ABS antilock braking systems for passenger cars

ABS antilock braking systems are closed-loop control devices within the braking system which prevent wheel lock-up during braking and, as a result, retain the vehicle's steerability and stability. The main ABS components are:

Hydraulic modulator, wheel-speed sensors, and the ECU for signal processing and control and triggering of the signal lamp and of the actuators in the hydraulic modulator.

Basic closed-loop control process

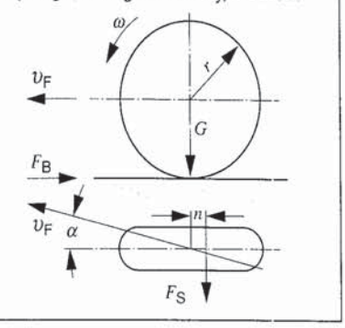
On initial braking, the brake pressure is increased; the brake slip λ rises and at the maximum point on the adhesion/slip curve, it reaches the limit between the stable and unstable ranges. From this point on, any further increase in brake pressure or braking torque does not cause any further increase in the braking force F_B. In the stable range, the brake slip is largely deformation slip, it increasingly tends towards skidding in the unstable range.

Brake slip $\lambda = (\upsilon_F - \upsilon_R)/\upsilon_F \cdot 100\,\%$
Wheel speed $\upsilon_R = r \cdot \omega$
Braking force $F_B = \mu_{HF} \cdot G$
Lateral force $F_S = \mu_S \cdot G$
μ_{HF} Coefficient of friction,
μ_S Lateral-force coefficient.

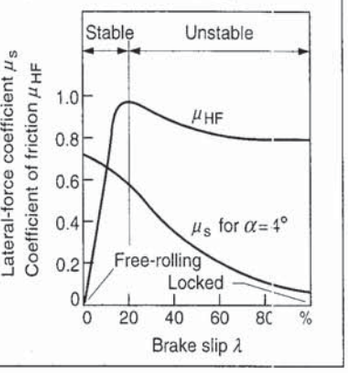
There is a more or less sharp drop in the coefficient of friction μ_{HF}, depending upon the shape of the slip curve. The resulting excess torque causes the wheel to lock-up very quickly (when braking without ABS); this is expressed as a sharp increase in wheel deceleration.

The wheel-speed sensors monitor the motion of the wheels. If one of the wheels shows signs of lock-up, there is a sharp rise in peripheral wheel deceleration and in wheel slip. If these exceed defined critical values, the controller sends commands to the solenoid-valve unit to stop or reduce the buildup of wheel-brake pressure until the danger of lock-up has passed. The brake pressure must then be built up again in order to ensure that the wheel is not underbraked. During automatic brake control, it is constantly necessary for the stability or instability of the wheel motion to be detected, and the

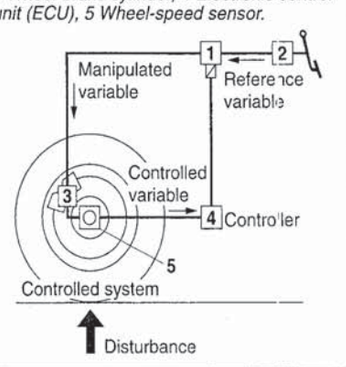
Forces at the braked wheel
G Force due to weight, F_B Braking force, F_S Lateral force, υ_F Vehicle speed, α Slip angle, ω Angular velocity, n Caster.



Adhesion/slip curve
The curve shape differs greatly as a function of road surface and tire condition.



ABS control loop
1 Solenoid-valve unit, 2 Master cylinder, 3 Wheel-brake cylinder, 4 Electronic control unit (ECU), 5 Wheel-speed sensor.



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

wheel must be kept in the slip range with maximum braking force by a succession of pressure-buildup, pressure-reduction and pressure-holding phases.

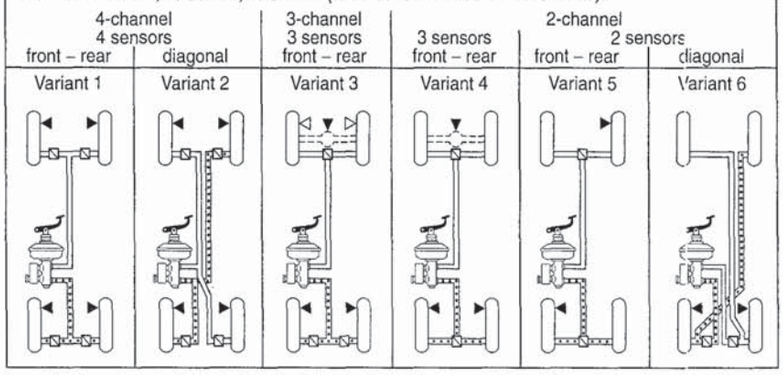
Disturbances in the closed control loop
The ABS system must take the following disturbances into account:
- Changes in the adhesion between the tires and the road surface caused by different types of road surface and changes in the wheel loadings, e.g. when cornering,
- Irregularities in the road surface causing the wheels and axles to vibrate,
- Out-of-roundness, brake hysteresis, brake fading,
- Variations in the pressure input to the master cylinder caused by the driver's brake-pedal actuation,
- Differences in wheel circumferences, for instance when the spare wheel is fitted.

Criteria of control quality
The following criteria for control quality must be fulfilled by efficient antilock braking systems:
- Maintenance of driving stability through provision of sufficient lateral guiding forces at the rear wheels.
- Maintenance of steerability through provision of adequate lateral guiding forces at the front wheels.
- Reduction in stopping distance as opposed to braking with locked-up wheels through optimum utilization of the adhesion between tires and road.
- Rapid matching of the braking force to different adhesion coefficients, for instance when driving through deep water or driving over patches of ice or hard snow.
- Guaranteeing low braking-torque control amplitudes to prevent vibrations in the running gear.
- High level of comfort due to silent actuators and low feedback through the brake pedal.

ABS system variants
A variety of versions are available depending upon the braking-force-distribution concept, the type of vehicle drive concerned, functional stipulations, and costs factor. The overview below shows six system variants, which are described in the following according to the number of channels and sensors.

4-channel systems (variants 1, 2)
These systems permit the individual control of the wheel-brake pressure of each wheel for the rear axle/front axle (II) and for the diagonal (X) braking-force-distribution concepts. When braking on split-coefficient road surfaces though, measures must be taken to ensure that the yaw moment (torque around the vertical axis) cannot adversely affect driving stability. The solution here is to control the wheels on the front axle individually and those on the rear axle in accordance with the "select-low" principle (that is, the rear wheel

ABS system variants
▨ Control channel, ◀ Sensor, ◁ Sensor (alternative to sensor on differential).



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

with the lowest coefficient of friction determines the braking pressure applied to both rear wheels).

3-channel system (variant 3)
The yaw moment when braking on split-coefficient road surfaces is reduced to such an extent (due to the system's operating principle) that passenger cars with a long wheelbase, and a high moment of mass inertia about the vertical axis, are well able to control this braking situation.

In the case of the 3- and 4-channel systems, passenger cars with a short wheelbase and a low moment of mass inertia, however, require electronic delay of the yaw-moment buildup. When braking on split-coefficient road surfaces, this causes a delayed buildup of the braking torque at the front wheel with the high coefficient of friction. As a result, the driver has enough time to correct the yaw by an appropriate steering adjustment.

2-channel systems (variants 4, 5, 6)
The 2-channel systems on the one hand need less components than the 3- and 4-channel versions, and this makes them less costly to manufacture. On the other hand though, this is accompanied by a number of functional limitations.

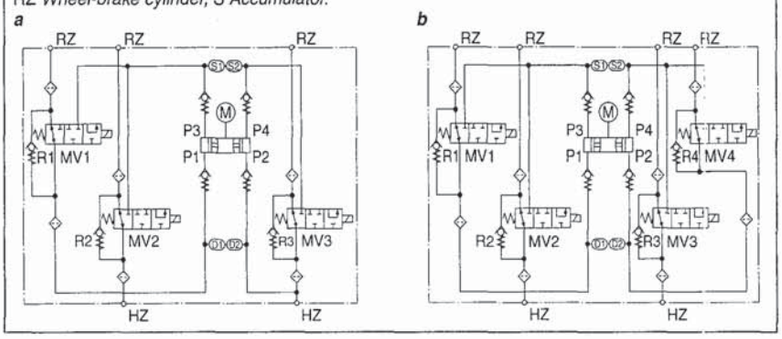
With variant 4 in the select-high mode (the front wheel with the higher coefficient of friction determines the brake pressure applied jointly to both front wheels), practically every time the driver hits the brakes hard (panic braking), one of the front wheels locks up. This is accompanied by a high level of tire wear and reduced steerability. With version 5, this always occurs when the "sensed" front wheel suddenly encounters a higher level of friction coefficient than the "non-sensed" wheel. Variant 6 can be used only with diagonal braking-force distribution (X). In this version, the brake pressures at the front wheels are controlled individually, while the brake pressures at the rear wheels are jointly controlled. Because the front-to-rear distribution of braking force bears the responsibility for ensuring that the rear wheels do not lock, this system provides somewhat lower deceleration rates than a 3- or 4-channel system.

Note: For some light-truck models with front-rear brake-circuit split in the American market there is a simple system consisting of a sensor on the rear differential and a control channel (without return pump) which prevents the rear wheels locking. The front wheels can lock up with sufficiently high braking pressures with the consequent loss of steering function. This system is not an ABS with the range of functions described at the beginning of this section and is used only for certain specialized types of vehicle.

