EUROPA REFERENCE BOOKS
for Automotive Technology

Modern Automotive Technology

Fundamentals, service, diagnostics

2nd English edition

The German edition was written by technical instructors, engineers and technicians

Editorial office (German edition): R. Gscheidle, Studiendirektor, Winnenden – Stuttgart

VERLAG EUROPA-LEHRMITTEL · Nourney, Vollmer GmbH & Co. KG
Düsselberger Straße 23 · 42781 Haan-Gruiten, Germany

Europa-No.: 23018

Modern Automotive Technology - Fundamentals, service, diagnostics, 2nd edition, 2014
Original title: Fachkunde Kraftfahrzeugtechnik, 30th edition, 2013

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2nd edition 2014
Impression 5 4
All impressions of the same edition can be used in parallel, as they do not differ from each other except with regard to the correction of printing errors.

ISBN 978-3-8085-2302-5

Cover design and illustration: Braunwerbeagentur, Stefanie Braun, 42477 Radevormwald, Germany, using photographs and illustrations provided by Dr. Ing. H. C. Porsche AG, Stuttgart, Audi AG, Ingolstadt, Volkswagen AG, Wolfsburg, KTM, Mattighofen, Austria (photo: H. Mitterbauer) and Mercedes Benz AG, Stuttgart.

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Printing: mediaprint solutions GmbH, 33100 Paderborn, Germany

Foreword

"Modern Automotive Technology" is a standard work covering the subject of automotive technology. This second English edition is based on the 30th German edition titled "Fachkunde Kraftfahrzeugtechnik". It has for many years proven to be a highly popular textbook used for training and further education. It provides apprentices, trainees, teachers and all those interested in this subject with the theoretical knowledge necessary to gain a firm grasp of the practical and technical skills involved. Fundamental, technical connections between individual systems are presented in a clear and comprehensible way.

The book is intended to be used as a reference work by employees in the automotive industry and in motor vehicle service outlets, by teachers, apprentices, trainees and automotive technology students to help them look up information and supplement their technical knowledge. The work is intended to be used by all those interested in automotive technology as a means of extending their technical knowledge through private study.

The 22 chapters are logically arranged by subject and cover the changes that have occurred in the field of automotive technology. The book is particularly suitable for practical training in all matters pertaining to motor vehicles.

This work covers the latest developments in automotive technology, including service and maintenance of vehicle systems, management, communication, supercharging technology, common-rail systems, dual clutch gearboxes, electronic transmission control, electronic brake systems, compressed-air monitoring systems, adaptive cornering lights, new headlamp systems, high-frequency technology, electrical circuit diagrams, multifunction regulators, new data bus systems (LIN, MOST, FlexRay), alternative drive concepts, electric drive systems, differential locks, axle alignment checks, driving dynamics, steering systems, electromagnetic compatibility and comfort and convenience systems such as adaptive cruise control, parking assistance and navigation. A large chapter is devoted to the subject of electrical engineering. Here, the detailed coverage of the fundamentals of electrical engineering forms the basis for all the crucial issues and topics pertaining to automotive electrics, up to and including data transmission in motor vehicles. A separate chapter is devoted to the increasing importance in engineering of comfort and convenience technology.

Reference is made to German and European standards in the chapters on environmental protection and occupational safety, emissions-control engineering, braking technology and motorcycle engineering. However, compliance with the standards applicable in the respective individual countries is required.

The work features numerous coloured pictures, drawings and system diagrams as well as particularly clearly and comprehensibly laid-out tables. These will help the reader to digest and comprehend the complex subject matter.

This edition includes a CD of all the illustrations found in the book.

The work has been written and compiled – in close co-operation with the automotive trade and industry – by a team of educationally experienced vocational school teachers, engineers and master tradesmen. The authors and the publishers will be grateful for any suggestions and constructive comments.

We would like to thank all the companies and organisations who have kindly contributed pictures and technical documents.

The Authors of the Automotive Technology Team Spring 2014

Abbreviations

AAS Adaptive air suspension
A/C Air conditioning
A/F Air/fuel (mixture)
ABA Active brake assist
ABC Active body control
ABS Antilock braking system
ABV Automatic braking-force distribution (German: Automatische Bremskraftverteilung)
AC Alternating current
ACC Adaptive cruise control, automatic cruise control
ACEA Association des Constructeurs Européens d'Automobiles
ACS Automatic clutch system
AD Analogue-digital (converter)
ADC Analog digital converter
ADSL Asymmetrical digital subscriber line
AFS Airflow sensor
AFRP Aramid fibre reinforced plastic
AGM Absorbed glass mat battery
AHL Automatic headlight leveling
ALDBFR Automatic load-dependent brake force regulator
ALSD Automatic limited-slip differential
AM Amplitude modulation
API American Petroleum Institute
APB Automatic parking brake
ARS Angle of rotation sensor
ASC Anti-stability control, acceleration skid control
ASHEV Axle split hybrid electric vehicle
ASTM American Society for Testing and Materials
ATC Adaptive transmission control
ATF Automatic transmission fluid
AWD All-wheel drive
AYC Active yaw control

BAS Brake assist system
BDC Bottom dead centre
BDW Brake disc wiping
BEV Battery powered electric vehicle

CA Crankshaft angle
CS Camshaft
CAN Controller area network
CAT Catalytic converter, catalyst
CB Centre bore, Common ball
CBS Combined brake system
CC Cruise control
CDI Capacitive discharge ignition
CFPP Cold filter plugging point
CFRP Carbon fibre reinforced plastic
CH Combination hump
CIH Camshaft in head
CIP Continuous improvement process
CN Cetane number
CNG Compressed natural gas
CPOD Child Seat Presence and Orientation Detection
CPU Central processing unit
CR Common rail
CRDI Common rail direct injection
CB Centre bore
CS Crankshaft
CV Commercial vehicle
CV Check valve
CVlft Check valve left
CVrt Check valve right
CVT Continuously variable transmission

DA Drive axle
DC Direct current
DCT Dual clutch transmission
DI Direct injection
DIN Deutsches Institut für Normung
DIP Distributor injection pump
DME Digital motor electronics
DOHC Double overhead cam-shaft
DOT Department of Transportation
DPNR Diesel particulate NO_x reduction system
DSC Dynamic stability control
DSG Direct-shift gearbox
DSP Dynamic shift program selection
DVD Digital versatile disc

EBA Electronic brake assist, emergency brake system
EBS Electronic braking system
Ec Exhaust valve closes
ECE Economic Commission for Europe
ECM Electronic clutch management
ECS Electronic clutch system
ECU Electronic control unit, engine control unit
EDC Electronic diesel control, electronic damper control
EDP Electronic data processing
EDTC Engine drag torque control
EEPROM Electrically erasable programmable read-only memory
EGR Exhaust gas recirculation
EGS Electronic gearbox control unit (German: Elektronisches Getriebesteuergerät)
EH Extended hump
EHB Electro-hydraulic braking system
EI Emissions inspection, electronic ignition
ELSD Electronic limited-slip differential
EMC Electromagnetic compatibility
EMS Electronic engine management system
Eo Exhaust valve opens
EOBD European on board diagnostics
EP Exhaust passage, extreme pressure, epoxy resin
EPS Electronic power steering
ESI Electronic service information
ESP Electronic stability program
ETC Electronic throttle control
ETN European type number
EV Exhaust valve
FA Front axle
FB Function button
FC Fuel cell
FF Free-form (reflector)
FH Flat hump
FL Front left
FOC Fibre optic cable
FOT Fibre optic transceiver
FR Front right

GD/GND Ground
GDI Gasoline direct injection
GFRP Glass fibre reinforced
GI General inspection
GPS Global positioning system

HDC Hill descent control
HEV Hybrid electric vehicle
HF High frequency
HGV Heavy goods vehicle
HHC Hill hold control
HNS Homogeneous numerically calculated surface
HS High-solid (paints)
HTHS High temperature, high shear
HUD Head up display

