valve, which changes the area of the venturi.

There is one rod and one jet for each bore of the carburetor. The rod moves back and forth in the jet when the air valve moves. When the venturi valve is closed, the largest diameter of the rod is in the jet. When the valve is wide open, the smallest diameter of the rod is in the jet. In that way, effective metering of the fuel is controlled by the position of the rod, Fig. 21-42.

SPECIAL FEATURES

Float spring: A requirement of fuel metering systems is that the fuel level in the float bowl be maintained at as near a constant level as possible. In the Holley 4150C carburetor, a float spring is incorporated under the float to keep the float in a stable position, Fig. 21-44.

Float needle valves: Instead of using steel for float needle valves, most carburetors are now using nylon or a similar material for their construction. A better seal is obtained and, in addition, the material has better wearing qualities. Also it is not readily affected by small foreign particles.

Secondary throttles: Four-barrel carburetors have two primary bores supplying air-fuel mixtures throughout the entire engine operation, while the two secondary bores function only when speed and load require them. At lower speeds, the secondary throttle plates remain closed.

When engine speed increases to a point where additional breathing capacity is required, vacuum is used to open the secondary throttle plates. Vacuum taken from one of the primary barrels, and the secondary barrels, acts on a diaphragm which controls the secondary throttle plates, Fig. 21-45.

CARBURETOR DEGASSER

The degasser, Fig. 21-46, is an auxiliary device built into the carburetor. It is used to correct the over-rich mixture condition that occurs when the throttle is closed suddenly.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

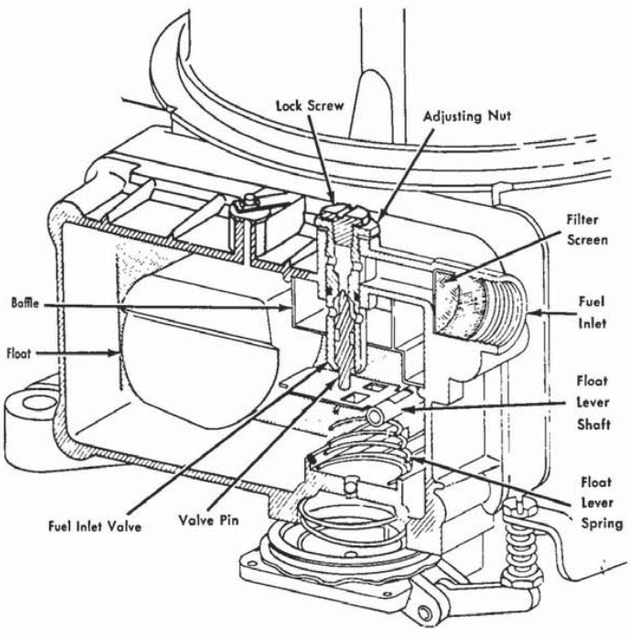


Fig. 21-44. Float lever spring helps steady action of float in maintaining a constant fuel level in float bowl.

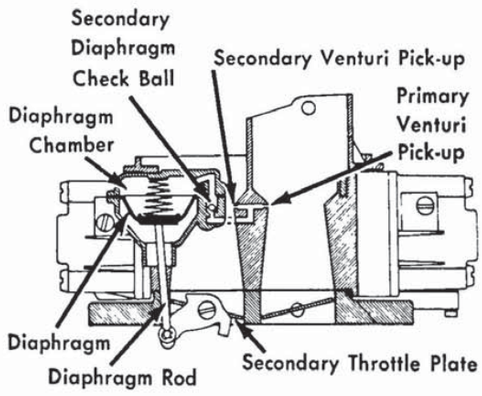


Fig. 21-45. Showing connections for operation of secondary throttle plate in a Holley carburetor.

Under this condition, abnormally high vacuum builds up above the throttle valve, resulting in too much fuel being drawn into the engine through the idle system.

The degasser consists of two die-cast housings clamped together with a diaphragm sandwiched between them. The diaphragm is attached to a plunger which actuates a walking beam, the end of which bears against a needle valve. Normally the valve is held off its seat by the spring. The upper diaphragm chamber is connected, by a bypass line, to an opening into the intake manifold above the throttle.

With the throttle in the idle position and the engine turning

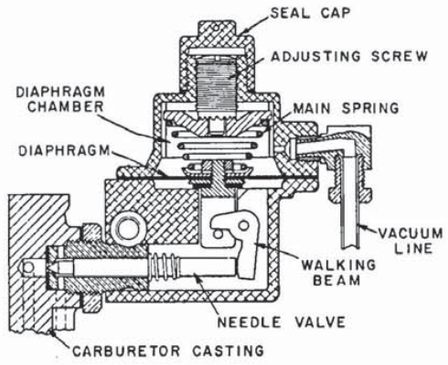


Fig. 21-46. Details of Bendix degasser.

over at idle speed, the proper amount of fuel is drawn through the idle jet. During periods of deceleration, the engine rpm will be much higher than normal idle rpm, causing the vacuum in the passages above the throttle plate to rise much higher than at normal idle speeds.

With the degasser in operation, the abnormally high vacuum during deceleration is transferred to the chamber above the diaphragm, raising the plunger and compressing the diaphragm spring. This movement actuates the walking beam to force the needle valve against its seat to shut off the flow of fuel through the idle hole.

As engine speed approaches idle, and intake manifold vacuum decreases to normal, the diaphragm is forced down by the spring. This backs off the walking beam, which unseats the needle valve and restores the flow of fuel to the idle hole.

DECEL VALVE

Some recent model cars, such as the Ford Pinto, are equipped with a decel valve which is designed to meter to the engine an additional amount of fuel and air during engine deceleration. This additional amount of fuel and air together with engine modification, permits more complete combustion with resultant lower levels of exhaust emissions.

During periods of engine deceleration, manifold vacuum forces the diaphragm assembly against the spring, Fig. 21-47, which, in turn, raises the decel valve. With the valve open, existing manifold vacuum pulls a metered amount of air and fuel from the carburetor through the valve body assembly into the intake manifold. The decel valve remains open and continues to feed additional air and fuel for a specified time.

THROTTLE SOLENOID

The Autolite-Weber model 5200 carburetor installed on the Ford Pinto 2000 cc engine is equipped with a throttle solenoid adjustment designed to control idling speed on automatic transmission-equipped cars. The curb idle is adjusted by turning the throttle solenoid plunger. First disconnect the throttle solenoid wire, then, set the lower curb idle speed screw. Connect the throttle solenoid wire, open the throttle

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

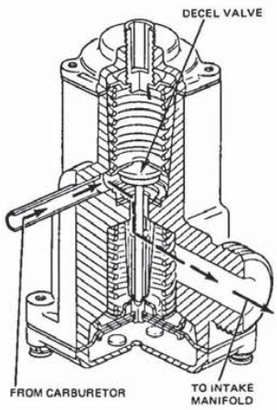


Fig. 21-47. Sectional view of decel valve showing valve in open position.