ABS versions

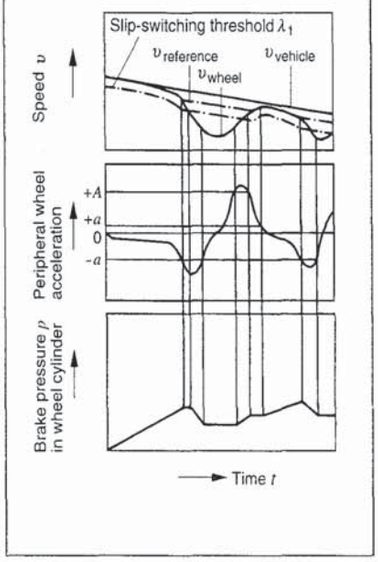
ABS 2S-3-channel/-4-channel systems (Bosch)
In this system, the ABS and the brake booster are separate units.

Functional diagrams
a) Three-channel hydraulic modulator, b) Four-channel hydraulic modulator.
D *Damper,* HZ *Master cylinder,* M *Electric motor,* MV *Solenoid valve,* P *Pump, R Control channel,* RZ *Wheel-brake cylinder,* S *Accumulator.*



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

ABS control cycle for high friction coefficients



The 3-channel hydraulic modulator for the II braking-force-distribution version (front/rear) comprises three solenoid valves with three possible positions, and a return pump with electric drive motor.

In the first, de-energized position, there is an unhindered passage from the master cylinder to the wheel-brake cylinder, with the result that the wheel-brake pressure rises during initial braking and during automatic brake control. In the second, semi-energized position, the passage from the master cylinder to the wheel-brake cylinder is interrupted, with the result that the wheel-brake pressure is kept constant. In the third, fully energized position, the wheel-brake cylinder is connected to the return and the wheel-brake pressure drops.

Pressure dissipation takes only about 20 ms so that the wheel does not lock up; pressure build-up, on the other hand, takes place in several stages with intervening holding phases and typically takes around 200 ms.

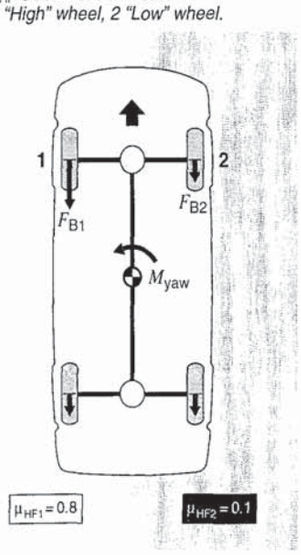
The 4-channel hydraulic-modulator valve for diagonal braking-force distribution calls for four solenoid valves, because the rear-wheel brakes belong to different brake circuits. However, both the rear-wheel valves are jointly energized, so that there is the same pressure in each of the rear-wheel-brakes, and the "select-low" control mode is easy to implement.

The depicted control cycle shows automatic brake control in the case of a high friction coefficient. The change in wheel speed (deceleration) is calculated in the ECU. After the value falls below the $(-a)$ threshold, the hydraulic modulator valve unit is switched to the pressure-holding mode. If the wheel speed then also drops below the slip-switching threshold λ_1, the valve unit is switched to pressure reduction; this is done as long as the $(-a)$ signal is present. During the subsequent pressure-holding phase, the peripheral wheel acceleration increases until the $(+a)$ threshold is exceeded; thereupon, the brake pressure continues to be kept constant. After the relatively high $(+A)$ threshold has been exceeded, the brake pressure is increased, so that the wheel is not accelerating excessively as it enters the stable range of the adhesion/slip curve. After the $(+a)$ signal has dropped out, the brake pressure is slowly raised until, when the wheel acceleration again falls below the $(-a)$ threshold, the second control cycle is initiated, this time with an immediate pressure reduction. In the first control cycle, a short pressure-holding phase was necessary initially for the filtering of disturbances. In the case of high wheel moments of inertia, low friction coefficient and slow pressure rise in the wheel-brake cylinder (cautious initial braking, e.g., on black ice), the wheel might lock-up without the deceleration switching threshold having responded. In this case, therefore, the wheel slip, too, is used in automatic brake control.

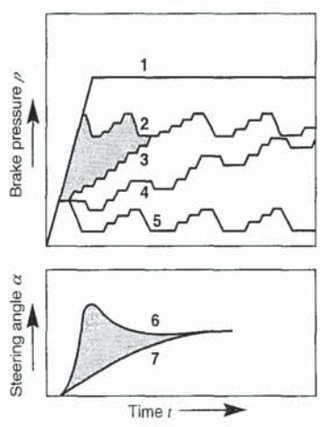
Under certain road-surface conditions, passenger cars with all-wheel drive and with differential locks engaged pose problems when the ABS system is in operation; this calls for special measures to support the reference speed, lower the wheel-deceleration thresholds, and reduce the engine drag torque.

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

Buildup of yaw moment induced by large differences in friction coefficients
M_{yaw} Yaw moment, F_B Braking-force, μ_{HF} Coefficient of friction. 1 "High" wheel, 2 "Low" wheel.



Curves for brake pressure/steering angle with delayed yaw-moment buildup *(GMA) 1 Master-cylinder pressure p_{MC}, 2 Braking pressure p_{high} w/o GMA, 3 p_{high} with GMA 1, 4 p_{high} with GMA 2, 5 p_{low} at "Low" wheel, 6 Steering angle α w/o GMA, 7 Steering angle α with GMA.*



Brake control with yaw-moment buildup delay

When the brakes are applied on an asymmetrical road surface (for instance, left wheels on dry asphalt, right wheels on ice), the result is vastly different braking forces at the front wheels. This difference induces a turning motion (yaw moment) around the vehicle's vertical axis.

When a heavy passenger car with ABS is braked, the resulting yaw sets in slowly and the driver has time for corrective steering maneuvers. On smaller cars, the ABS must be supplemented by an additional yaw-moment buildup-delay device (GMA) to ensure that control is maintained during panic stops on asymmetrical surfaces. GMA delays the pressure buildup in the wheel cylinder of the front wheel with the higher coefficient of braking force at the road surface ("high" wheel).

The GMA concept is demonstrated in the diagram: Curve 1 represents the master-cylinder pressure p_{MC}. Without GMA, the wheel on asphalt soon arrives at the pressure p_{high} (Curve 2), while the wheel which is running on ice goes to p_{low} (Curve 5); each wheel achieves the maximum retardation available under the given circumstances (individual control).

The GMA 1 System (Curve 3) is suited for use with vehicles with a less critical response pattern, while GMA 2 is designed for cars which display an especially marked tendency toward yaw-induced instability (Curve 4).

In all cases in which GMA comes into effect, the "High" wheel is under-braked at first. This means that the GMA must always be very carefully adapted to the vehicle in question in order to limit increases in stopping distances.

ABS 2E (Bosch)

This economical "full ABS" design (a 3-position solenoid valve with electronic control stage is replaced by a plunger/floating piston arrangement) offers the same safety features and functions as the ABS2S system with only minimal loss of comfort in terms of brake pedal feedback and noise.

Under normal braking, without active ABS, brake fluid flows to the right rear

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

wheel through the rear-axle solenoid valve (4), while the plunger's central valve (6) supplies the left rear wheel.

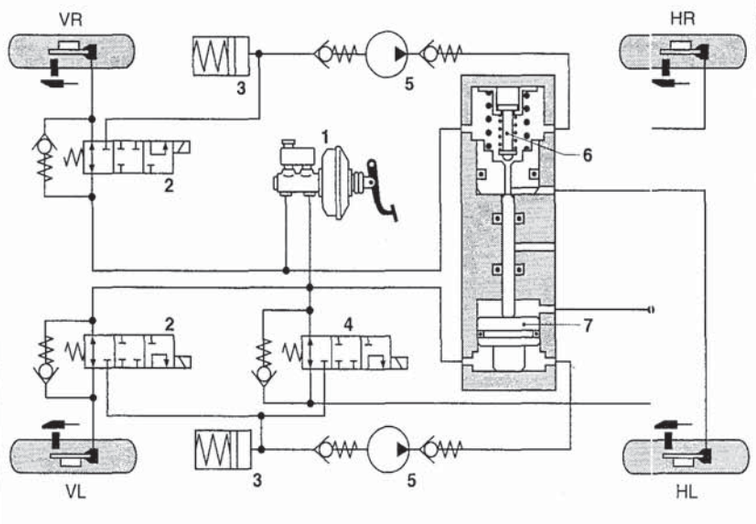
When the ABS is activated, each of the left-side solenoid valves (2) controls a front brake, while the rear-axle solenoid (4) directly controls the rear right wheel (HR). The rear-axle solenoid valve (4) switches to position 3 upon receiving the "pressure-reduce" command from the ECU. In the process, fluid is released from the rear right wheel (HR) into the accumulator chamber (3) via the valve (4) so that the pressure at the wheel brake (HR) is reduced. Since the upper side of the floating piston (7) is hydraulically connected to the wheel brake (HR), this pressure reduction is also applied above the floating piston (7). The underside of the piston (7) is subjected to pressure from the master cylinder (1), and the resulting force on the piston (7) causes the floating piston assembly to move upwards. The upper plunger now comes into contact with the central valve pin (6) so that the central valve closes and volume can be accepted from the rear brake (HL) when upward movement continues. At the same time, the pressure in the brake (LR) and on the underside of the top plunger also drops as required. The movement of the plunger then comes to a standstill when the resulting force on the plunger assembly has dropped to zero. This is the case when the pressure in the two brakes (HL) and (HR) is equal. The processes for "pressure hold" and "pressure buildup" are analogous to the pressure-reduction process and are controlled by the position of the solenoid valve (4).