Abbreviations

HV	Hybrid vehicle, high voltage
IC	Integrated circuit
Ic	Inlet valve closes
IC	Individual control
IHPF	Internal high-pressure forming
Io	Inlet valve opens
IP	Inlet passage
IPO	Input/Processing/Output (principle)
IS	Input shaft
ISA	Integrated starter alternator
ISAD	Integrated starter alternator damper
ISC	Idle speed control
ISG	Integrated starter generator
ISO	International Organization for Standardization
IV	Inlet valve
IVlft	Inlet valve left
IVrt	Inlet valve right
LA	Lifting axle
LAN	Local area network
LDC	Liquid crystal display
LDR	Light-dependent resistor
LED	Light-emitting diode
LEV	Low-emission vehicle
LF	Low frequency
LI	Load index
LIN	Local interconnect network
Li-ion	Lithium ion
LNG	Liquefied natural gas
LS	Limited slip
LSG	Laminated safety glass
LU	Logical unit
LV	Low voltage
LW	Long wave
MAF	Mass air flow
MAG	Metal active-gas (welding)
MC	Microcomputer
MC	Main cylinder
ME	Motor electronics
MED	Motor electronics direct injection
MG	Motor generator
MIG	Metal inert-gas (welding)
MIL	Malfunction indicator lamp
MODIC	Mobile diagnostic computer
MON	Motor octane number
MOST	Media oriented systems
MPI	Multipoint injection
MS	Medium-solid (paints)
MW	Medium wave
NEDC	New European driving cycle
NF	Non-ferrous
NIT	Network idle time
NLGI	National Lubricating Grease Institute
NTC	Negative temperature coefficient
OBD	On-board diagnostics
OD	Outside diameter
OHC	Overhead camshaft
OHV	Overhead valves
ON	Octane number
OV	Outlet valve
OVlft	Outlet valve left
OVrt	Outlet valve right
PBC	Parking brake circuit
PC	Polycarbonate, personal computer
PCD	Pitch circle diameter
PEM	Proton exchange membrane
PES	Poly ellipsoid system (reflector)
PHEV	Plug-in hybrid electric vehicle
PIN	Personal identification number
PM	Particulate matter
POF	Plastic optical fibre
POT	Plastic optical transceiver
PS	Pressure sensor
PTC	Positive temperature coefficient
PWM	Pulse width modulation
QA	Quality assurance
QM	Quality management
RA	Rear axle
RAM	Random access memory
RDS	Radio data system
RL	Rear left
RLFS	Return-less fuel system
RON	Research octane number
ROM	Read-only memory
ROP	Rollover protection
ROV	Rotating high voltage distribution (German: Rotierende Hochspannungs-verteilung)
RR	Rear right
RRC	Radio remote control
RUV	Static high voltage distribution (German: Ruhende Hochspannungs-verteilung)
SAC	Self-adjusting clutch
SAE	Society of Automotive Engineers
SAM	Signal acquisition and actuation module
SBC	Sensotronic brake control
SC	Signal conditioning
SCR	Selective catalytic reduction
SCV	Solenoid control valve
SDC	Semi-drop centre
SE	Sensor
SG	Strain gauge
SI	Safety inspection
SL	Special ledge
SLC	Select-low control
SoC	State of charge
SPI	Single-point injection
SRR	Short range radar
SRS	Safety restraint systems, supplemental restraint system
SSlft	Speed sensor left
SSrt	Speed sensor right
STP	Shielded twisted pair
STVZO	Straßenverkehrszulas-sungsordnung (Germany)
SUV	Sport Utility Vehicle
SV	Solenoid valve
SV	Side valve
SW	Short wave
SWR	Standing wave ratio
Tc	Transfer passage closes
TC	Turbocharger
TCS	Traction control system
TDC	Top dead centre
TIG	Tungsten-inert gas
TL	Tubeless
TMC	Traffic message channel
To	Transfer passage opens
TP	Transfer passage
TPC	Tyre pressure check, tyre pressure control
TSG	Tempered safety glass
TÜV	German technical inspection association
TWI	Tread wear indicator
UIS	Unit injector system
UPS	Unit pump system
VDC	Vehicle dynamics controller
VDR	Voltage-dependent resistor
VF	Variable focus (reflector)
VHF	Very high frequency
VI	Viscosity index
VT	Viscosity temperature
VTEC	Variable valve timing and lift electronic control
VTG	Variable turbine geometry

We wish to thank the companies listed below for providing technical advice, information, photographs and illustrations.

Alfa-Romeo Automobiles
Milan, Italy
ALLIGATOR Ventilfabrik GmbH
Giengen/Brenz, Germany
Aprilia Motorrad-Vertrieb
Düsseldorf, Germany
Aral AG, Bochum, Germany
Audatex Deutschland, Minden, Germany
Audi AG, Ingolstadt – Neckarsulm, Germany
Autokabel, Hausen, Germany
Autoliv, Oberschleißheim, Germany
G. Auwärter GmbH & Co
(Neoplan) Stuttgart, Germany
BBS Kraftfahrzeugtechnik AG,
Schiltach, Germany
BEHR GmbH & Co, Stuttgart, Germany
Beissbarth GmbH, Automobil Servicegeräte, Munich, Germany
BERU, Ludwigsburg, Germany
Aug. Bilstein GmbH & Co KG
Ennepetal, Germany
Boge GmbH, Eitdorf/Sieg, Germany
Robert Bosch GmbH, Stuttgart, Germany
Bostik GmbH
Oberursel/Taunus, Germany
BLACK HAWK, Kehl, Germany
BMW Bayerische Motoren-Werke AG
Munich/Berlin, Germany
CAR-OLINER, Kungsör, Sweden
CAR BENCH INTERNATIONAL.S.P.A.
Massa, Italy
Continental Teves AG & Co, OHG
Frankfurt, Germany
Celette GmbH, Kehl, Germany
Citroen Deutschland AG
Cologne, Germany
Dataliner Richtsysteme
Ahlerstedt, Germany
Deutsche BP AG, Hamburg, Germany
DUNLOP GmbH & Co KG
Hanau/Main, Germany
ESSO AG, Hamburg, Germany
FAG Kugelfischer Georg Schäfer KG aA
Ebern, Germany
J. Eberspächer, Esslingen, Germany
EMM Motoren Service, Lindau, Germany
Ford-Werke AG, Cologne, Germany
Carl Freudenberg
Weinheim/Bergstraße, Germany
GKN Löbro, Offenbach/Main, Germany
Getrag Getriebe- und Zahnradfarbrik
Ludwigsburg, Germany
Girling-Bremsen GmbH
Koblenz, Germany
Glasurit GmbH
Münster/Westphalia, Germany
Globaljig, Deutschland GmbH
Cloppenburg, Germany
Glyco-Metall-Werke B.V. & Co KG
Wiesbaden/Schierstein, Germany
Goetze AG, Burscheid, Germany
Grau-Bremse, Heidelberg, Germany
Gutmann Messtechnik GmbH
Ihringen, Germany
Hazet-Werk, Hermann Zerver
Remscheid, Germany