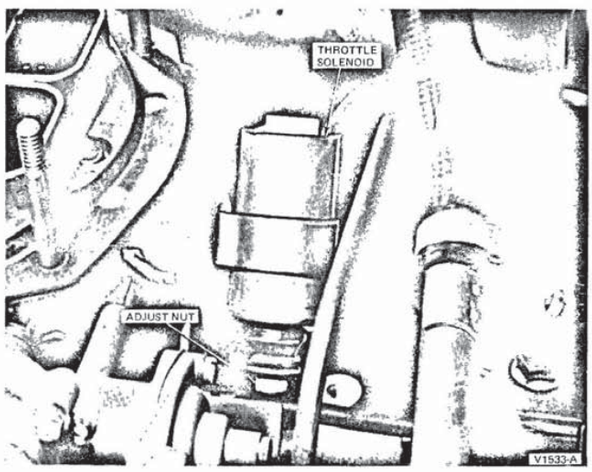


Fig. 21-48. Throttle solenoid adjustment on Autolite-Weber model 5200 carburetor.

slightly by hand to allow the plunger to extend, then, set the higher curb idle speed by turning the solenoid plunger, Fig. 21-48.

SMALL ENGINE CARBURETORS

Many of the basic principles found in large carburetors are also incorporated in carburetors used on small engines. This is particularly true in the case of engines used on many lawn mowers, Fig. 21-49. Carburetors using the float system of controlling fuel flow are good examples of this similarity.

Two cycle engines designed to operate at varying angles (chain saws) are often equipped with a floatless carburetor. On these installations, a diaphragm type carburetor is used

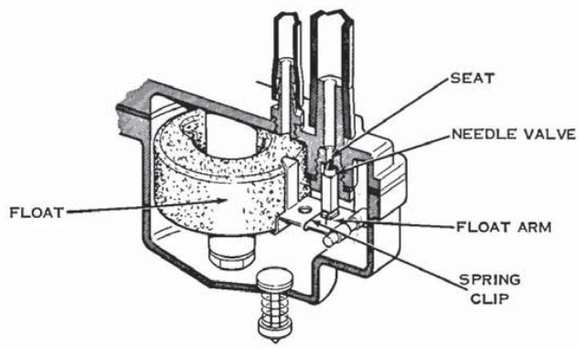


Fig. 21-49. Some small engines use float type carburetors. Note similarity of float bowl parts to large automotive carburetor parts.

because it will function at a steep angle or even in an inverted position for a short time.

Diaphragm type carburetors use the upper part of the unit for carburetion, while the lower part houses a fuel pump. The two parts are bolted together to form a single assembly.

The pump utilizes the positive and negative pressure pulsations in the crankcase for its operation. Fuel is delivered to the inlet supply channel either by the integral fuel tank or by gravity.

When the engine is idling at nearly closed throttle, fuel is drawn through an idle tube or, for inverted operation, past the idle adjusting screw and into the engine via the primary idle discharge port.

As the throttle is opened progressively, the vacuum at idle position is nearly eliminated, but the increase in air velocity through the venturi puts increased vacuum on the nozzle to unseat a nylon ball. The nozzle then delivers the power mixture metered in relation to the demands of the engine.

In the case of the suction feed carburetor fuel system, the fuel tank is mounted below the carburetor, Fig. 21-50.

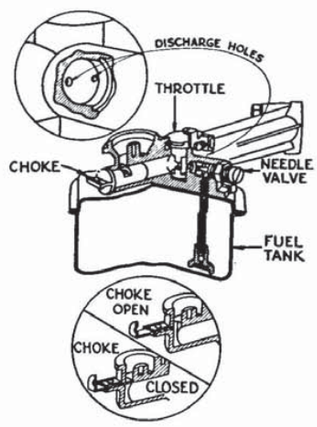


Fig. 21-50. Sectional view of suction feed carburetor used on lawn mowers and similar small engines.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Principles of Carburetion

Atmospheric pressure is utilized as the force to move the fuel. The fuel tank cap is vented to allow pressure in the tank to remain constant. As the piston goes down on the intake stroke with the throttle open, a low pressure is created in the carburetor throat. A slight restriction is placed between the air horn and the carburetor throat and the choke. This helps maintain the low pressure.

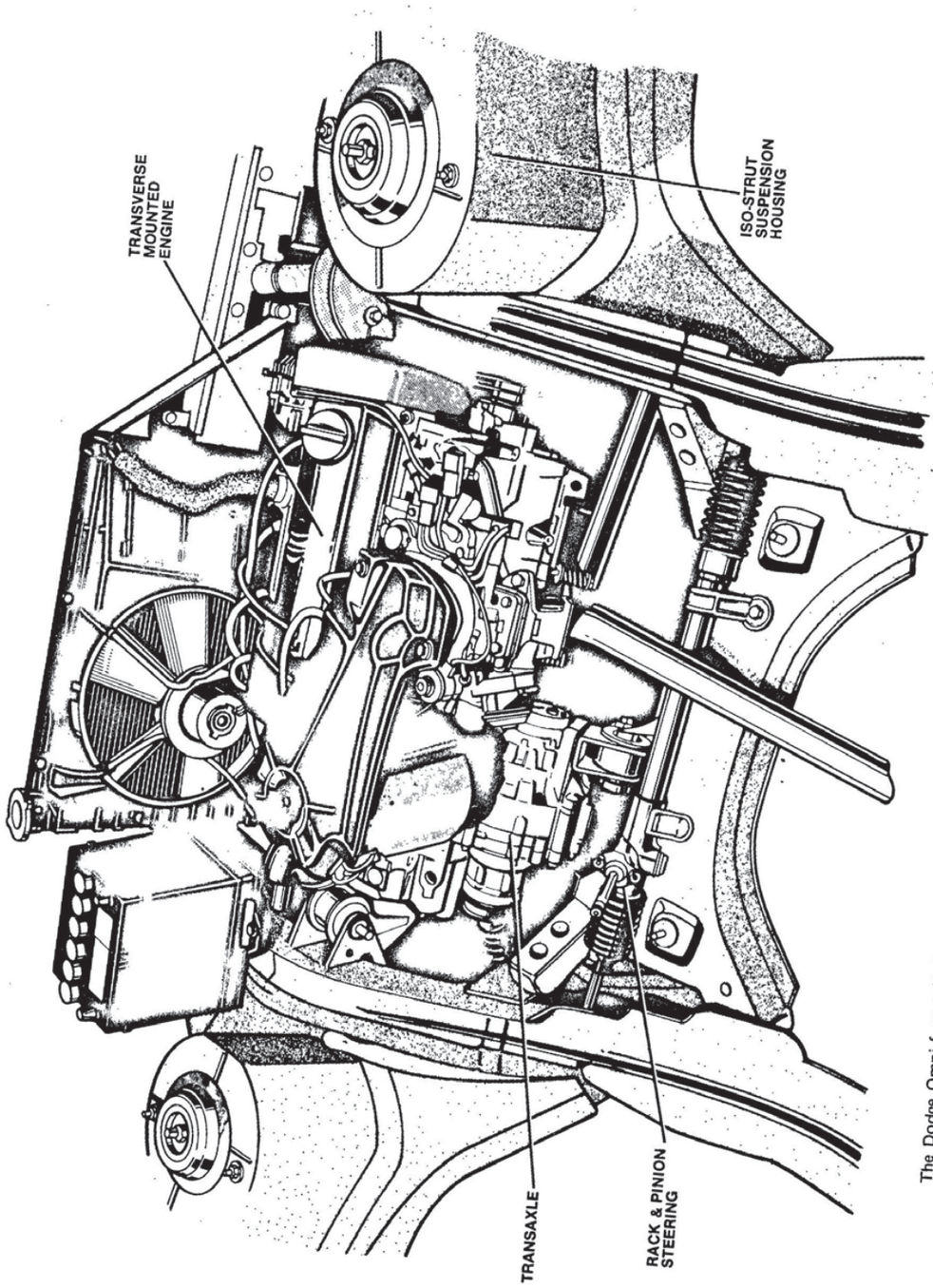
Therefore, the difference in pressure in the tank and in the carburetor throat forces the fuel up the fuel pipe, past the needle valve, through the two discharge holes. The throttle is relatively thick on this type of carburetor, so there is in effect a venturi at this point to aid vaporization. A spiral is placed in the throat to help acceleration and also to help keep the engine from dying when the throttle is opened suddenly.