ABS5 Family (Bosch)

As a result of the development of solenoid valves with two hydraulic positions it has been possible to thoroughly revolutionize the ABS system while retaining the range of functions of the ABS2S. The ABS5 is based upon the tried and proven return principle as used in the ABS2S. It contains the following components for each brake circuit (with X and II braking-force distribution):

- Return pump,
- Accumulator,

ABS2E hydraulic system *(X braking-force distribution)*
1 Brake booster, 2 Solenoid valves, 3 Accumulator chambers, 4 Rear-axle solenoid valve, 5 2-circuit return pump, 6 Central valve, 7 Plunger piston.
V *front,* H *rear,* R *right,* L *left.*



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

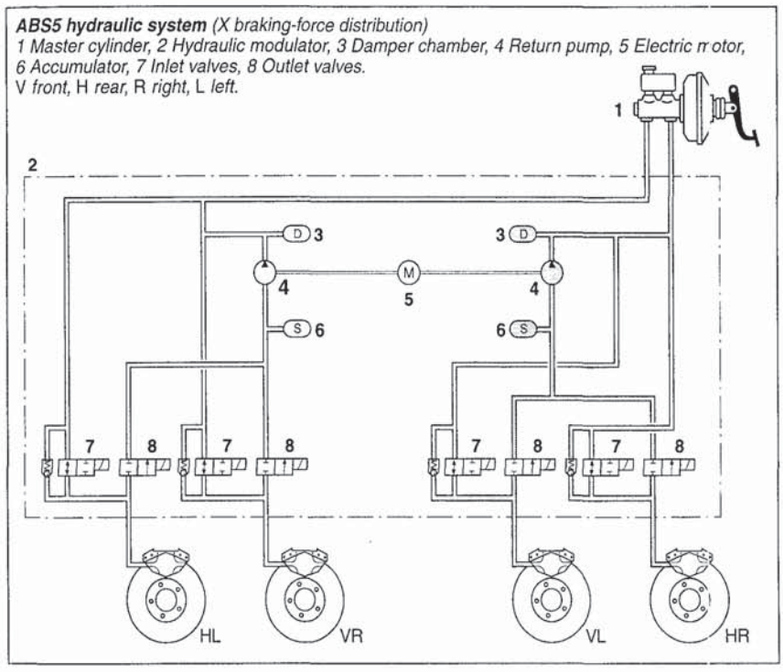
- Damper chamber, and
- 2/2 solenoid valves with two hydraulic positions and two hydraulic connections.

Each wheel (or the rear axle in the case of II braking-force distribution) is allocated a solenoid-valve pair, a solenoid valve (EV – open when de-energized) for the pressure increase (inlet) and a solenoid valve (AV – closed when de-energized) for pressure reduction (outlet). In order to achieve rapid release of pressure at the brakes when the pedal is released, the inlet valves each have a non-return valve which is integrated in the valve body (e.g. non-return valve sleeves or unsprung non-return valves).

Pressure increase and decrease are each allocated a solenoid valve which features only 1 active (energized) position. This leads to compact valve designs with only 2 hydraulic connections, smaller volume, lower weight, and low magnetic forces. The design means that only a single switching transistor is needed for the electrical triggering, with the attendant reduced electrical power loss in the solenoid coils and in the ECU. The valve block for mounting the 2/2 solenoid valves results in a smaller and lighter hydraulic modulator and means that the ECU can be attached directly to the hydraulic modulator. This has the advantage that the vehicle's wiring harness needs less lines. Because of their compact design, the 2/2 solenoid valves enable shorter electrical switching times and even pulse-width-modulated cyclic operation which substantially improves function (e.g. adaptation to changes in coefficient of friction) and control convenience (e.g. smaller delay fluctuations with the aid of pressure stages and lower levels of valve noise).

By coordinated development of mechanical valve design and pulse-width-modulated control (mechatronic optimization), it has been possible to produce an ABS system with "quiet" solenoic valves which represents a new milestone in terms of noise generation and pedal feedback.

Electric-motor variants, together with hydraulic throttling (restriction) of the flow



ABS5 hydraulic system *(X braking-force distribution)*
1 Master cylinder, 2 Hydraulic modulator, 3 Damper chamber, 4 Return pump, 5 Electric motor, 6 Accumulator, 7 Inlet valves, 8 Outlet valves.
V *front,* H *rear,* R *right,* L *left.*

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

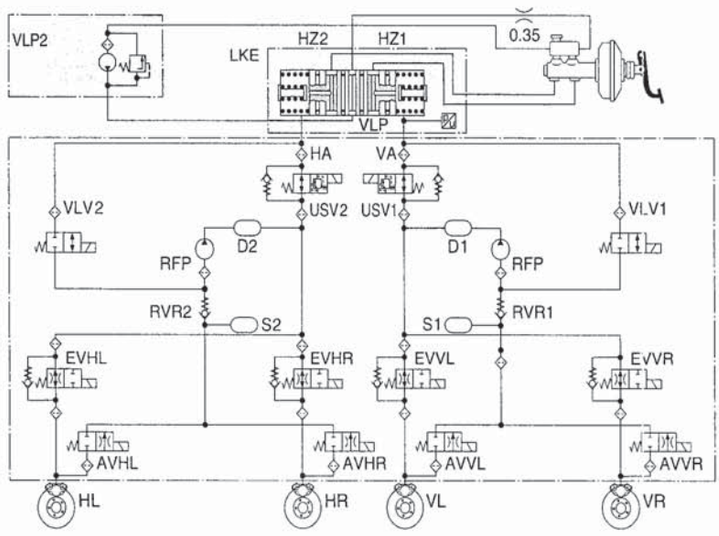
cross sections in the solenoid valves, and variations in the accumulator volumes, mean that the ABS5-family represents a new generation of ABS systems suitable for installation in all series-production passenger cars.

ABS with TCS (Bosch)
See chapter "TCS traction control system," P. 606

ABS and ESP hydraulics (Bosch)
Proper control of vehicle-handling dynamics by means of ESP Electronic Stability Program (previously known as VDC Vehicle Dynamics Control) requires sufficiently rapid build-up of braking force in the brakes. On the one hand, low temperatures and low coefficients of friction are the conditions under which the ESP is called upon most often. On the other though, at low temperatures the brake-fluid viscosity increases considerably, thus making it necessary to modify the hydraulic concept compared to that used with ABS/TCS. The ABS/TCS5 system as described in the Chapter "ABS with TCS (Bosch)" was taken as the basic system. Here, the pre-charge pump (VLP) was incorporated to ensure the return-pump delivery capacity when the ESP is needed under cold-weather conditions. The requirement for closed and separate brake circuits meant that this pre-charge pump could not be connected hydraulically directly upstream of the return pump. Instead it is applied to a charge-plunger unit (LKE) connected between the master cylinder and the ABS/TCS hydraulics. As soon as brake pressure is needed, the pre-charge pump switches on (together with the pre-charge valves (V_V) and the changeover valves (USV)) and delivers brake fluid to the charge-plunger unit (LKE) so that the two plungers in the unit move apart.

This mechanically closes the central valves of the LKE and the brake-fluid volume from the two LKE cylinders is forced through the opened pre-charge valves to the return pumps of the ABS/TCS hydraulics. The pre-charging of the return

Hydraulic system for ABS and ESP
VLP *Pre-charge pump,* VLV *Pre-charge valve,* RFP *Return pump,* RVR *Non-return valve,* LKE *Charge-plunger unit,* USV *Change-over valve,* D *Damper,* AV *Outlet valve,* EV *Inlet valve,* HZ *Master cylinder,* S *Accumulator,* VA *Front axle,* HA *Rear axle,* V *Front,* H *Rear,* R *Right,* L *Left.*



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

pumps means that sufficiently rapid brake-pressure buildup is ensured at the wheel brakes even at low temperatures. A separate line with a small restriction is provided between the LKE and the reservoir in order that the brake fluid in the pre-charge circuit can be bled, and the LKE plungers return to their initial position when the pre-charge pump is switched off.

By further optimization of the master cylinder and the ABS/TCS5 induction valves with the aim of increasing the hydraulic flow cross-section, it has been possible to produce an ESP hydraulic modulator that enables adequate pressure generation dynamics even without a precharger pump at low temperatures and thus further reduces the number of system components.

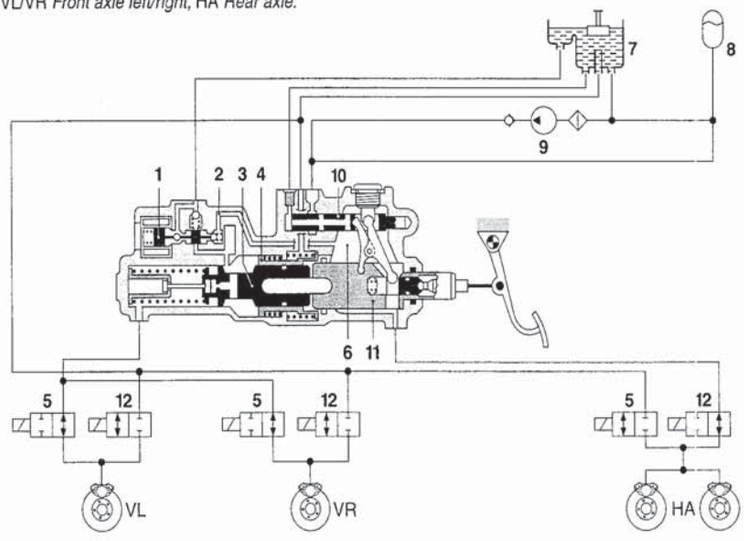
MK 2 (Teves)

The hydraulic components – brake booster and ABS – form a compact integrated unit for installation on the firewall. Under normal braking, the booster piston impels brake fluid directly to the rear brakes while pushing the master cylinder piston to the left, supplying brake fluid to the front brakes.

When the ABS is activated, the main valve opens, connecting the booster chamber with the primary side of the master cylinder piston while closing off the connection between the primary side and the reservoir. Brake fluid flows from the booster chamber to the front brakes via the connecting line and seal of the master-cylinder piston. During ABS-controlled braking, booster pressure is exerted against the left side of the positioning sleeve, maintaining master cylinder and booster piston in a middle position. This ensures that sufficient piston travel remains available for front-wheel braking in the event of ABS failure.

The supply and discharge valves provide optimal regulation of the pressures in the wheel cylinders during ABS-controlled braking maneuvers, with the brake fluid which is ejected from the wheel cylinder flowing back to the reservoir.