HAMEG GmbH, Frankfurt/Main, Germany
Hella KG, Hueck & Co
Lippstadt, Germany
Hengst Filterwerke, Nienkamp, Germany
Fritz Hintermayr, Bing-Vergaser-Fabrik
Nuremberg, Germany
HITACHI Sales Europa GmbH
Düsseldorf, Germany
HONDA DEUTSCHLAND GMBH
Offenbach/Main, Germany
Hunger Maschinenfabrik GmbH
Munich and Kaufering, Germany
IBM Deutschland, Böblingen, Germany
IVECO-Magirus AG, Neu-Ulm, Germany
ITT Automotive (ATE, VDO, MOTO-METER, SWF, KONI, Kienzle)
Frankfurt/Main, Germany
IXION Maschinenfabrik
Otto Häfner GmbH & Co
Hamburg-Wandsbeck, Germany
Jurid-Werke, Essen, Germany
Alfred Kärcher GmbH & Co. KG
Winnenden, Germany
Kawasaki-Motoren GmbH
Friedrichsdorf, Germany
Knecht Filterwerke GmbH
Stuttgart, Germany
Knorr-Bremse GmbH, Munich, Germany
Kolbenschmidt AG, Neckarsulm, Germany
KS Gleitlager GmbH
St. Leon-Rot, Germany
KTM Sportmotorcycles AG
Mattighofen, Austria
Kühnle, Kopp und Kausch AG
Frankenthal/Palatinate, Germany
Lemmerz-Werke, Königswinter, Germany
LuK GmbH, Bühl/Baden, Germany
MAHLE GmbH, Stuttgart, Germany
Mannesmann Sachs AG
Schweinfurt, Germany
Mann und Hummel, Filterwerke
Ludwigsburg, Germany
MAN Maschinenfabrik Augsburg-Nürnberg AG
Munich, Germany
Mazda Motors Deutschland GmbH
Leverkusen, Germany
MCC – Mikro Compact Car GmbH
Böblingen, Germany
Messer-Griesheim GmbH
Frankfurt/Main, Germany
Mercedes Benz, Stuttgart, Germany
Metzeler Reifen GmbH
Munich, Germany
Michelin Reifenwerke KGaA
Karlsruhe, Germany
Microsoft GmbH
Unterschleißheim, Germany
Mitsubishi Electric Europe B.V.
Ratingen, Germany
Mitsubishi MMC, Trebur, Germany
MOBIL OIL AG, Hamburg, Germany
NGK/NTK Europe GmbH
Ratingen, Germany
Adam Opel AG, Rüsselsheim, Germany
OSRAM AG, Munich, Germany
OMV AG, Vienna, Austria

Oxigin-, Carmanin-LM-Räder,
Unterensingen, Germany
Peugeot Deutschland GmbH
Saarbrücken, Germany
Pierburg GmbH, Neuss, Germany
Pirelli AG, Höchst im Odenwald, Germany
Dr. Ing. h.c. F. Porsche AG
Stuttgart-Zuffenhausen, Germany
Renault Nissan Deutschland AG
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SATA Farbspritztechnik GmbH & Co
Kornwestheim, Germany
SCANIA Deutschland GmbH
Koblenz, Germany
SEKURIT SAINT-GOBAIN
Deutschland GmbH, Aachen, Germany
Schäffler Automotive, Langen, Germany
Siemens AG, Munich, Germany
SKF Kugellagerfabriken GmbH
Schweinfurt, Germany
Snap-on/SNA Germany,
Hohenstein-Ernstthal, Germany
SOLO Kleinmotoren GmbH
Sindelfingen, Germany
SONAX GmbH, Neuburg, Germany
Stahlwille E. Wille
Wuppertal, Germany
Steyr-Daimler-Puch AG
Graz, Austria
Subaru Deutschland GmbH
Friedberg, Germany
SUN Elektrik Deutschland
Mettmann, Germany
Suzuki GmbH
Oberschleißheim/Heppenheim, Germany
Technolit GmbH, Großlüder, Germany
Telma Retarder Deutschland GmbH
Ludwigsburg, Germany
Temic Elektronik, Nuremberg, Germany
TOYOTA Deutschland GmbH
Cologne, Germany
UNIWHEELS GmbH
Bad Dürkheim, Germany
VARTA Autobatterien GmbH
Hannover, Germany
Vereinigte Motor-Verlage GmbH & Co KG
Stuttgart, Germany
ViewSonic Central Europe
Willich, Germany
Voith GmbH & Co KG
Heidenheim, Germany
Volkswagen AG, Wolfsburg, Germany
Volvo Deutschland GmbH
Brühl, Germany
Wabco Westinghouse GmbH
Hannover, Germany
Webasto GmbH, Stockdorf, Germany
Yamaha Motor Deutschland GmbH
Neuss, Germany
ZF Getriebe GmbH
Saarbrücken, Germany
ZF Sachs AG, Schweinfurt, Germany
ZF Zahnradfabrik Friedrichshafen AG
Friedrichshafen/Schwäbisch Gmünd, Germany

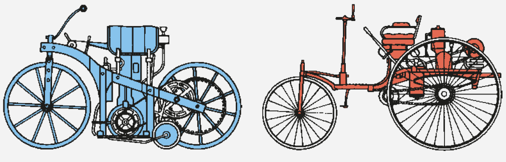
Table of contents

1 Motor vehicle

1.1 Evolution of the motor vehicle

1860 The Frenchman **Lenoir** constructs the first internal-combustion engine; this powerplant relies on city gas as its fuel source. Thermal efficiency is in the 3% range.

1867 **Otto and Langen** display an improved internal-combustion engine at the Paris International Exhibition. Its thermal efficiency is approximately 9%.



Daimler motorcycle, 1885
1 cylinder, 58 mm bore
100 mm stroke, 0.26 l
0.37 kW at 600 rpm, 12 km/h

Benz patented motor carriage, 1885
1 cylinder, 91.4 mm bore
150 mm stroke, 0.99 l
0.66 kW at 400 rpm, 15 km/h

Fig. 1: Daimler motorcycle and Benz motor carriage

1876 **Otto** builds the first gas-powered engine to utilise the **four-stroke compression cycle.** At virtually the same time **Clerk** constructs the first gas-powered **two-stroke engine** in England.

1883 **Daimler** and **Maybach** develop the first high-speed **four-cycle petrol engine** using a **hot-tube ignition system.**

1885 The first **automobile** from **Benz** (patented in 1886). First **self-propelled motorcycle** from **Daimler (Fig. 1).**

1886 First **four-wheeled motor carriage** with **petrol engine** from **Daimler (Fig. 2).**

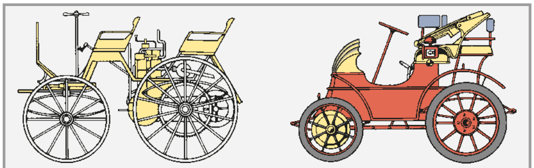
1887 **Bosch** invents the **magneto ignition.**

1889 **Dunlop** in England produces the first **pneumatic tyres.**

1893 **Maybach** invents the **spray-nozzle carburettor**. **Diesel** patents his design for a heavy oil-burning powerplant employing the self-ignition concept.

1897 **MAN** presents the first workable diesel engine.

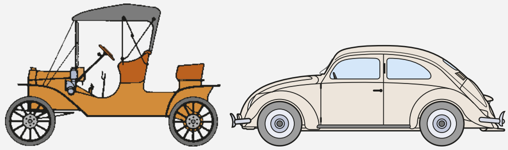
1897 First **Electromobile** from **Lohner-Porsche (Fig. 2).**



Daimler motor carriage, 1886
1 cylinder, bore 70 mm
Stroke 120 mm, 0.46 l
0.8 kW at 600 rpm, 18 km/h

Electromobile, 1897
Lohner-Porsche system
Transmission-free drive with
wheel-hub electric motor

Fig. 2: Daimler motor carriage and the first Electromobile



Ford Model T, 1908
2.9 l, 15.7 kW at
1,600 rpm, 70 km/h

VW Beetle, 1938
985 cc, 17.3 kW at
3,000 rpm, 100 km/h

Fig. 3: Ford Model T and VW Beetle

1913 **Ford** introduces the **production line** to automotive manufacturing. Production of the **Tin Lizzy** (Model T, **Fig. 3).** By 1925, 9,109 were leaving the production line each day.