The amount of fuel flowing at operating speed is metered by the needle valve and seat. Because of its compact design, the suction feed carburetor fuel system is used primarily on lawn mower engines.

REVIEW QUESTIONS – PRINCIPLES OF CARBURETION

1. What is the purpose of the fuel system in an internal combustion engine?
2. List the main parts of a fuel system.
3. The rate of flow through a carburetor is the same under all operating conditions. True or False?
4. When starting an internal combustion engine, the fuel mixture should be:
   a. Rich.
   b. Lean.
   c. Average.
5. Which speed requires a richer mixture?
   a. Idling.
   b. 30 mph.
6. Will all cylinders of a multi-cylinder engine receive an air-fuel mixture having the same octane rating?
7. For normal operating conditions, what air-fuel ratio will give the best economy?
   a. 16 to 1.
   b. 20 to 1.
   c. 25 to 1.
8. For quick acceleration, what is the best air-fuel ratio?
   a. 5 to 1.
   b. 10 to 1.
   c. 12 to 1.
   d. 20 to 1.
9. Are the molecules forming a gas held more tightly together than those of a metal?
10. Name two factors affecting the rapidity of evaporation.
11. What causes the air-fuel mixture to be drawn into the combustion chamber of an internal combustion engine?
12. The purpose of a venturi in a carburetor is to:
    a. Increase speed of air passing through carburetor.
    b. Maintain correct air-fuel ratio.
    c. Provide extra fuel for acceleration.
13. There are five main circuits in a modern carburetor. Name four of them.
14. In a carburetor venturi, which point has the highest vacuum?
    a. Entrance to the venturi.
    b. Narrowest point of the venturi.
    c. Point one inch beyond the venturi.
15. The idle system of a carburetor supplies fuel at what speeds?
    a. Idle speed only.
    b. Speeds up to 40 mph.
    c. Speeds up to 25 mph.
16. How many fuel discharge ports does the conventional idle system have?
    a. One.
    b. Two.
    c. Three.
    d. Four.
17. When the idle system is no longer supplying fuel to the engine, which system then supplies fuel?
    a. Air bleed system.
    b. Main system.
    c. Vaporizing system.
18. The purpose of an economizer valve is to supply more fuel, or less fuel?
19. The metering rod is designed to vary the size of which jets?
    a. Idle jets.
    b. Accelerating jets.
    c. High speed jets.
    d. Float level jets.
20. Under what conditions is ice most likely to form in a carburetor?
    a. 20 deg. below zero and high humidity.
    b. 32 deg. above zero and high humidity
    c. Zero deg. and low humidity.
21. On what type of car are you most likely to find an anti-stall dashpot?
    a. Cars with automatic transmission.
    b. Cars with conventional transmission.
    c. Cars fitted with 1 Bbl. carburetors.
    d. Cars fitted with 4 Bbl. carburetors.
22. In addition to updraft and downdraft carburetors, what other basic type is there?
23. The calibrated cluster in the Rochester 2GV carburetor cannot be removed from the carburetor. True or False?

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The Dodge Omni four cylinder engine is mounted transversely and is combined with a transaxle to power the front wheels. Note carburetor and unique air cleaner.

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Foreword to the 5th Edition

The "Automotive Handbook", a reliable guide full of up-to-date and concise information, has grown over a period of six decades from a calendar supplement of 96 pages to a 960-page reference work. In that time, over a million copies have been produced worldwide and the text translated into numerous languages.

The 5th edition, in common with its predecessors, is supported by two main pillars: the expertise of the technical staff at our company and in the automotive industry. They have fully revised the contents of this manual and brought it completely up to date. Thanks are due to all those involved.

This book is intended primarily as a source of important facts and figures and as a review of present-day technology for the automotive engineer and technician, but also for anyone else with an interest in technical matters. Accordingly, the automotive technology content is restricted to passenger cars and commercial vehicles, and the remaining content to that required for practical purposes.

Within the framework of a pocketbook it is impossible to present detailed coverage of individual technical subjects. On the other hand, bearing in mind the very wide range of readers, we do not want to dispense with generally applicable topics and data. However, we have dispensed with the "Conversion Tables" as the calculator is now an everyday item of equipment and any figure required can easily be calculated using the conversion formulas provided. The chapter "Road Traffic Legislation (Germany)" has also been deleted due to the international usage of the booklet.

These deletions have made way for new and updated topics which have added an extra 70 pages to the book.

We recommend readers to scan through the "Automotive Handbook" in order to gain an overall impression before using it.

The Editors

For your information

The following topics have been updated/extended since the 4th edition:

Vibration • Acoustics • Electronics (integrated circuits, micromechanics, mechatronics, sensors) • Statistics • Reliability • Closed and open-loop control systems • Materials technology (basic principles, materials, lubricants, fuels, consumables) • Corrosion • Hardness • Calculating fuel consumption • Vehicle dynamics.

Internal-combustion engines (direct fuel injection, diesel combustion systems) • Engine cooling (cooling-module technology, thermomanagement, exhaust cooling) • Turbochargers and superchargers (multistage) • Engine management on gasoline engines (mixture control, fuel-injection systems, fuel injectors, spark plugs, ME-Motronic, exhaust gases) • Engine management on diesel engines (axial/radial-piston pumps, injectors, exhaust gases, start-assist systems).

Electric drive units • Drivetrain (transmission, traction control systems (TCS) for passenger cars and commercial vehicles) • Steering • Braking systems (ABS for passenger cars, ABS and EBS for commercial vehicles) • Bodywork, commercial vehicles • Lighting systems (stepped reflectors, Bi-Litronic, headlamps and lights).

Car radios • Park Pilot systems • Navigation systems • Vehicle information systems • Mobile phones • Safety and security systems (impact detection, interior-movement detection) • Automotive hydraulics (electric proportional control valves).

Circuit diagrams and symbols • Vehicle electrical system (batteries, battery testers, water-cooled alternators, electromagnetic compatibility (EMC))

Passenger-car specifications.

The following topics have been introduced:

Fuel filters • MED-Motronic • Natural gas operation (spark-ignition engines) • Fuel cells • EHB for passenger cars • Automatic Cruise Control (ACC) • Instrumentation • Traffic telematics • Car radios (DAB) • Connectors • Cartronic.

and the following have been dropped:

Conversion tables • Road traffic legislation (Germany).