Schematic diagram: ABS MK 2 *(Teves)*
Brakes not actuated.
1 Main valve, 2 Connecting line, 3 Master-cylinder piston, 4 Positioning sleeve, 5 Outlet valves, 6 Servo chamber, 7 Fluid reservoir, 8 Pressure accumulator, 9 Pump, 10 Brake valve, 11 Servo piston, 12 Inlet valves.
VL/VR *Front axle left/right,* HA *Rear axle.*



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

The front brakes are controlled individually. The rear brakes are regulated together, whereby the wheel with the lower coefficient of traction determines the level of pressure (select low).

MK 4 with TCS (Teves)
This version is used with a conventional vacuum booster to provide "separate ABS". The system can also be extended to include TCS.

When the start of active ABS control makes it necessary to reduce the brake pressure at one of the wheels, the discharge valve is opened while the supply valve remains closed, allowing brake fluid to flow back to the reservoir from the brake. When the supply valve opens to increase the pressure, brake fluid flows from the master-cylinder chamber, and the pedal gives way somewhat. The hydraulic unit must supply new energy, as repeated cycles would otherwise cause the pedal to drop too far.

The ABS hydraulic energy-supply unit employs an electrically-driven, dual piston pump which is triggered when the system recognizes incipient wheel lock. The pump extracts brake fluid from the reservoir and pumps it through the supply-valve orifice and to the brake at a suitably increased pressure.

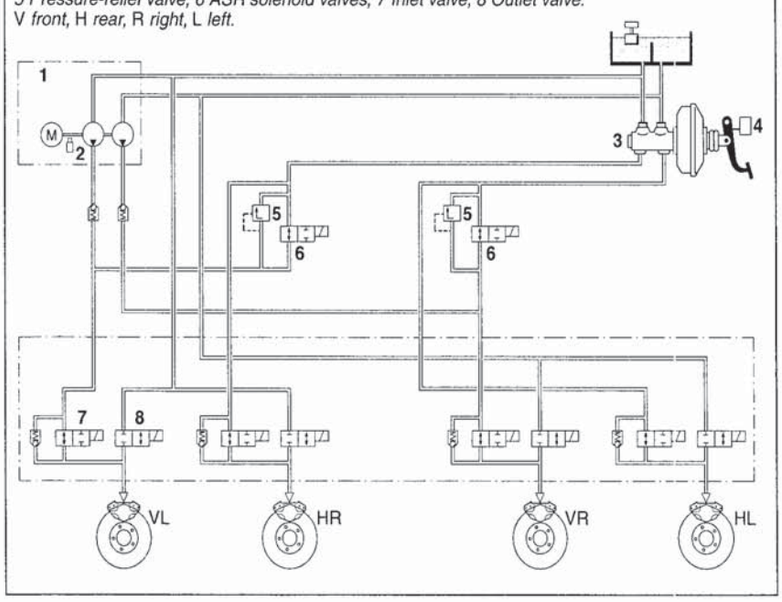
The excess flow quantity from the pump flows into the chambers of the master cylinder, where it presses back the master-cylinder piston and the brake pedal. The position sensor triggers and switches off the pump so as to ensure that the intermittent flow which it produces results in adequate feel and travel at the pedal.

The hydraulics can be expanded for traction control by adding 2 TCS solenoid valves, which serve to isolate the master cylinder from the TCS, and 2 pressure-relief valves, responsible for regulating pressure in the TCS system.

The rotation sensor is a security device for monitoring the operation of the pump motor.

MK 20 Family (Teves)
In contrast to the MK4, the MK 20 system operates according to the return principle using sealed brake circuits. Pressure

Schematic diagram: ABS/TCS MK 4 *(Teves)*
1 Energy supply, 2 Wheel-speed sensor, 3 Master-cylinder piston, 4 Position sensor, 5 Pressure-relief valve, 6 ASR solenoid valves, 7 Inlet valve, 8 Outlet valve.
V *front*, H *rear*, R *right*, L *left*.



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

modulation is by means of a pair of 2/2 solenoid valves (inlet/outlet) for each wheel and the system can be upgraded to TCS/ESP by the addition of two changeover valves and two induction valves. The hydraulic components thus correspond exactly to the arrangement employed by the Bosch ABS5 Family.

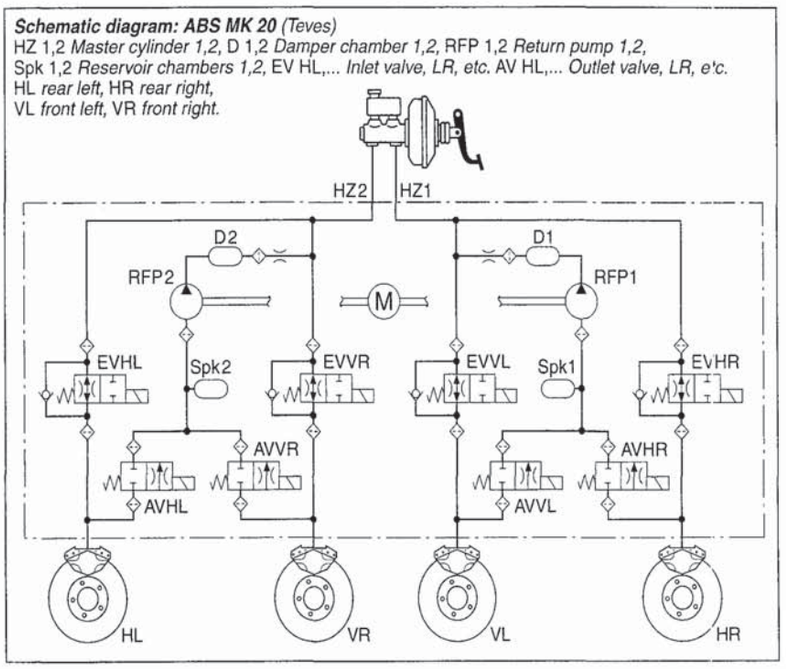
Pumpless ABS (Denso)

For a certain section of the Japanese market, a greatly simplified ABS system was developed which dispenses with damper chambers and return pumps together with their electric motors and control systems. It operates according to the following principle:

If the wheel-speed sensors detect that wheels are about to lock under braking, the appropriate inlet valves are closed in order to prevent further increase of pressure in the wheel cylinders. If this does not succeed in preventing the wheels locking, the corresponding pressure release valve is opened until the wheel stops slipping and is then closed again. The brake fluid that flows out of the wheel cylinders in the process returns to the reservoir chambers. Once the wheel speed becomes stable again, the inlet valves concerned are opened again. The process described repeats itself continually until the driver stops braking or the vehicle comes to a standstill. When the brake pedal is released by the driver, the brake fluid that has collected in the reservoir chambers flows back through the reservoir-chamber springs and the non-return valves to the master cylinder. The system is then ready for ABS braking again.

The smaller number of components compared with conventional systems offers considerable cost savings but the system has significant functional deficiencies. Among other things, under extended periods of ABS braking (e.g. from high speeds on road surfaces with poor adhesion or in situations where adhesion fluctuates dramatically), the reservoir chambers can reach their capacity while at the same time the brake-pedal travel increases considerably in an unfamiliar way. Apart from the loss in pedal-opera-

Schematic diagram: ABS MK 20 *(Teves)*
HZ 1,2 *Master cylinder 1,2,* D 1,2 *Damper chamber 1,2,* RFP 1,2 *Return pump 1,2,*
Spk 1,2 *Reservoir chambers 1,2,* EV HL,... *Inlet valve, LR, etc.* AV HL,... *Outlet valve, LR, e'c.*
HL *rear left,* HR *rear right,*
VL *front left,* VR *front right.*



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

tion comfort, this means that the pressure in the wheel cylinders can not be reduced any further with the result that the wheels could lock up. For that reason, this type of system is only used on certain vehicles with limited top speeds and has not as yet become established in the European or American automobile markets.

ABS components (Bosch)

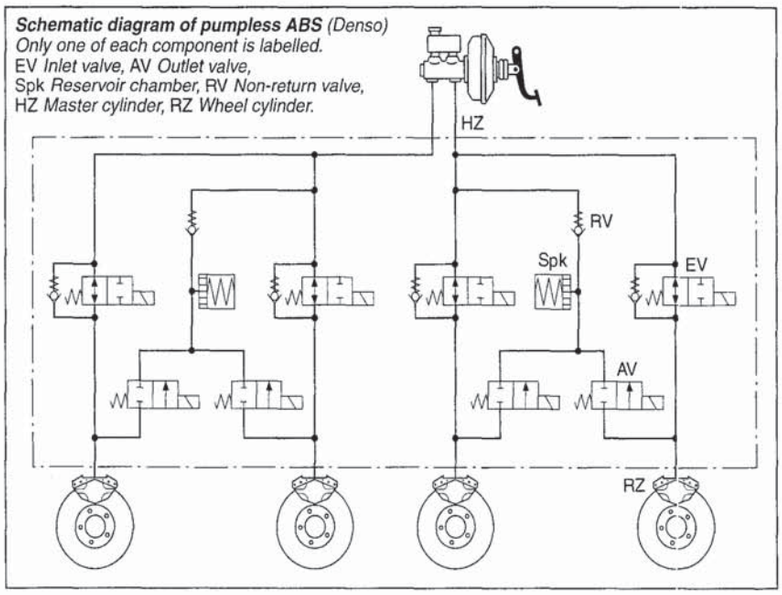
Wheel-speed sensor
The inductive wheel-speed sensor provides the control unit (ECU) with information on wheel speed.

ECU unit with vehicle-specific LSI circuits
The ECU shown in schematic form in a 4-channel system receives, filters and amplifies the speed-sensor signals and ascertains from them the degree of wheel slip and the acceleration of the individual wheels as well as the reference speed, which is the best possible calculation of vehicle road speed.

Input circuit:
The input circuit consists of a low-pass filter and input amplifier; the circuit suppresses interference and amplifies the signals from all wheel-speed sensors (Channels 1...4).