1916 The **Bavarian Motor Works** are founded.

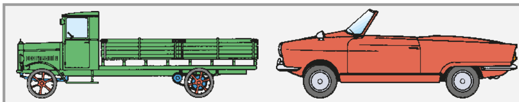
1923 First **motor lorry** powered by a **diesel engine** produced by **Benz-MAN (Fig. 4).**

1936 **Daimler-Benz** inaugurates series-production of passenger cars propelled by **diesel engines.**

1938 The **VW Works** are founded in Wolfsburg.

1949 First **low-profile tyre** and first **steel-belted radial tyre** produced by **Michelin.**

1954 **NSU-Wankel** constructs the **rotary engine (Fig. 4).**



Benz-MAN truck, 5 K 3
1st diesel truck, 1923

NSU Spider with Wankel
engine, 1963, 500 cc,
37 kW at 6,000 rpm, 153 km/h

Fig. 4: Diesel-engined lorry Passenger car with Wankel rotary engine

1966 **Electronic fuel injection (D-Jetronic)** for standard production vehicles produced by **Bosch.**

1970 **Seatbelts** for driver and front passengers.

1978 Mercedes-Benz installs the first **Antilock Braking System (ABS)** in vehicles.

1984 Debut of the **airbag** and **seatbelt tensioning system.**

1985 Advent of a **catalytic converter** designed for operation in conjunction with closed-loop mixture control, intended for use with unleaded fuel.

1997 Electronic **suspension control systems (ESP).** Toyota builds first passenger car with a **hybrid drive. Alfa Romeo** introduces the **common-rail direct injection (CRDI) system** for diesel engines.

As of 2000 **Advanced driver assistance systems**, such as parking assistance, distance warning systems, lane change assistance.

1

1.2 Motor vehicle classifications

Road vehicles is a category comprising all vehicles designed for road use, as opposed to operation on tracks or rails **(Fig. 1)**.

There are basically two vehicle classes: motor vehicles and trailers. Motor vehicles always possess an integral mechanical propulsion system.

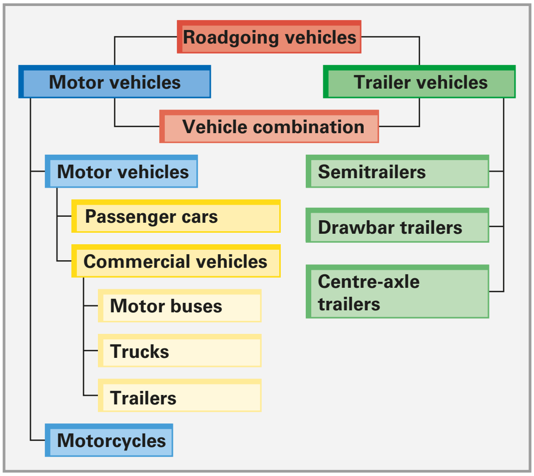


Fig. 1: Overview of road vehicles

Dual-track vehicles

Motor vehicles with more than two wheels can be found in dual-track and multiple-track versions. These include:

- **Passenger cars.** These are primarily intended for use in transporting people, as well as their luggage and other small cargo. They can also be used to pull trailers. The number of seats, including that of the driver, is restricted to nine.
- **Commercial vehicles.** These are designed to transport people and cargo and for pulling trailers. Passenger cars are not classified as commercial vehicles.

Single-track vehicles

Motorcycles are single-track vehicles with 2 wheels. A sidecar may be attached to the motorcycle, which remains classified as such provided that the unladen weight of the combination does not exceed 400 kg. A motorcycle can also be employed to pull a trailer. Single-track vehicles include:

- **Motorcycles.** These are equipped with permanent, fixed-location components (fuel tank, engine) located adjacent to the knees as well as footrests.
- **Motor scooters.** Since the operator's feet rest on a floor board, there are no fixed components at knee level on these vehicles.
- **Bicycles with auxiliary motors.** These vehicles share the same salient features as bicycles, e.g. pedals (mopeds, motorised bicycles, etc.).

1.3 Design of the motor vehicle

The motor vehicle consists of component assemblies and their individual components.

The layout of the individual assemblies and their relative positions is not governed by invariable standards. Thus, for example, the engine may be designed as an independent assembly, or it may be integrated as a subassembly within a larger powertrain unit.

One of the options described in this book is to divide the vehicle into 5 main assembly groups: engine, drivetrain, chassis, vehicle body and electrical system.

The relationships between the assemblies and their constituent components are illustrated in **Fig. 2.**

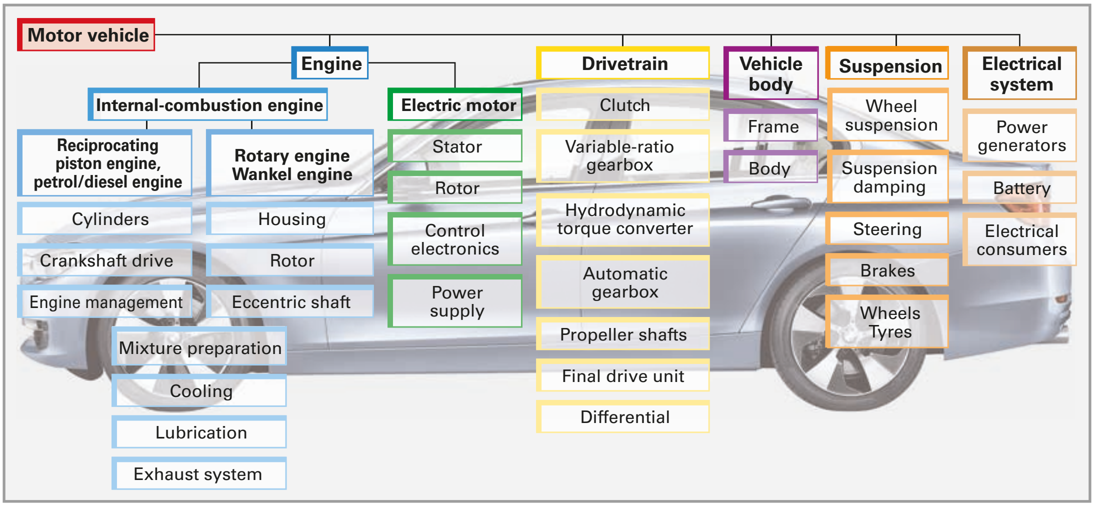


Fig. 2: Design of the motor vehicle

1.4 The motor vehicle as technical system

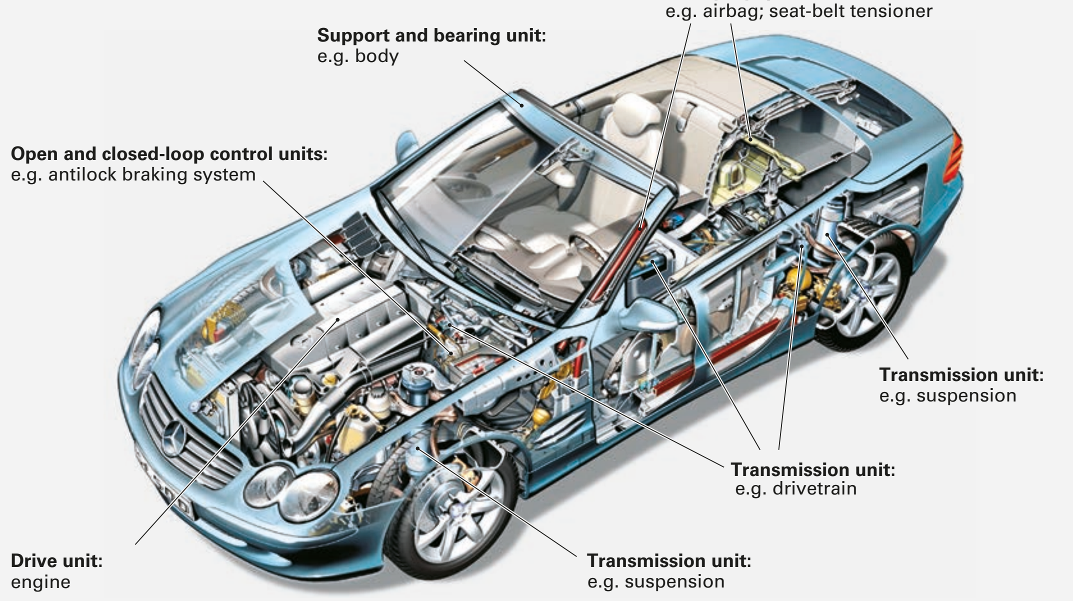


Fig. 1: The motor vehicle as a system with operational units

1.4.1 Technical systems

Every machine forms a complete technical system.