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Contents

Basic principles, Physics
Quantities and units 12
Conversion of units 19
Vibration 29
Mechanics 34
Strength of materials 42
Acoustics 50
Heat 56
Electrical engineering 60
Electronics 76
Sensors 94
Actuators 124
Electrical machines 132
Technical optics 137

Mathematics, Methods
Mathematics 144
Quality 150
Technical statistics, measurement 156
Reliability 165
Control engineering 167
Data processing in motor vehicles 172

Materials
Chemical elements 176
Terminology, parameters 180
Material groups 182
Properties of solids 186
Properties of metallic materials 193
Lubricants 230
Fuels 238
Antifreeze and brake fluid 247
Chemicals 250
Corrosion and corrosion protection 256
Heat treatment, hardness 268

Machine parts
Tolerances 279
Sliding bearings and rolling bearings 282
Spring calculations 290
Gears and tooth systems 296
Belt drives 306
Basic principles of threaded fasteners 310

Joining and bonding techniques
Welding, soldering 319
Adhesive technologies, riveting 322
Bonding and joining 324
Punch riveting 325

Sheet-metal processing
Deep-drawing technology 326
Laser technology 328

Tribology, wear 329

Influences in motor veicles
Road-going vehicle requirements 334
Basic requirements for fuels 335
Dynamics of linear motion 338
Dynamics of lateral motion 350
ISO procedures for vehicle handling 354
Operating dynamics for commercial vehicles 359
Requirements for agricultural tractors 362
Environmental stresses 364

Internal-combustion engines
Operating concepts and classifications 366
Cycles 367
Reciprocating-piston engines with internal combustion 369
- The spark-ignition (Otto) engine 372
- The diesel engine 377
- Hybrid processes 383
- Gas exchange 384
- Supercharging processes 390
- Power transfer 394
- Cooling, lubrication 410
- Data for calculation 412

Reciprocating-piston engine with external combustion (Stirling engine) 424
Wankel rotary engine 426
Gas turbine 428

Engine cooling
Air and water cooling 430
Intercooling (charge-air cooling) 433
Oil cooling, cooling-module technology 434
Thermomanagement, exhaust-gas cooling 435

Fuel filters 436

Air supply
Air filters, turbochargers 438
Exhaust systems 448

Engine management spark-ignition (SI) engines
Requirements, cylinder charge 452
Fuel delivery 455
A/F-mixture formation 458
Carburetors 460
Gasoline injection systems 463
- Single-point injection systems (Mono-Jetronic) 465
- Multipoint injection systems (K-, KE-, L-, LH-Jetronic) 467
- Electromagnetic fuel injectors 476

Ignition 477
- Ignition coil, spark plug 481
- Ignition systems 487
- (CI, TI, CDI, EI, DLI) Knock control 496

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Combined ignition and injection system (Motronic)
System overview 498
ME-Motronic 498
MED-Motronic 507

Engine-test technology 510

Spark-ignition engines for alternative fuel
LPG systems 512
Natural-gas operation 515
Operation on alcohol 516
Operation on hydrogen 517

Exhaust emissions from spark-ignition engines
Combustion products 518
Emissions control 519
Lambda closed-loop control 522
Testing exhaust and evaporative emissions 526
Test cycles 528
Exhaust-gas analyzers 532
Emissions limits 533

Diesel-engine management
Fuel metering 534
In-line fuel-injection pump (PE) 536
In-line control-sleeve fuel-injection pump 542
Distributor-type fuel-injection pump (VE) 543
Mechanic control 543
EDC with solenoid control 544
Solenoid-controlled axial- and radial-piston distributor pumps 546
Solenoid-controlled distributor pumps with integral ECU 548
Time-controlled single-cylinder pump systems (UIS/UPS) 548
Common-rail system (CRS) 551
Injection-pump test benches 552
Nozzles and nozzle holders 554

Exhaust emissions from diesel engines
Emissions control 560
Emissions testing 561
Test cycles and exhaust-emission limits 563
Smoke Emission Test Equipment 566

Start-assist systems (diesel engines)
Sheathed-element glow plugs 568
Glow control unit 569

Starting systems
Starters 571
Starter protection 574

Alternative drives
Electric drives 575
Hybrid drives 581
Fuel Cells 584

Drivetrain
Basic principles 588
Power take-up elements 590
Transmission control 592
Final drive units 602
Differential 604
All-wheel drive and transfer case 605
TCS traction control system 606

Chassis systems
Suspension 612
Suspension linkage 620
Wheels 624
Tires 628
Steering 638

Braking systems
Definitions, Principles 644
Legal regulations 648
Design and components of a braking system 652
Braking-system design 653
Brake-circuit configurations 654
Braking systems for passenger cars and light utility vehicles 656
Control devices 656
Wheel brakes 657
Braking-force metering device 658
ABS antilock braking system for passenger cars 659
Electrohydraulic Brakes (EHB) 673
Braking systems for commercial vehicles 674
System and configuration 674
Braking-force metering 675
Wheel brakes 678
Parking-brake and retarder braking systems 682
Components for compressed-air brakes 687
Antilock braking systems (ABS) for commercial vehicles 693
Electronically controlled braking system (ELB) 697
Brake test stands 702

Electronic Stability Program (ESP)
Basic principles 704
Vehicle handling 705
ESP control systems 706
System realization 712

Adaptive Cruise Control (ACC) 714

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Road-vehicle systematics
Overview 716
Classification 717

Vehicle bodies, passenger cars
Main dimensions 718
Body structure 722
Body materials 723
Body surface, body finishing 724
Safety 726
Calculations 730

Vehicle bodies, commercial vehicles
Commercial vehicles, delivery trucks and vans 732
Medium- and heavy-duty trucks and tractor vehicles 733
Buses 735
Passive safety 737

Lighting
Functions, regulations, definitions 738
Main headlamps 740
- European system 740
- American system 749
- European regulations 749
- Headlamp aiming devices 752
- North American regulations 753

Headlight leveling control (vertical-aim control) 754
Headlamp cleaning systems 755
Fog lamps 755
Auxiliary driving lamps 756
Lights and lamps 757
- Turn-signal indicators 759
- Hazard-warning and turn-signal devices 760
- Side-marker, clearance and tail lamps 761
- License-plate lamps, stop lamps 761
- Fog warning lamps (rear fog lamps) 762

Backup (reversing) lamps
Daytime running lamps 763
Motor-vehicle bulbs 763

Signaling and theft-deterrent devices
Acoustic signaling devices 766
Theft-deterrent systems 767

Windshield and rear-window cleaning
Windshield wiper systems 770
Rear-window cleaning systems 771
Headlamp cleaning systems
Wiper motors 772
Washing systems 773
Automotive windshield and window glass 774

Heating, ventilation and air conditioning
Systems deriving heat from the engine 776
Air conditioners 777
Auxiliary heater installations 779

Communications and information systems
Instrumentation 780
Automotive sound systems 786
Parking systems 791
Trip recorders 794
Navigation systems 796
Traffic telematics 798
Mobile radio 800
Vehicle information system 802