Digital controller:
The digital controller consists in the case of ABS2S of two identical but independent digital vehicle-specific LSI circuits which each process the information from two wheels (channels 1+2 or 3+4) simultaneously and perform the logical processes. Once processed, the wheel frequency data continues in the circuit to a serial arithmetic-logic unit. This logic unit, in turn, uses the data to calculate the values for "wheel slip" and "circumferential deceleration" or "circumferential acceleration" required for closed-loop control. A self-adapting, complex controller logic converts the control signals into position commands for the solenoid valves. A serial interface, connected to the input stage, arithmetic-logic unit and controller logic via data link, maintains data communications between the two digital LSI circuits.

Yet another function block contains the monitoring circuit for error recognition and analysis. Should the ECU malfunction, a warning lamp informs the vehicle operator that the ABS is no longer opera-



Schematic diagram of pumpless ABS *(Denso)*
Only one of each component is labelled.
EV *Inlet valve,* AV *Outlet valve,*
Spk *Reservoir chamber,* RV *Non-return valve,*
HZ *Master cylinder,* RZ *Wheel cylinder.*

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

tional. However, the braking system retains full normal operating capability when the ABS is deactivated.

Output circuits:
Two output circuits function as current regulators for Channels 1 + 2 and 3 + 4 while receiving the position commands employed for solenoid excitation from the LSI circuits.

Output stage:
The output stage employs the input from the current regulators in the two output circuits in providing the excitation current for the solenoid valves.

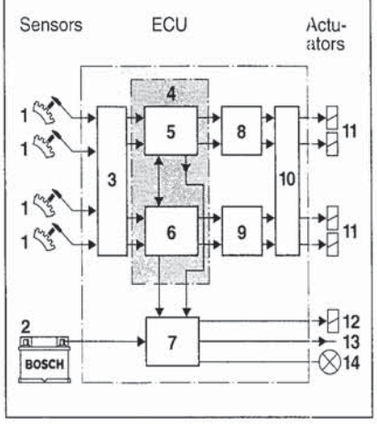
Voltage stabilizer, fault memory:
This function block stabilizes the supply voltage and monitors it to ensure that it remains within the tolerances required for reliable operation. The block also incorporates undervoltage recognition, which reacts to insufficient on-board voltage by shutting down the unit, as well as relays and the warning-lamp control circuit.

ECU unit with microcontrollers
Instead of the vehicle-specific LSI circuits, this control unit has two microcontrollers which take care of signal processing, "running" the controller program and self-monitoring on the part of the ABS system. The unit also carries out diagnosis in accordance with ISO standards, making it possible to track down defective ABS components with the aid of either the warning lamp or an "intelligent" tester.

The use of microcontrollers could achieve substantial optimization of controller algorithms incorporating customization to vehicle and driver requirements. For example, more precise calculation of wheel slip enables early detection of excessive rear-wheel braking which can then be corrected in time by changes in brake pressure with the result that, on some vehicles, the rear-wheel pressure reducer can be dispensed with. This achieves better overall vehicle braking (electronic brake balancing).

Further hybridization of the electronic components has succeeded in considerably reducing their number and thereby the size of the control unit as well.

***ECU** (Bosch, 4-channel layout).*
1 Wheel-speed sensors, 2 Battery, 3 Input circuit, 4 Digital controller, 5 LSI circuit 1, 6 LSI circuit 2, 7 Voltage stabilizer/fault memory, 8 Output circuit 1, 9 Output circuit 2, 10 Output stage, 11 Solenoid valves, 12 Safety relay, 13 Stabilized battery voltage, 14 Warning lamp.



Hydraulic modulator (for ABS2S and ABS5S with II and X braking-force distribution)
For each brake circuit, the hydraulic modulator consists of:
– Electric-motor-driven return pump P,
– Accumulator chamber S,
– Damper chamber D, and
– Various solenoid valves.

Return pump P:
The return pump returns the brake fluid from the wheel-brake cylinders to the master cylinder.

Accumulator S:
The accumulators provide temporary storage of the large quantity of brake fluid which accompanies pressure reduction.

Damper chamber D:
The dampers and their downstream throttling devices serve to smooth the high levels of pulsation which occur during the return of brake-fluid to the master cylinder.

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

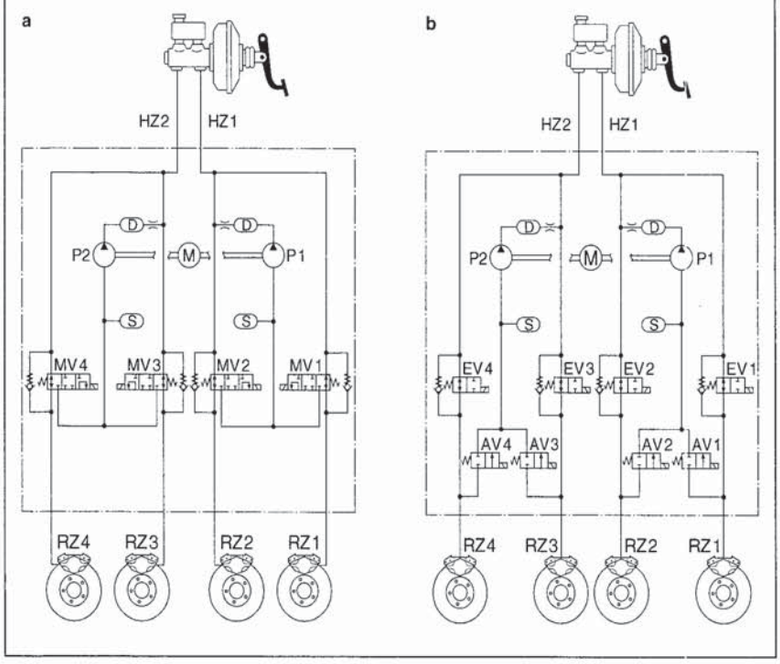
They ensure that the noise level is kept to a minimum.

3/3 solenoid valves on ABS2S:
Each wheel is allocated a 3/3 solenoid valve. The valve serves to modulate the pressure in the wheel cylinders during active ABS control. The modulation takes place in 3 modes (build-up, hold, and reduce).

2/2 solenoid valves on ABS5:
Each wheel is allocated an EV/AV valve pair. The same pressure-modulation modes as above can be achieved for each wheel brake by appropriate control of the valves.

In addition to the effect of the damper chambers, PWM control of the 2/2 solenoid valves allows the required pressure changes in the wheel cylinders to be achieved with a greater degree of driver comfort in terms of noise, initiation of suspension vibration and pedal feedback.

Schematic diagram of hydraulic modulator
a) ABS2S system, b) ABS5 system.
HZ *Master cylinder,* M *Electric motor,* P *Plunger pump,* D *Damper,* S *Volume accumulator,* MV *3/3 solenoid valve,* EV *2/2 inlet valves,* AV *2/2 outlet valve,* RZ *Wheel cylinder.*



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

Electrohydraulic Brakes (EHB)

In contrast to antilock braking systems (ABS), the traction control system (TCR) and electronic stability program (ESP) can generate pressure in the wheel cylinders independently of driver action. This capability forms an important basis for electrohydraulic brakes.

Function

In conventional car braking systems, the force applied by the driver is transmitted mechanically by the lever action of the brake pedal to the vacuum brake servo and from there in amplified form to the master cylinder. The pressure thus generated is used to achieve the desired braking effect with the individual brakes on each wheel. With electrohydraulic brakes, that purely mechanical-hydraulic sequence of actions is broken and replaced by sensors, an ECU and a hydraulic pressure supply. Under normal operating conditions, there is no mechanical link between the brake pedal and the wheel brake.

Design

An electrohydraulic braking system consists of the following components (see diagram):

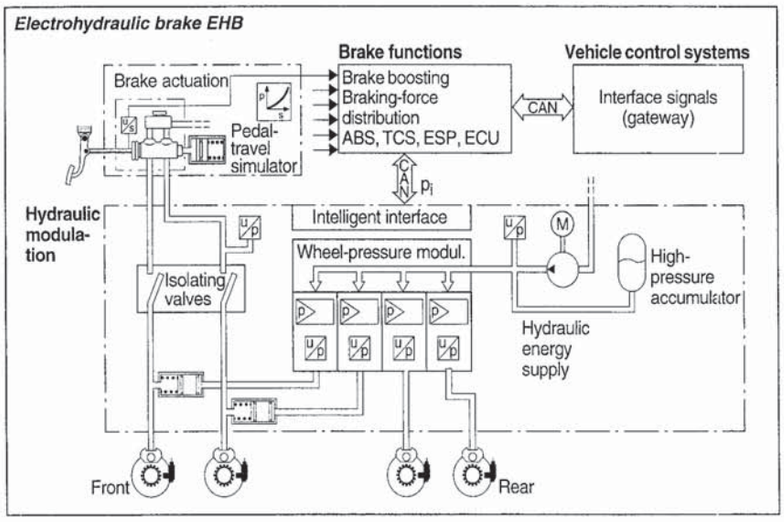
- Actuator unit,
- Hydraulic pressure modulator
- Sensors (e.g. wheel-speed sensor),
- Add-on ECU (at the hydraulic pressure modulator),
- or separate ECU,
- Control and pressure lines.

Mode of operation

For safety reasons, two separate sensors (one on the actuator unit for detecting the pedal travel and a pressure sensor on the hydraulic modulator) are used to detect a "braking request" and transmit it to the ECU. Using software, this ECU also incorporates the brake servo, ABS, TCS and ESP functions. The other sensors in the ABS, TCS and ESP systems provide the ECU with data relating to aspects of vehicle dynamics such as road speed, cornering, and the motion of the wheels. Using this information, the ECU calculates the signals to be sent to the hydraulic modulator which are converted by the wheel pressure modulators into the brake pressures for the individual wheels. An electrically driven hydraulic pump with a high-pressure accumulator and a pressure monitoring system provides the hydraulic pressure supply.