Characteristics of technical systems:
- Defined system borders delineate their limits relative to the surrounding environment.
- They possess input and output channels.
- The salient factor defining system operation is the total function, and not the individual function, which is discharged internally, within the system.

The rectangle in the figure represents the technical systems **(Fig. 2)**.

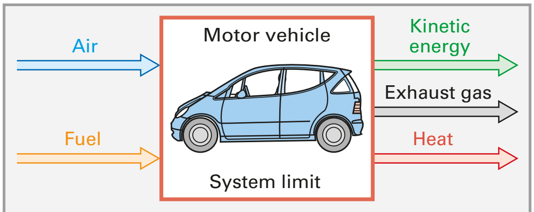


Fig. 2: Example of a basic system using a motor vehicle

Input and output variables are represented by arrows. The number of arrows varies according to the number of input and output variables.

The smaller rectangle symbolises the **system limit** (hypothetical boundary) separating each individual technical system from the other systems and/or the surrounding environment.

The distinctive, defining features of individual systems include:
- **I**nput (input variables or parameters) entering from beyond the system limits
- **P**rocessing within the system limits
- **O**utput (output variables or parameters) issued and relayed to destinations lying outside the limits of the system **(IPO concept)**

1.4.2 Motor vehicle system

The motor vehicle is a complex technical system in which various subsystems operate in harmony to fulfil a defined function.
The function of the passenger car is to transport people, while the function of the motor lorry, or truck, is to carry cargo.

Operational units within the motor vehicle

Systems designed to support operational processes are combined in operational units **(Fig. 1)**. Familiarity with the processes performed in operational units such as the engine, drivetrain, etc. can enhance our

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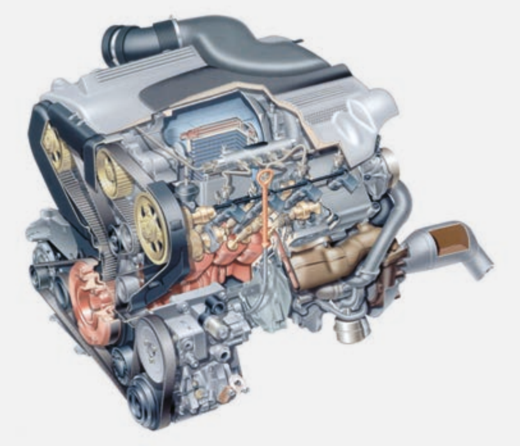
understanding of the complete system represented by the motor vehicle in its implications for maintenance, diagnosis and repair.

The concept is suitable for application with any technical system. Among the **operational units** that comprise the motor vehicle are the:

- Power unit
- Power-transfer assembly
- Support and load-bearing structure
- Electro-hydraulic systems
  (open and closed-loop control systems, etc.)
- Electrical and electronic systems
  (such as safety devices)

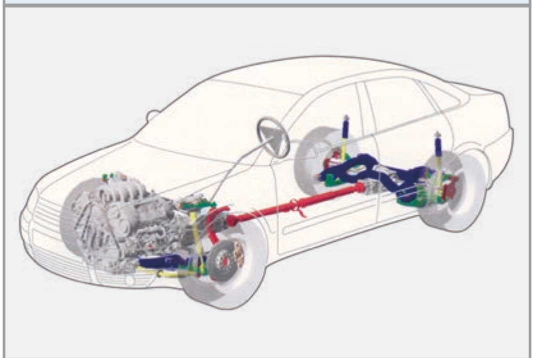
Each operational unit acts as a subsystem by assuming a specific function.

Operational unit: Power unit – engine



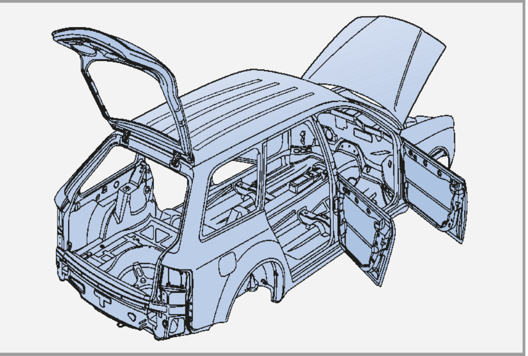
Subfunction: Provides energy for propulsion purposes

Operational unit: Power-transfer assembly, such as drivetrain



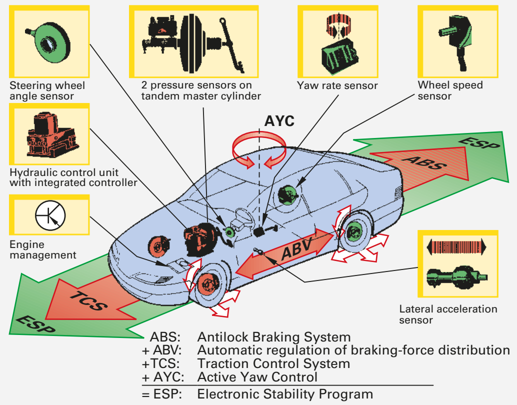
Subfunction: Relays mechanical energy from the power unit to the drive wheels

Operational unit: Vehicle structure as support structure, exemplified by body



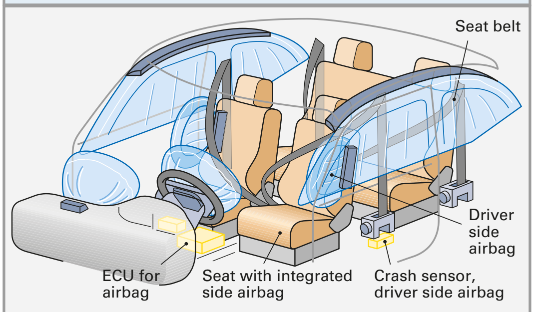
Subfunction: Support function, support for all subsystems

Operational unit: Electro-hydraulic systems (open and closed-loop control systems, such as ABS, ESP, etc.)



Subfunction: Active occupant protection, improvements in dynamic response

Operational unit: Electr., electron. systems (safety and security devices, such as airbags, seatbelt tensioners)