Safety systems
Occupant safety systems 803
- Seat belts and seat-belt tighteners 803
- Front and side airbag 805

Rollover protection systems 809

Comfort and convenience systems
Power windows 812
Power sunroof 813
Seat and steering-column adjustment 814
Central locking system 815

Automotive hydraulics
Basic principles 816
Gear pumps and motors 817
Piston pumps and motors 818
Electrohydraulic pumps and small units 819
Valves 820
Cylinders 822
Tractor hydraulics 823
Hydraulic accumulators and auxiliary drives 827
Hydrostatic fan drives 828
Hydrostatic drives 830

Automotive pneumatics
Operation of bus doors 832

Electrical power supply
Circuit diagrams 834
Schematic diagrams 839
Calculation of conductor sizes 858
Connectors 860
Automotive electrical systems, Energy supply 862
Starter batteries 866
Battery testers and chargers 872
Alternators 874
CAN, CARTRONIC 884
EMC and interference suppression 890

Alphabets and numbers 897

Passenger-car specifications 898

Index of headings 932

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Passenger-car specifications
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PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantities and units

SI units

SI denotes "Système International d'Unités" (International System of Units). The system is laid down in ISO 31 and ISO 1000 (ISO: International Organization for Standardization) and for Germany in DIN 1301 (DIN: Deutsches Institut für Normung – German Institute for Standardization).

SI units comprise the seven base SI units and coherent units derived from these base SI units using a numerical factor of 1.

Base SI units

Base quantity and symbols		Base SI unit Name	Symbol
Length	l	meter	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Thermodynamic temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I	candela	cd

All other quantities and units are derived from the base quantities and base units. The international unit of force is thus obtained by applying Newton's Law:

force = mass × acceleration

$F = m \cdot a$

where m = 1 kg and a = 1 m/s², thus F = 1 kg · 1 m/s² = 1 kg · m/s² = 1 N (newton).

Definitions of the base SI units

1 meter is defined as the distance which light travels in a vacuum in 1/299,792,458 seconds (17th CGPM, 1983[1]). The meter is therefore defined using the speed of light in a vacuum, c = 299,792,458 m/s, and no longer by the wavelength of the radiation emitted by the krypton nuclide ^{86}Kr. The meter was originally defined as the forty-millionth part of a terrestrial meridian (standard meter, Paris, 1875).

1 kilogram is the mass of the international prototype kilogram (1st CGPM, 1889 and 3rd CGPM, 1901[1]).

1 second is defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of atoms of the ^{133}Cs nuclide (13th CGPM, 1967.[1])

1 ampere is defined as that constant electric current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-sections, and placed 1 meter apart in a vacuum will produce between these conductors a force equal to 2 x 10^{-7} N per meter of length (9th CGPM, 1948.[1])

1 kelvin is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point[2]) of water (13th CGPM, 1967.[1])

1 mole is defined as the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of the carbon nuclide ^{12}C. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles (14th CGPM[1]), 1971.

1 candela is the luminous intensity in a given direction of a source which emits monochromatic radiation of frequency 540 x 1012 hertz and of which the radiant intensity in that direction is 1/683 watt per steradian (16th CGPM, 1979.[1])

Decimal multiples and fractions of SI units

Decimal multiples and fractions of SI units are denoted by prefixes before the name of the unit or prefix symbols before the unit symbol. The prefix symbol is placed immediately in front of the unit symbol to form a coherent unit, such as the milligram (mg). Multiple prefixes, such as microkilogram (µkg), may **not** be used.

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[1]) CGPM: Conférence Générale des Poids et Mesures (General Conference on Weights and Measures).

[2]) Fixed point on the international temperature scale. The triple point is the only point at which all three phases of water (solid, liquid and gaseous) are in equilibrium (at a pressure of 1013.25 hPa). This temperature of 273.16 K is 0.01 K above the freezing point of water (273.15 K).

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Prefixes are not to be used before the units angular degree, minute and second, the time units minute, hour, day and year, and the temperature unit degree Celsius.

Prefix	Prefix symbol	Power of ten	Name
atto	a	10^{-18}	trillionth
femto	f	10^{-15}	thousand billionth
pico	p	10^{-12}	billionth
nano	n	10^{-9}	thousand millionth
micro	µ	10^{-6}	millionth
milli	m	10^{-3}	thousandth
centi	c	10^{-2}	hundredth
deci	d	10^{-1}	tenth
deca	da	10^{1}	ten
hecto	h	10^{2}	hundred
kilo	k	10^{3}	thousand
mega	M	10^{6}	million
giga	G	10^{9}	milliard[1])
tera	T	10^{12}	billion[1])
peta	P	10^{15}	thousand billion
exa	E	10^{18}	trillion

Legal units

The Law on Units in Metrology of 2 July 1969 and the related implementing order of 26 June 1970 specify the use of "Legal units" in business and official transactions in Germany.[2])

Legal units are

- the SI units,
- decimal multiples and submultiples of the SI units,
- other permitted units; see the tables on the following pages.

Legal units are used in the Bosch Automotive Handbook. In many sections, values are also given in units of the technical system of units (e.g. in parentheses) to the extent considered necessary.

Systems of units not to be used

The physical system of units

Like the SI system of units, the physical system of units used the base quantities length, mass and time. However, the base units used for these quantities were the centimeter (cm), gram (g), and second (s) (CGS System).

The technical system of units

The technical system of units used the following base quantities and base units:

Base quantity	Base unit Name	Symbol
Length	meter	m
Force	kilopond	kp
Time	second	s

Newton's Law, $F = m \cdot a$, provides the link between the international system of units and the technical system of units, where force due to weight G is substituted for F and acceleration of free fall g is substituted for a.

In contrast to mass, acceleration of free fall and therefore force due to weight depend upon location. The standard value of acceleration of free fall is defined as g_n = 9.80665 m/s² (DIN 1305). The approximate value

g = 9.81 m/s²

is generally acceptable in technical calculations.

1 kp is the force with which a mass of 1 kg exerts pressure on the surface beneath it at a place on the earth. With

$G = m \cdot g$,

thus

1 kp = 1 kg · 9.81 m/s² = 9.81 N.

---

[1]) In the USA: 10^9 = 1 billion, 10^{12} = 1 trillion.

[2]) Also valid: "Gesetz zur Änderung des Gesetzes über Einheiten im Meßwesen" dated 6 July 1973; "Verordnung zur Änderung der Ausführungsverordnung" dated 27 November 1973; "Zweite Verordnung zur Änderung der Ausführungsverordnung" dated 12 December 1977.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantities and units

Overview (from DIN 1301)

The following table gives a survey of the most important physical quantities and their standardized symbols, and includes a selection of the legal units specified for these quantities. Additional legal units can be formed by adding prefixes (see P. 13). For this reason, the column "other units" only gives the decimal multiples and submultiples of the SI units which have their own names. Units which are not to be used are given in the last column together with their conversion formulas. Page numbers refer to conversion tables.