For safety reasons, in the event of a fault in the system it switches to an operating mode in which the vehicle can be braked without power assistance.

Electrohydraulic brake EHB



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

Braking systems for commercial vehicles above 7.5 t laden weight

System and configuration

Power-braking systems of medium and heavy-duty commercial vehicles mostly operate with:

- Compressed air (normal pressure level) as a medium for energy supply and as a transmission device.
- Pneumatic-hydraulic power transmission in the service-braking system and pneumatic power transmission in the parking-brake system, or
- Pneumatic high pressure level (Figs. B & C).

Service-braking system for towing (tractor) vehicles

For practical operations, in medium and heavy commercial vehicles, the force exerted by the driver's foot alone is not sufficient to generate adequate braking deceleration. For this reason, compressed-air power-brake systems are principally used; these systems use compressed air as a stored form of energy to control or actuate the service-braking system. Diaphragm actuators create the brake application forces on the wheel brakes. "Air-over-hydraulic" brake systems are becoming less and less common, as the air pressure required to control the wheel brakes must be converted into hydraulic pressure by means of brake servo-unit cylinders, compact brake assemblies or actuating cylinders.

A modern dual-circuit compressed-air brake system with trailer-brake connection, spring-type brake actuator, secondary and parking-brake system consists of the following main components:

- Energy supply,
- Compressed-air reservoir,
- Brake valves,
- Braking-force controller,
- Wheel brakes, and
- Control and air supply for the trailer braking system (diagram D).

The energy supply comprises a compressor and pressure regulator. Where necessary, antifreeze pumps, automatic water drainage, air filters, air dryers and intermediate reservoir are added, providing clean and well-drained air.

As there may be a number of air-consuming installations apart from the braking system in the tractor-trailer combinations used in modern-day commercial-vehicle operations, it is advisable to install considerably more powerful compressors than those, for instance, required by EC/ECE brake regulations.

The four-circuit protection valve is located at the interface point between the energy supply and the compressed air reservoir. In the event of a fault, this protection valve ensures the security and continuing supply of the individual brake circuits and of priority secondary consumers.

The actuating mechanism for the service brakes starts with the brake pedal and ends at the mechanically operated components of the dual-circuit brake valve.

Sometimes, in commercial vehicles, the limited space available makes it necessary to fit the brake valve on the frame behind the cab instead of in the (tipping) cab itself. The problem of left-hand and right-hand drive trucks with the brake valve in the same position on the frame is solved by means of a dual-circuit hydraulic transmission device for the braking-circuit control. In this process an electrical warning system monitors the level of fluid in the compensating reservoirs of both circuits.

Additional installations in towing vehicles for pulling trailers/semitrailers with compressed-air brake systems (see "Basic components of a braking system") help to supply air to the trailer/semitrailer braking system, and provide a controlling function with regard to the braking effect (trailer control valve, coupling heads, etc.).

Two-line braking system for trailers

In the case of the two-line braking system, which is the standard European design version, one line (supply line) connects the energy reservoirs in the towing vehicle with those in the trailer/semitrailer; and this line is permanently under pressure.

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

The second line (brake line) leads from the trailer control valve in the towing vehicle to the trailer brake valve in the trailer/semitrailer (diagram E). Braking occurs as a result of pressure increase. Automatic braking when the trailer/semitrailer accidentally comes loose from the towing vehicle is ensured in this system by the supply line. If the supply line comes loose or breaks, air flows out of it and the brake valve in the trailer/semitrailer activates the brakes. With the aid of a dual-circuit trailer control valve and the four-circuit protection valve, it is possible to continue the supply of air to the trailer/semitrailer and to control braking, even if one circuit of the dual-circuit braking system in the towing vehicle fails. The standardized coupling heads for "supply" and "brake" are fitted with an automatic shut-off element, which opens during the coupling process.

Automatic load-sensitive device for braking-force metering

The automatic device for correcting braking forces as a function of load (ALB) is a vital element of the braking-system transmission device. With the vehicle partially-loaded or empty, braking-force metering valves permit the braking forces to be adjusted to the reduced axle loading e.g., by sensing of the axle ride clearances) and thus permit a correction of braking-force metering to the vehicle's axles ("kinked load-sensitive braking-force metering"), or they permit a set level of braking (important for vehicles in road train or tractor-trailer operation). There are two kinds of load-sensitive braking-force metering valves (Fig. A):

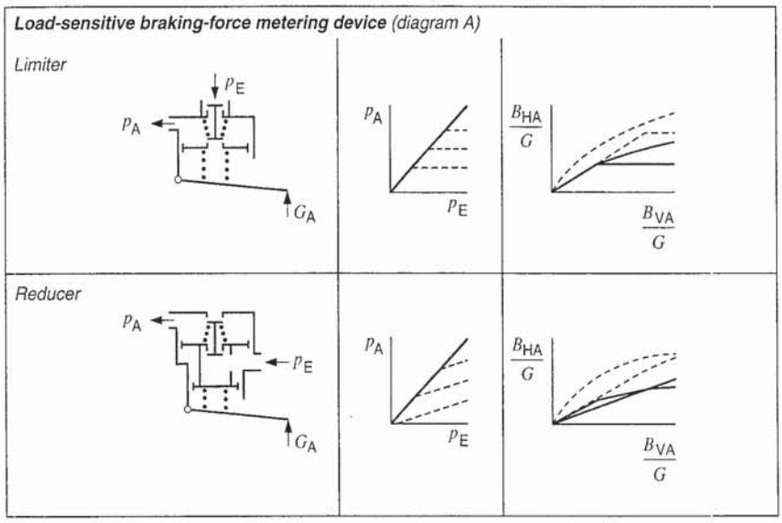
1. Braking-force limiters

Above a given "switchover point", the braking-force limiter restricts the increase of braking force (e.g., on the rear axle), that is to say there is a "kink" in the braking-force metering characteristic.

2. Braking-force reducers

Even under most unfavorable load conditions, load-sensitive braking-force reducers permit braking-force metering which approaches the parabola of the dynamic (ideal) braking-force metering characteristic (see "Design of a braking system"). In the area above the switchover point the braking forces on the particular axle are reduced with respect to the original braking-force metering level. Here, the installed braking-force metering is dependent on the transmission ratio and on the switchover pressure (which in turn is dependent on axle load) of the braking-force metering valve.

Load-sensitive braking-force metering device *(diagram A)*

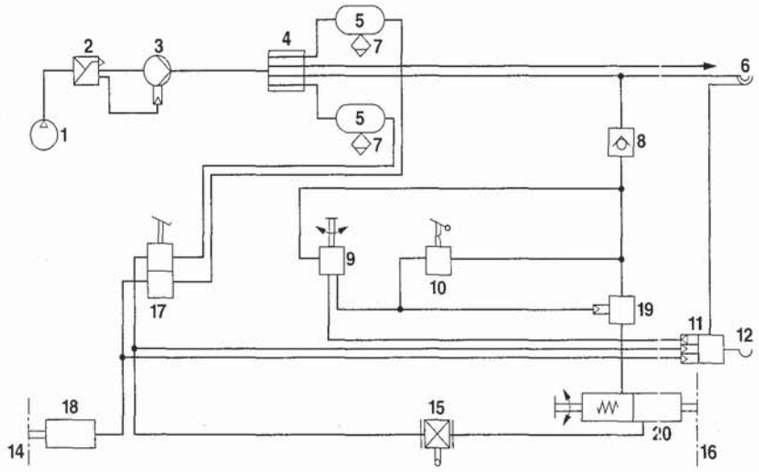


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

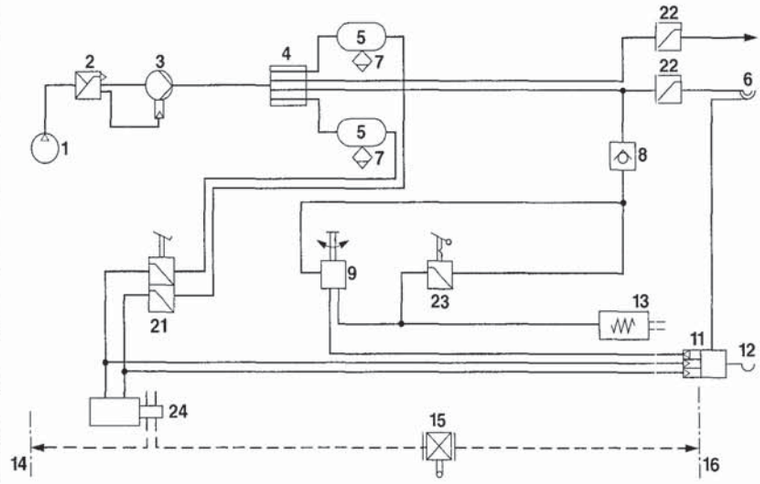
Compressed-air braking systems for trucks

1 Compressor,
2 Pressure regulator,
3 Anti-freeze pump,
4 Four-circuit safety valve,
5 Compressed-air cylinder,
6 Coupling head with automatic shutoff valve,
7 Water drain valve,
8 Non-return valve,
9 Test valve,
10 Parking-brake valve,
11 Trailer-control valve,
12 Coupling head without shutoff valve,
13 Spring-type brake cylinder,
14 Front wheels,
15 Automatic Load-sensitive Braking-force metering (ALB),
16 Rear wheels,
17 Service-brake valve,
18 Brake cylinder

Dual-circuit two-line power-brake system with pneumatic transmission device *(Fig. B)*