Subfunction: Passive protection for vehicle occupants

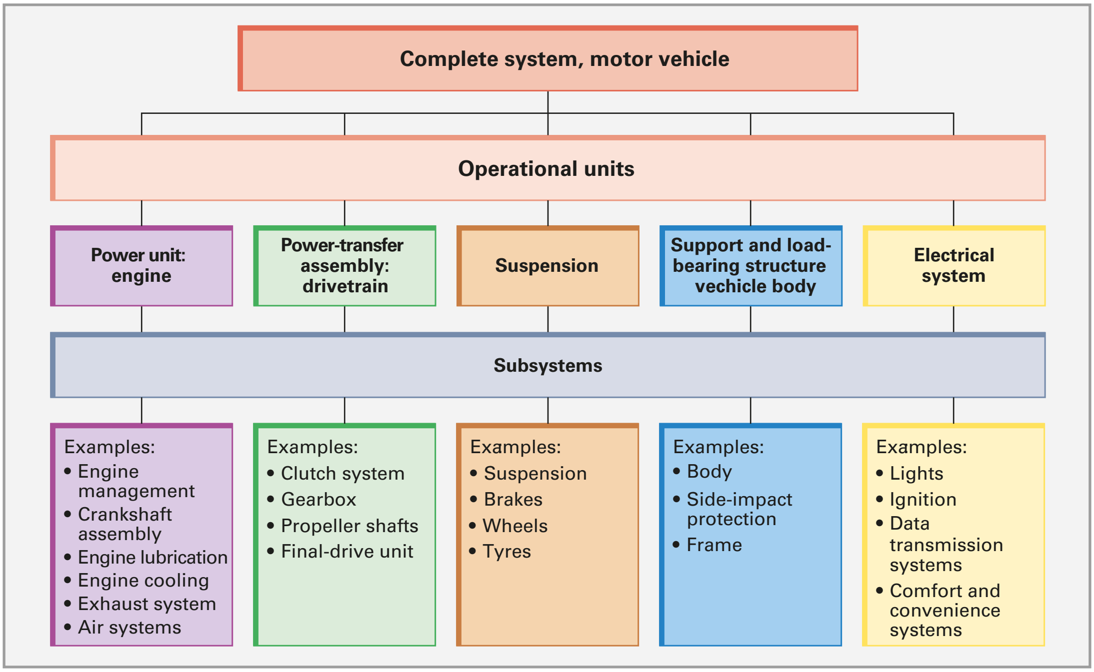


Fig. 1: The motor vehicle as composite system

Various subsystems must operate together for the motor vehicle to perform its primary functions **(Fig. 1)**. Reducing the scale of the system's limits shifts the focus to progressively smaller subsystems, ultimately leading to the level of the individual component.

The motor vehicle as a complete system

Defining the limits of the system to coincide with those of the overall vehicle produces boundaries in which the system's limits border on environmental entities such as air and the road surface. On the input side, air and fuel are the only factors entering from beyond the system's limits, while exhaust gas joins kinetic and thermal energy outside this boundary on the output side **(Fig. 2, Fig. 3)**.

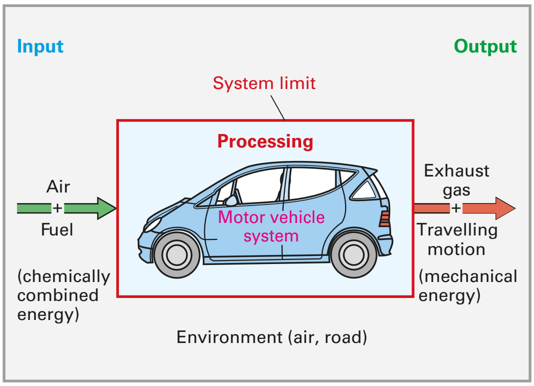


Fig. 2: System: Motor vehicle

1.4.3 Subsystems in the motor vehicle

Each subsystem is subject to the **IPO** concept **(Fig. 3)**.

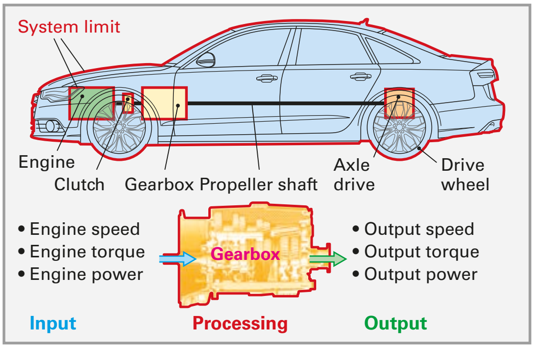


Fig. 3: Subsystem: Gearbox

Input. The factors operating on the input side of the gearbox are engine speed, engine torque and engine power.

Processing. The crankshaft's rotational speed and the transferred torque are converted in the gearbox.

Output. The elements exiting the subsystem on the output side include output-shaft speed, output torque and output power as well as heat.

Efficiency level. The efficiency of the drivetrain is reduced by energy losses sustained within the gearbox.

The "gearbox" subsystem is connected to the drive wheels via other subsystems, such as the propeller shaft, final-drive unit, and half shafts.

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1.4.4 Classifications of technical systems and subsystems by processing mode

Technical systems **(Fig. 1)** are classified according to the type of processing within overall systems:

- Material-processing systems such as the fuel-supply system
- Energy-processing systems such as the internal-combustion engine
- Information-processing systems such as the on-board computer, the steering system, etc.

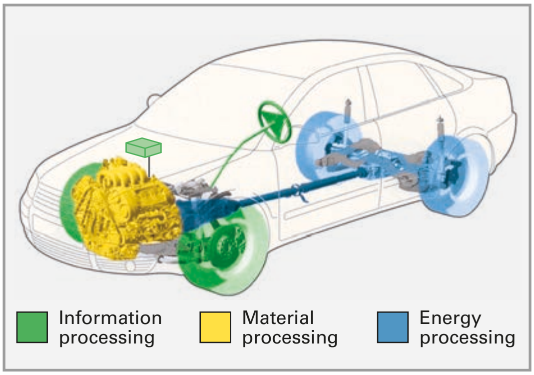

Fig. 1: Systems classified according to processing mode

Material-processing systems

Material-processing systems modify materials in their geometrical configuration (reshape) or transport them from one position to another (re-position).

Transport media and basic machinery are employed to convey substances and materials. Machine tools assume responsibility for shaping materials. To cite an example: in the material-transport process, a pump induces motion in a static fluid (gasoline in the fuel tank) in order to transport it to the fuel-injection system. For this purpose, electrical energy must be supplied to the operational machinery, such as a fuel pump, that is responsible for the process.

Overview of material-processing systems:

Machines for reshaping include machine tools such as drills, mills and lathes as well as the equipment found in foundries and stamping plants such as metal presses.

Machines for repositioning include all conveyors, transporters and machines used to transport solid materials (conveyor belts, fork lift trucks, trucks, passenger cars), liquids (pumps) and gases (fans, turbines).

Examples of material-processing systems within the motor vehicle:

- Lubrication system, in which the oil pump provides the motive power for material propulsion.
- Cooling system, in which the water pump transports a medium to support thermal transfer.

Energy-processing systems

Energy-processing systems transform energy from an external source from one form into another.

This class embraces all manner of power-generation machines, including internal-combustion engines and electric motors, steam engines and gas power plants, as well as energy units such as heat pumps, photovoltaic systems and fuel cells. In the realm of energy conversion the operative distinction is between:

- **Heat engines,** such as spark-ignition and diesel engines, and gas turbines
- **Hydraulically powered machines,** such as water turbines
- **Wind-energy devices,** such as wind-powered generators
- **Solar-energy converters,** such as photovoltaic systems
- **Fuel cells**

Within the internal-combustion engine, the fuel's chemical energy is initially converted into thermal energy before undergoing a second transformation to emerge as kinetic energy **(Fig. 2)**.

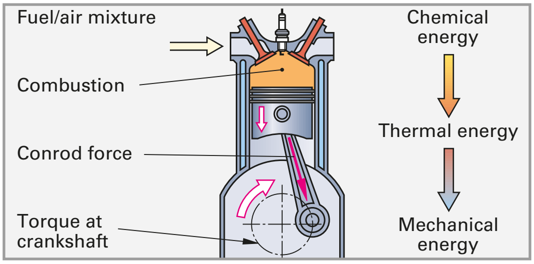

Fig. 2: Energy processing in the spark-ignition engine

This process can generate additional substances and information. Since these are of secondary importance in the operation of the energy-processing machine, they are not usually primary objects of attention.

The flow of substances and materials (entry of fuel and emission of exhaust gases) and the flow of information (fuel/air mixture, engine-speed control, steering, etc.) all assume the role of secondary functions.

Energy-processing system. The primary focus is on converting chemical energy contained in fuel into kinetic energy to propel the vehicle, with the **internal-combustion engine** serving as the energy-processing system.