Quantity and symbol	Legal units SI	Others	Name	Relationship	Remarks and units not to be used, incl. their conversion
1. Length, area, volume (PP. 19 ... 20)					
Length l	m		meter		1 µ (micron) = 1 µm 1 Å (ångström) = 10^{-10} m 1 X.U. (X-unit) ≈ 10^{-13} m 1 p (typograph. point) = 0.376 mm
		nm	international nautical mile	1 nm = 1852 m	
Area A	m^2		square meter		
		a	are	1 a = 100 m^2	
		ha	hectare	1 ha = 100 a = 10^4 m^2	
Volume V	m^3		cubic meter		
		l, L	liter	1 l = 1 L = 1 dm^3	
2. Angle (P. 21)					
(Plane) angle α, β etc.	rad[1])		radian	1 rad = $\frac{1\text{ m arc}}{1\text{ m radius}}$	
		°	degree	1 rad = 180°/π = 57.296° ≈ 57.3°	1 ∟ (right angle) = 90° = (π/2) rad = 100 gon
		′	minute	1° = 0.017453 rad	1ᵍ (centesimal degree) = 1 gon
		″	second	1° = 60′ = 3600″	1ᶜ (centesimal minute) = 1 cgon
		gon	gon	1 gon = (π/200) rad	1ᶜᶜ (centesimal second) = 0.1 mgon
Solid angle Ω	sr		steradian	1 sr = $\frac{1\text{ m}^2\text{ spherical surface}}{1\text{ m}^2\text{ sphere radius}^2}$	
3. Mass (PP. 22 ... 23)					
Mass (weight)[2]) m	kg		kilogram		1 γ (gamma) = 1µg 1 quintal = 100 kg 1 Kt (karat) = 0.2 g
		g	gram		
		t	ton	1 t = 1 Mg = 10^3 kg	

[1]) The unit rad (P. 21) can be replaced by the numeral 1 in calculations.
[2]) The term "weight" is ambiguous in everyday usage; it is used to denote mass as well as weight (DIN 1305).

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantity and symbol	Legal units SI	Others	Name	Relationship	Remarks and units not to be used, incl. their conversion
Density ϱ	kg/m³			1 kg/dm³ = 1 kg/*l* = 1 g/cm³ = 1000 kg/m³	Weight per unit volume γ (kp/dm³ or p/cm³). Conversion: The numerical value of the weight per unit volume in kp/dm³ is roughly equal to the numerical value of the density in kg/dm³
		kg/dm³			
		kg/*l*			
		g/cm³			
Moment of inertia J (mass moment, 2nd order)	kg · m²			$J = m \cdot i^2$ i = radius of gyration	Flywheel effect $G \cdot D^2$. Conversion: Numerical value of $G \cdot D^2$ in kp · m² = 4 x numerical value of J in kg · m²

4. Time quantities (P. 28)

Time, duration, interval t	s		second[1]		In the energy industry, one year is calculated at 8760 hours
		min	minute[1]	1 min = 60 s	
		h	hour[1]	1 h = 60 min	
		d	day	1 d = 24 h	
		a	year		
Frequency f	Hz		hertz	1 Hz = 1/s	
Rotational speed (frequency of rotation) n	s⁻¹			1 s⁻¹ = 1/s	min⁻¹ and r/min (revolutions per minute) are still permissible for expressing rotational speed, but are better replaced by min⁻¹ (1 min⁻¹ = 1 r/min = 1 min⁻¹)
		min⁻¹ 1/min		1 min⁻¹ = 1/min = (1/60)s⁻¹	
Angular frequency ω $\omega = 2\pi f$	s⁻¹				
Velocity v	m/s	km/h		1 km/h = (1/3.6) m/s	
		kn	knot	1 kn = 1 nm/h = 1.852 km/h	
Acceleration a	m/s²			acceleration of free fall g P.13	
Angular velocity ω	rad/s²)				
Angular acceleration α	rad/s²[2]				

5. Force, energy, power (PP. 24 ... 25)

Force F Force due to weight G	N N		newton	1 N = 1 kg · m/s²	1 p (pond) = 9.80665 mN 1 kp (kilopond) = 9.80665 N ≈ 10 N 1 dyn (dyne) = 10⁻⁵ N

[1]) Clock time: h, m, s written as superscripts; example: $3^h\ 25^m\ 6^s$.
[2]) The unit rad can be replaced by the numeral 1 in calculations.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantity and symbol	Legal units SI	Others	Name	Relationship	Remarks and units not to be used, incl. their conversion
Pressure, gen. p	Pa		pascal	1 Pa = 1 N/m²	1 at (techn. atmosphere) = 1 kp/cm² = 0.980665 bar ≈ 1 bar 1 atm (physical atmosphere) = 1.01325 bar[1]) 1 mm w.g. (water gauge) = 1 kp/m² = 0.0980665 hPa ≈ 0.1 hPa 1 torr = 1 mm Hg (mercury column) = 1.33322 hPa dyn/cm² = 1 µbar
Absolute pressure p_{abs} Atmospheric pressure p_{amb}		bar	bar	1 bar = 10^5 Pa = 10 N/cm² 1 µbar = 0.1 Pa 1 mbar = 1 hPa	
Gauge pressure p_e $p_e = p_{abs} - p_{amb}$	Gauge pressure etc. is no longer denoted by the unit symbol, but rather by a formula symbol. Negative pressure is given as negative gauge pressure. Examples: previously: 3 atg; 10 ata; 0.4 atu now: p_e = 2.94 bar ≈ 3 bar; p_{abs} = 9.81 bar ≈ 10 bar; p_e = −0.39 bar ≈ −0.4 bar				
Mechanical stress σ, τ	N/m²			1 N/m² = 1 Pa	1 kp/mm² = 9.81 N/mm² ≈ 10 N/mm² 1 kp/cm² ≈ 0.1 N/mm²
		N/mm²		1 N/mm² = 1 MPa	
Hardness (P. 274)	Brinell and Vickers hardness are no longer given in kp/mm². Instead, an abbreviation of the relevant hardness scale is written as the unit after the numerical value used previously (including an indication of the test force etc. where applicable).				Examples: previously: HB = 350 kp/mm² → now: 350 HB HV30 = 720 kp/mm² → 720 HV30 HRC = 60 → 60 HRC
Energy, E, W Heat, Q Quantity of heat (P. 25)	J		joule	1 J = 1 N · m = 1 W · s = 1 kg m²/s²	1 kp · m (kilopondmeter) = 9.81 J ≈ 10J 1 HP · h (horsepower-hour) = 0.7355 kW · h ≈ 0.74 kW · h 1 erg (erg) = 10^{-7}J 1 kcal (kilocalorie) = 4.1868 kJ ≈ 4.2 kJ 1 cal (calorie) = 4.1868 J ≈ 4.2 J
		W · s	watt-second		
		kW · h	kilowatt-hour	1 kW · h = 3.6 MJ	
		eV	electron-volt	1 eV = 1.60219·10^{-19}J	
Torque M	N · m		newton-meter		1 kp · m (kilopondmeter) = 9.81 N · m ≈ 10 N · m
Power P Heat flow Q, (P. 25) Φ	W		watt	1 W = 1 J/s = 1 N · m/s	1 kp · m/s = 9.81 W ≈ 10 W 1 HP (horsepower) = 0.7355 kW ≈ 0.74 kW 1 kcal/s = 4.1868 kW ≈ 4.2 kW 1 kcal/h = 1.163 W