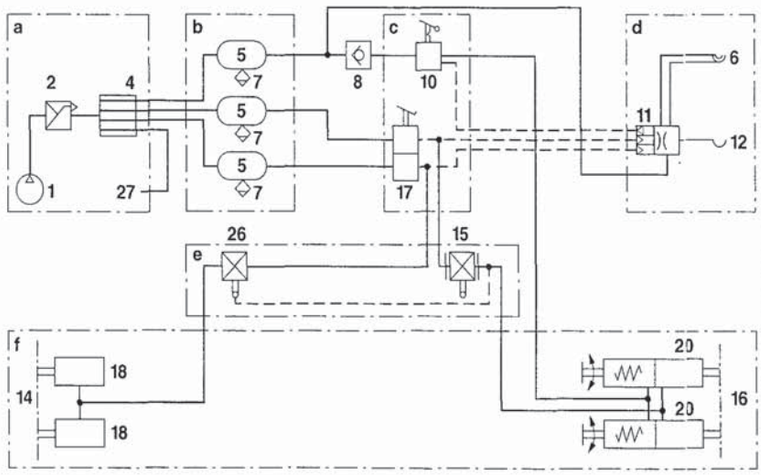
Dual-circuit two-line power-brake system ("Air-over-hydraulic" braking system) with hydraulic transmission device *(Fig. C)*



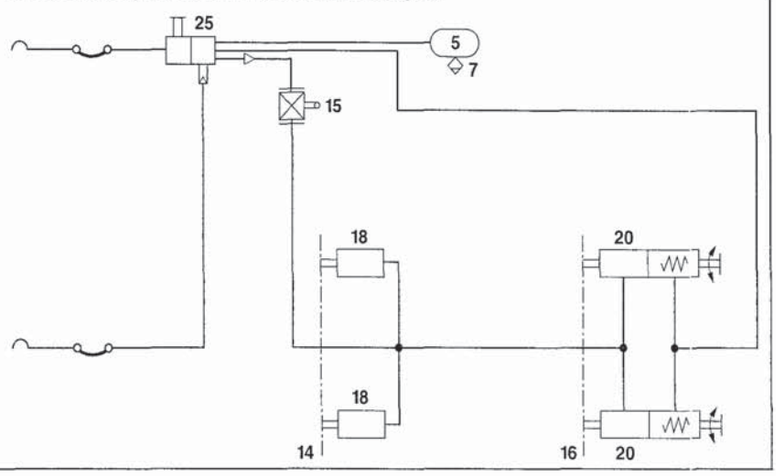
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

19 Relay valve,
20 Combination brake cylinder,
21 Service-brake valve with pressure limiter,
22 Pressure limiter valve,
23 Parking-brake valve with pressure limiter,
24 Precharger cylinder, dual-circuit,
25 Trailer-brake valve,
26 Loaded/empty valve,
27 Ancillary systems, (e.g. Engine braking system).

Main components of a modern compressed-air power-brake system *(Fig. D)*
a) Energy supply device, b) Reservoir, c) Brake valves, d) Trailer control and supply device, e) Braking-force control, f) Wheel brakes.



Two-line braking system for trailer/semitrailer *(Fig. E)*



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

Basic comments on "kinked" braking-force metering

Load-sensitive braking-force metering devices adjust the installed braking-force metering to the dynamic (ideal) metering level and prevent the wheels of a given axle from locking prematurely. However, at low adhesion coefficients and low rear-axle load, it is possible for the wheels to lock. This is because the metering device's switchover point can enter the unstable range of braking-force metering if high engine braking torque (retarder braking torque), tolerance fluctuations in the metering device and/or high fluctuations at the wheel brakes occur.

A braking system which works precisely under all braking conditions is only possible if braking-force metering is optimized. Commercial vehicles with extreme differences between empty and fully laden conditions require braking systems with automatic load-sensitive braking-force control (ALB) on the rear axle together with empty/loaded valves (in order to increase the working range of the ALB, Fig. F).

Wheel brakes

In future, disc brakes will be fitted more and more on medium- to heavy-duty commercial vehicles (at least on the towing-vehicle's front axles). Currently, drum brakes are prevalent worldwide.

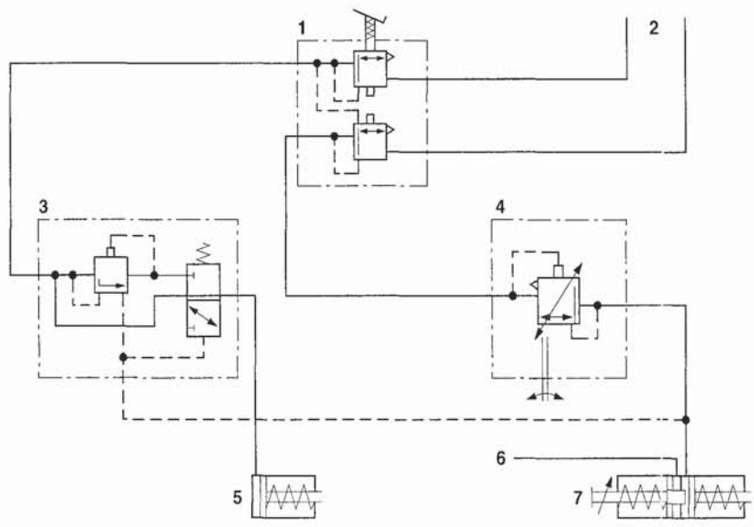
The brake factor C^* as an assessment criterion for brake performance, indicates the ratio of braking force to actuating force. This value takes into account the influence of the internal transmission ratio of the brake as well as the friction coefficient, which in turn is mainly dependent on the parameters speed, brake pressure and temperature (Fig. G).

Drum brakes

The actual construction of the drum brake depends upon the requirements imposed by brake-shoe actuation, anchorage, and adjustment.

Simplex drum brakes (Fig. H): These differ in particular according to their type of application (floating, fixed) and type of support or anchorage (rotating shoes,

ALB function diagram for four-wheel vehicles *(Fig. F)*
1 Service-brake valve, 2 From pressure supply, 3 Load/empty valve (FA), 4 ALB valve (RA), 5 Diaphragm actuator (FA), 6 From parking brake, 7 Combination brake cylinder (RA). RA = Rear axle, FA = Front axle.



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

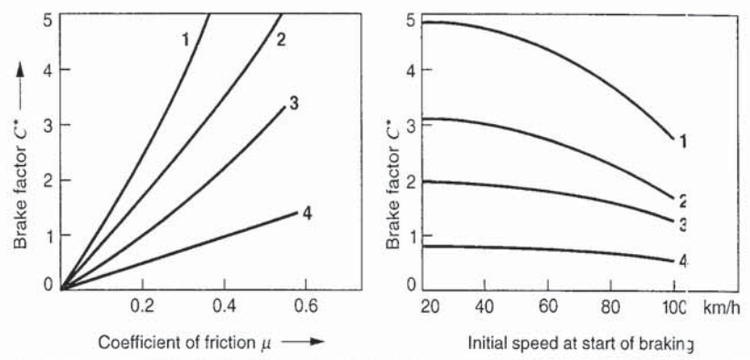
sliding shoes). Wheel brakes with floating-brake application and rotating-shoe support are common. In the case of hydraulic braking-force actuation, for instance, the brakes are applied by means of floating pressure pistons whose travel is not fixed, and which develop actuating forces which are equal in both directions. One of the shoes is the leading shoe and the other the trailing shoe. In the former, the frictional forces between the brake lining and the brake drum support the actuating force, whereas in the latter the frictional forces oppose it.

In the case of the Simplex drum brake, C^* is the sum of the values for the individual shoes, and is ≈ 2.0 (referred to a coefficient of friction of $\mu = 0.38$; it always appears in the following C^* observations as the basis value). A disadvantage of this design is the considerable difference in the braking effect between the two brake shoes, and the resulting greatly increased wear on the leading shoe as compared to the trailing shoe.

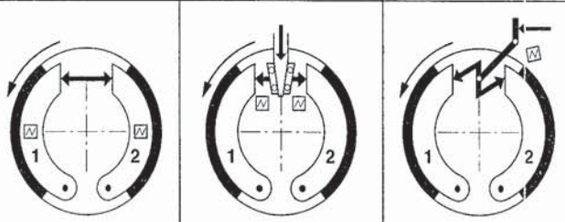
For this reason, the trailing shoe often has a much thinner lining than the leading shoe.

The simplex drum brake can also be actuated by means of a wedge unit (with integrated adjusting mechanism). This has become more and more prevalent,

Brake factor C* as a function of the coefficient of friction and initial road speed *(Fig. G)*
1 Duo-servo drum brake, 2 Duo-duplex drum brake, 3 Simplex drum brake, 4 Disc brake.



Simplex drum brakes *(Fig. H)*

Design	Rotating shoe	Wedge	S-cam
Operating principle			
Brake factor	$C^* = C_1 + C_2$		$C^* = 4/(1/C_1 + 1/C_2)$
Brake shoes	1 Leading shoe, 2 Trailing shoe		

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

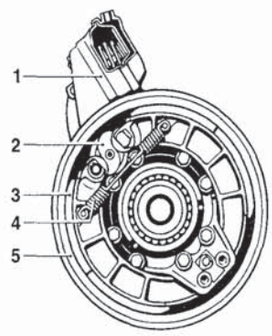
particularly in light and medium commercial vehicles with compressed-air braking systems (Figs. H, K).

The type of wheel brake used most often in heavy-duty commercial vehicles is the pneumatic S-cam simplex drum brake with fixed application (Fig. J).

Advantages:
- Uniform lining wear on leading and trailing shoes as a result of fixed application,
- Long lining life,
- An application mechanism which is simple, reliable and insensitive to temperature. It comprises diaphragm cylinder, automatic slack adjuster, brake shaft and S-cams,
- Little change in brake factor C^*,
- Simple operation of the parking-brake system via spring-brake actuators,
- Precise adjustment by means of automatic slack adjusters.

Disadvantages:
- High internal forces and thus relatively heavy brake construction, as unequal cam forces occur and lead to high free bearing forces,
- Relatively low brake factor C^*, which means considerable application work when braking,
- Due to the roughly equal application travel of leading and trailing shoes, compared to individual shoes, the application forces behave in the opposite manner.
- For the same coefficient of friction, the brake factor C^* is somewhat lower than that of simplex brakes with hydraulic or pneumatic application.