Information-processing systems

> These systems monitor, process and relay information and data and support communications.

Information-processing and relay systems, such as electronic control units (ECU), CAN bus controllers and diagnostic equipment (testers) assume vital significance in the maintenance of modern vehicles.

Information. Knowledge concerning conditions and processes. Examples within the vehicle include information on engine temperature, driving speed, load factor, etc. required to support vehicle operation. This information can be relayed from one electronic control unit to another. The data are registered in the form of signals.

Signals. Signals are data portrayed in physical form. Within the motor vehicle, sensors generate signals to represent parameters such as rotational speed, temperature and throttle-valve position.

Examples of information-processing systems in motor vehicles:

- **Engine control unit.** The engine-management ECU registers and processes an entire array of relevant data in order to adapt engine performance to provide ideal operation under any given conditions.
- **On-board computer.** Among its functions are to furnish the driver with information on average and current fuel consumption, estimated cruising range, average speed and outside temperature.

1.4.5 Using technical systems

Extensive familiarity with technical systems is essential for the operation and maintenance of motor vehicles. The manufacturer provides operating instructions (owner's manual) to help ensure that its vehicles operate in an environmentally responsible manner with optimal safety, security and reliability.

Operating instructions contain, among other information:

- System descriptions
- Explanations of functions and operation
- System illustrations
- Operating diagrams
- Instructions on correct operation and use of the controls
- Maintenance and service inspection schedules
- Instructions for responding to malfunctions
- Information on approved fluids, lubricants and service products, such as engine oils
- Technical data
- Emergency service addresses

Operation. Motor vehicles and machines should be operated by qualified and duly-authorised persons only.

Applicable stipulations include the following:

- The driver of a passenger car operating on public roads must be in possession of the regular driving licence required in the country of operation.
- Lift platforms and hydraulic hoists in automotive service facilities are to be operated exclusively by individuals over 18 years of age who have also received corresponding instruction in and authorisation for its use.
- The driver of a truck equipped with a crane must be in possession of a crane operator's licence.

This stipulation is intended to ensure that drivers of crane-equipped trucks have received the required training for operating lifts and hoisting equipment, and will provide the vehicle with the correct supplementary support **(Fig. 1)** while simultaneously observing all applicable accident-prevention regulations and operating the crane in a professional manner.

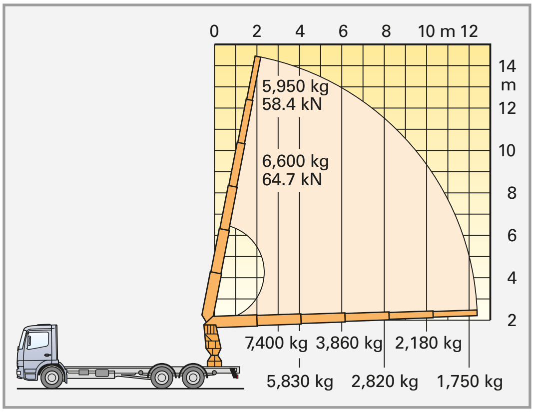

Fig. 1: Correct load distribution on a crane hoist

REVIEW QUESTIONS

1. **What are the parameters that define a technical system?**
2. **What is the IPO concept?**
3. **What are the different operational units in the motor vehicle?**
4. **Name three subsystems in the motor vehicle, and describe the corresponding input and output variables.**
5. **What is the primary function of an energy-processing system?**
6. **What information is available in the operating instructions (vehicle owner's manual)?**

1.5 Service and maintenance

Professional-quality service and maintenance, performed in accordance with the manufacturer's instructions (by the factory service organisation, etc.) are vital elements in ensuring continued vehicle safety and in maintaining the validity of the manufacturer's warranty.

Manufacturers issue **service and maintenance schedules**, spare part catalogues and **repair instructions** to guide and support these activities. This documentation is available in many forms, including menu-guided computer programs designed to run on personal computers (PCs).

Service and maintenance. Service procedures include:

- Inspections, such as test procedures
- General maintenance, comprising oil changes, lubrication and cleaning
- Remedial action, such as repairs and component replacement

Aftersales service. Vehicle manufacturers and automotive repair operations offer professional services to their customers. The services offered by these facilities include performing the prescribed preparations on new vehicles prior to delivery to the customer. Professional technicians also carry out service and maintenance work that the vehicle operator may not be able to perform. In the official service and maintenance guidelines the manufacturer defines an action catalogue intended to ensure unrestricted functionality and maintain the vehicle's value. The individual procedures are contained in the service and maintenance schedules for the specific vehicles.

Service intervals can be defined according to the following criteria:

- Fixed service intervals (maintenance schedule)
- Flexible service intervals
- Demand-based service concepts

Service, maintenance and inspection operations must be performed in accordance with defined schedules. Once operations have been carried out, they should be confirmed in a service record and signed by the responsible service technician.

Maintenance schedule

This provides information on the specified service and inspection intervals by specifying (for example) a major inspection every 20,000 km or 12 months.

Service inspection schedule. This schedule defines the contents and lists the procedures included in the service inspection **(Fig. 1, Page 19)**.

Flexible service intervals

Modern engine-management systems have allowed the advent of a new service concept characterised by adaptive scheduling. This concept reflects each individual vehicle's requirements based on its actual operating conditions. In addition to mileage, the system records and evaluates a variety of other factors (influencing variables) for inclusion in its calculations. A display then provides the driver with prompt notice as the inspection date approaches **(Fig. 1).** The process culminates with execution of the prescribed operations at the service facility in accordance with the service inspection schedule **(Fig. 1, Page 19).**

Oil change intervals. Two methods are available for defining oil change intervals:

- A virtual database, derived from such factors as mileage, overall fuel consumption and oil temperature curves, provides an index indicating how much the oil ages over a given period.
- The actual condition of the oil, meaning the quality and level of the oil as determined via the oil level sensor, in combination with the mileage and the registered engine load factors.

Brake pad wear. Brake pad wear is monitored electrically. When the brake pad reaches its wear limit a contact wire within the pad is perforated. The system then considers such factors as braking frequency, the duration of brake actuations and mileage in calculating the theoretically available mileage reserves, which are then reflected in the replacement intervals displayed to the driver.

Interior compartment filter wear status. Data gleaned from the outside air temperature sensor, information on heater use, use of the recirculated-air mode, vehicle speed, fan blower speed, mileage and dates all flow into calculations to determine the period remaining until the dust and pollen filter will be due for replacement.

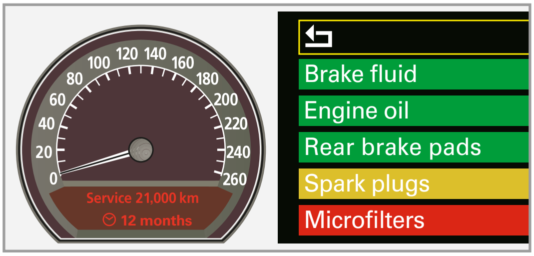

Fig. 1: Wear indicators

Spark plug replacement intervals are still based on a specific mileage, such as replacement after 100,000 km.

Replacement dates for **fluids and lubricants**, such as the coolant and brake fluid, are defined according to time, for instance, at intervals of 2 or 4 years.

Demand-based service concepts

The service date is calculated on the basis of data collected on the actual condition of wearing parts, fluids and lubricants, as well as information on the vehicle's operating conditions. When defined by this demand-based service concept, service and maintenance are carried out only when needed, for instance, when a component reaches its wear limit, or a fluid or lubricant has reached the end of its service life.

On-board computers now feature the ability to transmit coded data on the customer and the extent of the required service to the service facility. This gives the service representative time to order any required replacement parts such as brake pads and to consult with the customer in advance about a convenient service date.