6. Viscosimetric quantities (P. 27)

Dynamic viscosity η	Pa · s		Pascal-second	1 Pa · s = 1 N s/m² = 1 kg/(s · m)	1 P (poise) = 0.1 Pa · s 1 cP (centipoise) = 1 mPa · s
Kinematic viscosity ν	m²/s			1 m²/s = 1 Pa · s/(kg/m³)	1 St (stokes) = 10^{-4} m²/s = 1 cm²/s 1 cSt (centistokes) = 1 mm²/s

[1]) 1.01325 bar = 1013.25 hPa = 760 mm mercury column is the standard value for atmospheric pressure.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantity and symbol		Legal units SI	Others	Name	Relationship	Remarks and units not to be used, incl. their conversion
7. Temperature and heat (P. 26)						
Temperature	T	K	kelvin		$t = (T - 273.15\ \text{K})\ \frac{°C}{K}$	
	t		°C	degree Celsius		
Temperature difference	ΔT	K		kelvin	1 K = 1 °C	
	Δt		°C	degree Celsius		
		In the case of composite units, express temperature differences in K, e.g. kJ/(m · h · K); tolerances for temperatures in degree Celsius, e.g. are written as follows: $t = (40 \pm 2)$ °C or $t = 40\ °C \pm 2\ °C$ or $t = 40\ °C \pm 2$ K.				
Refer to 5. for quantity of heat and heat flow.						
Specific heat capacity (spec. heat)	c	$\frac{J}{kg \cdot K}$				1 kcal/(kg · grd) = 4.187 kJ/(kg · K) ≈ 4.2 kJ/(kg · K)
Thermal conductivity	λ	$\frac{W}{m \cdot K}$				1 kcal/(m · h · grd) = 1.163 W/(m · K) ≈ 1.2 W/(m · K) 1 cal/(cm · s · grd) = 4.187 W/(cm · K) 1 W/(m · K) = 3.6 kJ/(m · h · K)
8. Electrical quantities (P. 60)						
Electric current	I	A		ampere		
Electric potential	U	V		volt	1 V = 1 W/A	
Electric conductance	G	S		siemens	1 S = 1 A/V = 1/Ω	
Electric resistance	R	Ω		ohm	1 Ω = 1/S = 1 V/A	
Quantity of electricity, electric charge	Q	C		coulomb	1 C = 1 A · s	
			A · h	ampere-hour	1 A · h = 3600 C	
Electric capacitance	C	F		farad	1 F = 1 C/V	
Electric flux density, displacement	D	C/m²				
Electric field strength	E	V/m				

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Quantity and symbol	Legal units SI	Others	Name	Relationship	Remarks and units not to be used, incl. their conversion
9. Magnetic quantities (P. 60)					
Magnetic flux Φ	Wb		weber	1 Wb = 1 V · s	1 M (maxwell) = 10^{-8} Wb
Magnetic flux density, induction B	T		tesla	1 T = 1 Wb/m²	1 G (gauss) = 10^{-4} T,
Inductance L	H		henry	1 H = 1 Wb/A	
Magnetic field strength H	A/m			1 A/m = 1 N/Wb	1 Oe (oersted) = $10^3/(4\pi)$ A/m = 79.58 A/m
10. Photometric quantities and units (P. 137)					
Luminous intensity I	cd		candela[1])		
Luminance L	cd/m²				1 sb (stilb) = 10^4 cd/m² 1 asb (apostilb) = $1/\pi$ cd/m²
Luminous flux Φ	lm		lumen	1 lm = 1 cd · sr (sr = steradian)	
Illuminance E	lx		lux	1 lx = 1 lm/m²	
11. Quantities used in atom physics and other fields					
Energy W		eV	electron-volt	1 eV= 1.60219 · 10^{-19}J 1 MeV= 10^6 eV	
Activity of a radioactive substance A	Bq		becquerel	1 Bq = 1 s^{-1}	1 Ci (curie) = 3.7 · 10^{10} Bq
Absorbed dose D	Gy		gray	1 Gy = 1 J/kg	1 rd (rad) = 10^{-2} Gy
Dose equivalent Dq	Sv		sievert	1 Sv = 1 J/kg	1 rem (rem) = 10^{-2} Sv
Absorbed dose rate $\dot{D}$				1 Gy/s = 1 W/kg	
Ion dose J	C/kg				1 R (röntgen) = 258 · 10^{-6}C/kg
Ion dose rate $\dot{J}$	A/kg				
Amount of substance n	mol		mole		

[1]) The stress is on the second syllable: the candela.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Conversion of units

Units of length

Unit		X U	pm	Å	nm	µm	mm	cm	dm	m	km
1 XU	≈	1	10^{-1}	10^{-3}	10^{-4}	10^{-7}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	—
1 pm	=	10	1	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	—
1 Å	=	10^{3}	10^{2}	1	10^{-1}	10^{-4}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	—
1 nm	=	10^{4}	10^{3}	10	1	10^{-3}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-12}
1 µm	=	10^{7}	10^{6}	10^{4}	10^{3}	1	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-9}
1 mm	=	10^{10}	10^{9}	10^{7}	10^{6}	10^{3}	1	10^{-1}	10^{-2}	10^{-3}	10^{-6}
1 cm	=	10^{11}	10^{10}	10^{8}	10^{7}	10^{4}	10	1	10^{-1}	10^{-2}	10^{-5}
1 dm	=	10^{12}	10^{11}	10^{9}	10^{8}	10^{5}	10^{2}	10	1	10^{-1}	10^{-4}
1 m	=	–	10^{12}	10^{10}	10^{9}	10^{6}	10^{3}	10^{2}	10	1	10^{-3}
1 km	=	–	–	–	10^{12}	10^{9}	10^{6}	10^{5}	10^{4}	10^{3}	1

Do not use XU (X-unit) and Å (ångström)

Unit		in	ft	yd	mile	n mile	mm	m	km
1 in	=	1	0.08333	0.02778	–	–	25.4	0.0254	–
1 ft	=	12	1	0.33333	–	–	304.8	0.3048	–
1 yd	=	36	3	1	–	–	914.4	0.9144	–
1 mile	=	63 360	5280	1760	1	0.86898	–	1609.34	1.609
1 n mile[1])	=	72 913	6076.1	2025.4	1.1508	1	–	1852	1.852
1 mm	=	0.03937	$3.281 \cdot 10^{-3}$	$1.094 \cdot 10^{-3}$	–	–	1	0.001	10^{-6}
1 m	=	39.3701	3.2808	1.0936	–	–	1000	1	0.001
1 km	=	39 370	3280.8	1093.6	0.62137	0.53996	10^{6}	1000	1

in = inch, ft = foot, y = yard, mile = statute mile, n mile = nautical mile

Other British and American units of length

1 µin (microinch) = 0.0254 µm,
1 mil (milliinch) = 0.0254 mm,
1 link = 201.17 mm,
1 rod = 1 pole = 1 perch = 5.5 yd = 5.0292 m,
1 chain = 22 yd = 20.1168 m,
1 furlong = 220 yd = 201.168 m,
1 fathom = 2 yd = 1.8288 m.