Early recognition of potential problems should help avoid repairs stemming from vehicle breakdowns. Additional advantages include:

- Precisely defined dates
- Minimal waiting times
- No data loss
- Flexible service

Service inspection schedule		
Job no.: 900109	Vehicle model: Passat	Vehicle owner: Smith
km reading/ mileage: 53,400	Vehicle age: 3	Additional work, e.g. emissions inspection: ....

Servicing to be carried out	OK	Not OK	Rectified
Electrical system			
Front lights. Check function: Parking lights, dipped beam, main beam, fog lamps, direction indicators and hazard-warning signals			
Rear lights. Check function: Brake lights, tail lights, reversing lights, fog lamps, number plate lights, luggage compartment light, parking lights, turn indicators and hazard warning signals			
Interior and glove-compartment lights, cigarette lighter, signal horn and indicator lamps: Check function			
Self-diagnosis: Interrogate fault memories of all systems (insert printout at back of logbook wallet)			
Vehicle from the outside			
Door arresters and retaining bolts: Lubricate			
Windscreen wash/wipe system and headlight washer system: Check function and spray-nozzle setting			
Windscreen wiper blades: Check for damage, check home position; in event of rubbing wiper blades: Check contact angle			
Tyres			
Tyres: Check condition, tyre tread pattern and inflation pressure, enter tread depth			
FL ______ mm FR ______ mm			
RL ______ mm RR ______ mm			
Vehicle from below			
Engine oil: Drain or draw off, replace oil filters			
Engine and components in engine compartment: Visually check for leaks and damage			
V-belts, ribbed V-belts: Check condition and tension			
Gearbox, final-drive unit and joint boots: Visually check for leaks and damage			
Manual gearbox / axle drive: Check oil level			
Brake system: Visually check for leaks and damage			
Front and rear brake pads: Check thickness			
Undercoating: Visually check for damage			
Exhaust system: Visually check for leaks and damage			
Track-rod ends: Check play, mounting and sealing gaiters; axle joints: Visually check sealing gaiters for leaks and damage			
Engine compartment			
Engine oil: Check oil level (during inspection service with filter change, change oil)			
Engine and components in engine compartment (from above): Visually check for leaks and damage			
Windscreen wash/wipe system: Top up fluid			
Cooling system: Check coolant level and antifreeze; setpoint value: –25°C			
Actual value (measured value): ______°C			
Dust and pollen filter: Replace filter element (every 12 months or every 15,000 km)			
Toothed belt for camshaft drive: Check condition and tension			
Air filter: Clean housing and replace filter element			
Fuel filter: Replace			
Power steering: Check fluid level			
Brake-fluid level (dependent on brake-pad wear): Check			
Battery: Check			
Idle speed: Check			
Headlight adjustment / documentation / final inspection			
Headlight adjustment: Check			
Service sticker: Enter date/mileage for next service (also brake-fluid renewal) on sticker and attach sticker to door pillar (B-pillar)			
Take vehicle for test drive			
Date / Signature (mechanic)			
Date / Signature (final inspection)			

Fig. 1: Service inspection schedule

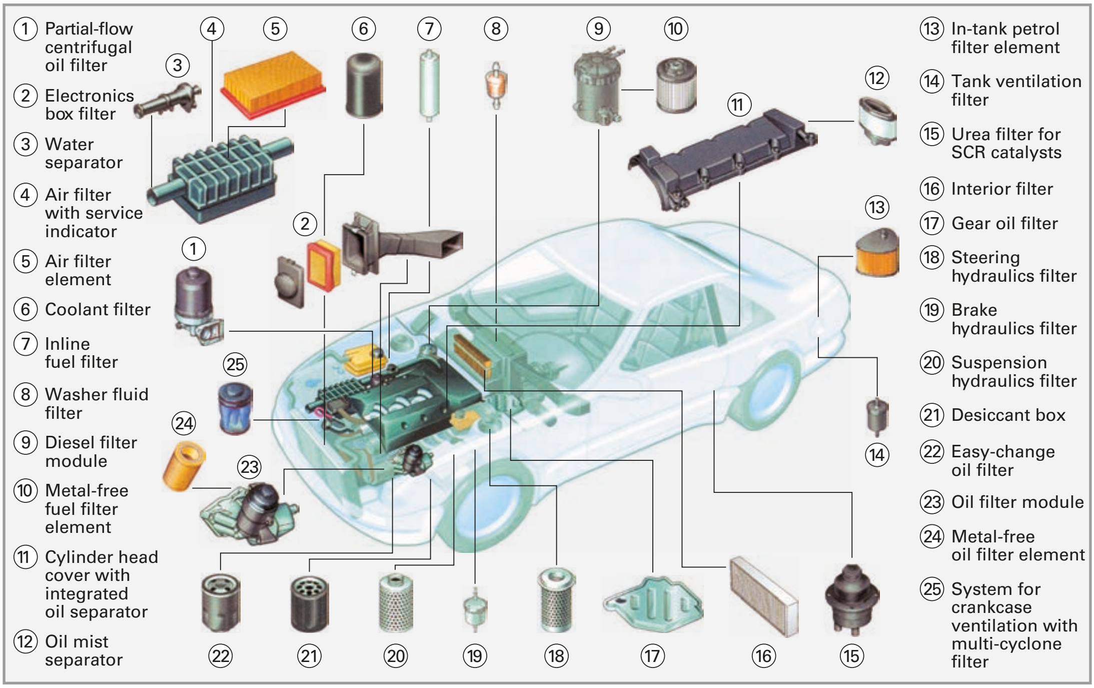

Fig. 1: Filters in modern motor vehicles

1.6 Filters, composition and maintenance

Filters installed in the motor vehicle protect the engine, other vehicle components, and the air of the vehicle's occupants against contaminants and impurities.

Motor vehicle filters **(Fig. 1)** can be classified according to two criteria: the **filtration concept** and the **medium** being filtered.

Filtration concepts. Solid contaminants are filtered from flowing media such as air, oil, fuel and water by:

- screen filtration, using sieve-type filter screens and fibre filters, etc.
- adhesive filtration, including wet filters
- magnetic filtration, as with magnetic separators
- centrifugal filtration, with centrifugal filters, etc.

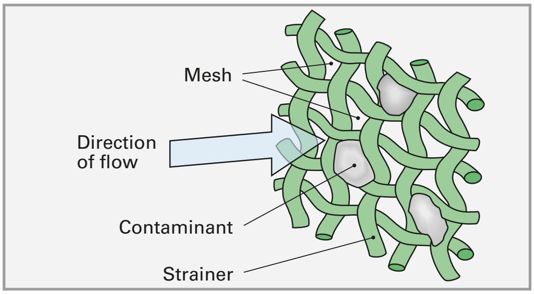

Fig. 2: Illustration of how the fine-mesh filter works

Strainers (filter screens). Filter mesh dimensions smaller than the contaminants facilitate filtration **(Fig. 2)**.

Adhesive filters. These are usually wet air filters. Contaminants such as dust adhere to the filter surface on contact.

Magnetic filter. The filter (for instance, on the oil drain plug) attracts and retains ferromagnetic contaminants suspended in the flowing medium.

Centrifugal filter. The object medium (such as air) is placed in a state of rotation. Centrifugal force propels the contaminants onto the filter's walls, where they settle as deposits.

Filter types include:

- Air and exhaust-gas filters
- Fuel filters
- Filters for lubricating oils
- Interior filters, such as pollen, smog and ozone filters
- Hydraulic filters, for ATF, etc.

1.6.1 Air filters

The purpose of the air filter is to purify induction air while simultaneously subduing induction roar.

Airborne dust particles are minute in size (0.005 mm to 0.05 mm). The air can also contain quartz. Dust concentrations vary considerably according to vehicle operating conditions (motorway, construction site). Should it enter the oil, this dust would form an abrasive film, leading to extreme wear, especially on the cylinder walls, the pistons and the valve guides.