Astronomical units

1 l.y. (light year) = $9.46053 \cdot 10^{15}$ m (distance traveled by electromagnetic waves in 1 year),
1 AU (astronomical unit) = $1.496 \cdot 10^{11}$ m (mean distance from earth to sun),
1 pc (parsec, parallax second) = 206 265 AU = $3.0857 \cdot 10^{16}$ m (distance at which the AU subtends an angle of one second of arc).

Do not use

1 line (watch & clock making) = 2.256 mm,
1 p (typographical point) = 0.376 mm,
1 German mile = 7500 m,
1 geographical mile = 7420.4 m (≈ 4 arc minutes of equator).

[1]) 1 n mile = 1 nm = 1 international nautical mile ≈ 1 arc minute of the degree of longitude.
1 knot = 1 n mile/h = 1.852 km/h.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Units of area

Unit		in^2	ft^2	yd^2	acre	$mile^2$	cm^2	m^2	a	ha	km^2
1 in^2	=	1		–	–	–	6.4516	–	–	–	–
1 ft^2	=	144	1	0.1111	–	–	929	0.0929	–	–	–
1 yd^2	=	1296	9	1	–	–	8361	0.8361	–	–	–
1 acre	=	–	–	4840	1	0.16	–	4047	40.47	0.40	–
1 $mile^2$	=	–	–	–	6.40	1	–	–	–	259	2.59
1 cm^2	=	0.155	–	–	–	–	1	0.01	–	–	–
1 m^2	=	1550	10.76	1.196	–	–	10000	1	0.01	–	–
1 a	=	–	1076	119.6	–	–	–	100	1	0.01	–
1 ha	=	–	–	–	2.47	–	–	10000	100	1	0.01
1 km^2	=	–	–	–	247	0.3861	–	–	10000	100	1

in^2 = square inch (sq in),
ft^2 = square foot (sq ft),
yd^2 = square yard (sq yd),
$mile^2$ = square mile (sq mile).

Paper sizes
(DIN 476)

Dimensions in mm

A 0	841 x 1189	**A 6**	105 x 148
A 1	594 x 841	**A 7**	74 x 105
A 2	420 x 594	**A 8**	52 x 74
A 3	297 x 420	**A 9**	37 x 52
A 4	210 x 297[1])	**A 10**	26 x 37
A 5	148 x 210		

Units of volume

Unit		in^3	ft^3	yd^3	gal (UK)	gal (US)	cm^3	dm^3(l)	m^3
1 in^3	=	1	–	–	–	–	16.3871	0.01639	–
1 ft^3	=	1728	1	0.03704	6.229	7.481	–	28.3168	0.02832
1 yd^3	=	46656	27	1	168.18	201.97	–	764.555	0.76456
1 gal (UK)	=	277.42	0.16054	–	1	1.20095	4546.09	4.54609	–
1 gal (US)	=	231	0.13368	–	0.83267	1	3785.41	3.78541	–
1 cm^3	=	0.06102	–	–	–	–	1	0.001	–
1 dm^3 (l)	=	61.0236	0.03531	0.00131	0.21997	0.26417	1000	1	0.001
1 m^3	=	61023.6	35.315	1.30795	219.969	264.172	10^6	1000	1

in^3 = cubic inch (cu in),
ft^3 = cubic foot (cu ft),
yd^3 = cubic yard (cu yd),
gal = gallon.

Other units of volume

Great Britain (UK)
1 fl oz (fluid ounce) = 0.028413 l
1 pt (pint) = 0.56826 l,
1 qt (quart) = 2 pt = 1.13652 l,
1 gal (gallon) = 4 qt = 4.5461 l,
1 bbl (barrel) = 36 gal = 163.6 l,

Units of dry measure:
1 bu (bushel) = 8 gal = 36.369 l.

[1]) Customary format in USA: 216 mm x 279 mm

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

United States (US)
1 fl oz (fluid ounce) = 0.029574 l
1 liq pt (liquid pint) = 0.47318 l
1 liq quart = 2 liq pt = 0.94635 l
1 gal (gallon) = 231 in^3 = 4 liq quarts = 3.7854 l
1 liq bbl (liquid barrel) = 119.24 l
1 barrel petroleum[1]) = 42 gal = 158.99 l

Units of dry measure:
1 bushel = 35.239 dm^3

Volume of ships
1 RT (register ton) = 100 ft^3 = 2.832 m^3; GRT (gross RT) = total shipping space, net register ton = cargo space of a ship.
GTI (gross tonnage index) = total volume of ship (shell) in m^3.
1 ocean ton = 40 ft^3 = 1.1327 m^3.

Units of angle

Unit[2])		°	′	″	rad	gon	cgon	mgon
1°	=	1	60	3600	0.017453	1.1111	111.11	1111.11
1′	=	0.016667	1	60	–	0.018518	1.85185	18,5185
1″	=	0.0002778	0.016667	1	–	0.0003086	0.030864	0.30864
1 rad[2])	=	57.2958	3437.75	206265	1	63.662	6366.2	63662
1 gon	=	0.9	54	3240	0.015708	1	100	1000
1 cgon	=	0.009	0.54	32.4	–	0.01	1	10
1 mgon	=	0.0009	0.054	3.24	–	0.001	0.1	1

Velocities

1 km/h = 0.27778 m/s,
1 mile/h = 1.60934 km/h,
1 kn (knot) = 1.852 km/h,
1 ft/min = 0.3048 m/min

1 m/s = 3.6 km/h,
1 km/h = 0.62137 mile/h,
1 km/h = 0.53996 kn,
1 m/min = 3.28084 ft/min,

x km/h $\triangleq \frac{60}{x}$ min/km $\triangleq \frac{3600}{x}$ s/km, x mile/h $\triangleq \frac{37.2824}{x}$ min/km $\triangleq \frac{2236.9}{x}$ s/km.

x s/km $\triangleq \frac{3600}{x}$ km/h.

The **Mach number** Ma specifies how much faster a body travels than sound (approx. 333 m/s in air). Ma = 1.3 therefore denotes 1.3 times the speed of sound.

Fuel consumption

1 g/PS · h = 1.3596 g/kW · h,
1 lb/hp · h = 608.277 g/kW · h,
1 liq pt/hp · h = 634.545 cm^3/kW · h,
1 pt (UK)/hp · h = 762.049 cm^3/kW · h,

1 g/kW · h = 0.7355 g/PS · h,
1 g/kW · h = 0.001644 lb/hp · h,
1 cm^3/kW · h = 0.001576 liq pt/hp · h,
1 cm^3/kW · h = 0.001312 pt (UK)/hp · h,

x mile/gal (US) $\triangleq \frac{235.21}{x}$ l/100 km, x l/100 km $\triangleq \frac{235.21}{x}$ mile/gal (US),

x mile/gal (UK) $\triangleq \frac{282.48}{x}$ l/100 km. x l/100 km $\triangleq \frac{282.48}{x}$ mile/gal (UK).

1) For crude oil.
2) It is better to indicate angles by using only one of the units given above, i.e. not α = 33° 17′ 27.6″ but rather α = 33.291° or α = 1997.46′ or α = 119847.6″.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540