Simplex drum brake with S-cam *(Fig. J)*
1 Diaphragm actuator, 2 S-cam, 3 Brake shoes, 4 Return spring, 5 Brake drum.



Duo-duplex drum brakes: The Duo-duplex brake with two leading shoes (for instance with wedge-unit control) (Fig. K) is rarely used nowadays.

This brake features floating application and the resulting sliding shoe anchorage. An advantage of this brake type is the practically equal brake-lining wear on both shoes and the significantly higher internal transmission ratio in comparison to simplex drum brakes. Twin leading shoes achieve characteristics of $C^* \approx 3.0$ which, however, can not be sustained constantly for long periods due to the tendency of this type of drum brake to fade.

Duo-servo drum brakes: In the past, these were widely used in light commercial vehicles (particularly on the rear axle). This brake's primary characteristic is the fact that both when driving forwards and when reversing, the support force of the primary shoe is used as the actuation force for the secondary shoe. The brake factor is $C^* \approx 5.0$.

The popularity of the duo-servo brake lies in the fact that the high brake factors achieved permit even relatively heavy vans and light-duty trucks up to a weight of approx. 7.5 t to be equipped with vacuum-assisted braking systems. At the same time, the manually operated parking brake incorporated in such systems generates a braking torque of considerable magnitude. However, under conditions of high thermal stress, significant brake-factor fluctuations occur. This fact limits the range of application of this type of brake and necessitates a braking-force metering system which is precisely adapted to the vehicle in question. In future wheel-braking systems, duo-servo drum brakes will for the most part no longer be used for the service-braking system.

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

Disc brakes

Apart from their use in express coaches, disc brakes are currently fitted to medium and heavy commercial vehicles.

The advantages of disc brakes in comparison to drum brakes are:
- Brakes can be applied with far more sensitivity,
- Equal wear of the inboard and outboard brake pads if the appropriate degree of heat dissipation is provided,
- Less tendency to brake noise,
- Relatively constant characteristics with minimal fade tendency.

Disadvantages:
- Shorter brake-lining life,
- Usually higher acquisition and operating costs (in comparison to drum brakes).

The high degree of adaptive braking required at high highway speeds is handled better by disc brakes. The brake discs are less susceptible to cracking than the drums of the drum brakes, apart from which disc brakes are less subject to fading. The brake factor of the disc brake is $C^* \approx 0.76$, referred to the basis value of $\mu = 0.38$.

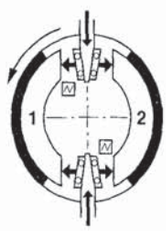
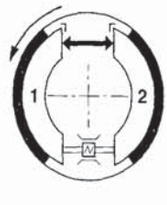
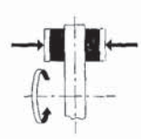
Floating-caliper disc brakes are currently replacing the fixed-caliper brakes used in the past. This development is the result of efforts to design lighter and cheaper brake assemblies which are more temperature-resistant. Floating calipers have a positive effect on variability and consistency of braking effect.

Automatic adjustment of wheel brakes

Brake-lining wear increases the clearance between brake lining and brake drum, and thus increases the braking distance. If the clearance is not adjusted correctly, in extreme cases the piston stroke in the brake cylinder may increase to such an extent that there is no braking effect. Automatic adjustment to the correct clearance is effected when the wheel brake is released.

When the vehicle is braked, the piston stroke in the brake cylinder necessary to bridge the total clearance can be divided into three sections:
- Preset constructive clearance between brake lining and brake drum/disc,
- Clearance resulting from lining wear,
- Clearance dependent on the elasticity of the brake drum/disc and of the brake linings, as well as on the transmission of force between brake cylinder and wheel brake ("elasticity clearance").

Duo-drum brakes and disc brake *(Fig. K)*

Design	***Duo-Duplex*** *Wedge*	***Duo-Servo*** *Positive-action* adjustment	***Disc brake***
Operating principle			
Brake factor	$C^* = C_1 + C_2$	$C^* = C_1 + C_2(k_1 + k_2 \cdot C_1)$	$C^* = 2 \cdot \mu$
Brake shoes	1 Leading shoe, 2 Trailing shoe		–

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

A slack adjuster automatically ensures the correct adjustment (Fig. L).

Parking-brake system

The braking systems with spring-type brake actuators which are usual in commercial vehicles above 7.5 t are a convenient form of parking-brake and service-braking system. In these, in a purely compressed-air braking system, spring-type brake cylinders from the parking-brake system and diaphragm brake cylinders from the service-braking system are combined.

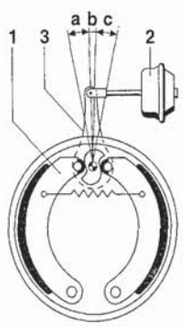
In the disengaged position the four-circuit protection valve and the handbrake valve connect the reservoirs of the service-braking system with the spring compression chamber, and maintain the spring under tension. In vehicles with a connection for the trailer/semitrailer braking system a buffer reservoir is also located in this line. When the handbrake valve is actuated, the pressure in the compression chamber is reduced. Consequently partial braking occurs at first and, with the handbrake valve still actuated, a pressure reduction down to the "surrounding conditions" takes place, and thus full braking of the spring-brake actuator (secondary braking), occurs. Further actuation defines a "Parking setting". With the aid of a further lever setting, in vehicle combinations only the tractor vehicle is braked, and not the entire tractor-trailer rig. As well as this test setting for checking the efficiency of the mechanical parking brake with a trailer attached, EU/ECE legislation for instance stipulates a safeguard emergency-air supply, as well as a nine-fold actuation and release using the energy reserve, a warning device indicating that the spring-brake is beginning to function, and an auxiliary release device.

Retarder braking systems (additional retarding braking systems)

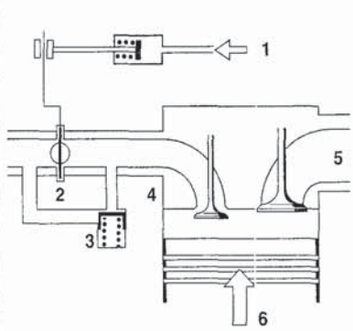
The wheel brakes used in passenger cars and commercial vehicles are not designed for continued retarding operation. In a prolonged period of braking (e.g., when driving downhill) the brakes can be thermally over-stressed, causing the braking effect to be reduced ("fading"). In extreme cases (particularly if the service-braking system has been badly maintained) this may even lead to complete braking-system failure. In order to permit continuous downhill braking, therefore, particularly vehicles with a high laden weight are frequently fitted with a wear-free supplementary retarding braking system in addition to their normal wheel brakes. This system is independent of the wheel brakes, and is also used for braking the vehicle so as to comply with speed limits.

This reduces brake wear as well as increasing braking comfort for the driver. In commercial vehicles two basic types of

Brake clearances *(Fig. L)*
a Due to elasticity. b Due to wear. c Constructive. 1 Brake shoe, 2 Diaphragm cylinder, 3 Automatic slack adjuster.



Exhaust brake with additional pressure-control valve *(Fig. M)*
1 Exhaust-flap actuation (compressed air), 2 Bypass, 3 Pressure-control valve, 4 Discharge, 5 Intake, 6 Piston (4th exhaust stroke).



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

additional retarding braking system are used:

1. Exhaust (engine) braking system

The exhaust braking power is comprised of the drag power together with the braking power (effected by the throttling of exhaust-gas flow in the exhaust stroke). The maximum drag power of standard engines is 5...7 kW/*l* depending upon engine swept volume. In contrast, standard engines with conventional exhaust brakes ("exhaust-flap brakes") achieve braking powers of 14...20 kW/*l*. A further increase in exhaust braking power is only possible by means of additional design modification. Decompression exhaust brakes (e.g., "C-brake", "Jake brake", "Dynatard" or "Powertard") as well as the constant-throttle exhaust brake can significantly improve braking power (Fig. P).

Exhaust brake system with exhaust flap:

The exhaust-flap brake is still the most common system in use today. In this system the driver is able to close a butterfly valve in the exhaust tract by means of compressed air (relatively little constructional outlay is involved). As a result, a counterpressure is generated in the exhaust-gas system which must be overcome by each piston during its exhaust stroke (Fig. M).

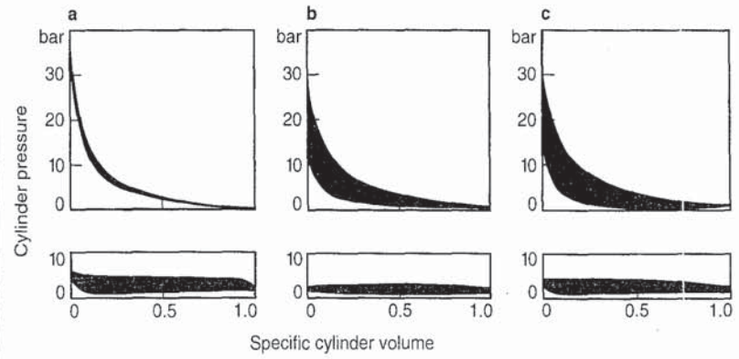
Through the use of a pressure-regulator valve in the bypass, in conjunction with an exhaust flap, the braking power can be increased in the engine's lower and medium speed ranges. At higher revs, the pressure-regulator valve prevents pressure increases beyond the limits which could lead to valve or valve-gear damage.

Exhaust brake system with constant throttle:

The conventional exhaust brake with exhaust flap utilizes only the energy available in the engine's gas-exchange process, i.e. during the 4th (exhaust) and 1st (intake) working strokes. Specific decompression during the 2nd and 3rd working strokes releases part of the compression energy. The "pressure-volume" diagrams below show the pressure curves in a cylinder for the "exhaust flap" and "constant throttle" exhaust braking systems as well as for the combination of both systems (Fig. N). The braking power when using the constant throttle system, as opposed to the flap system, is obtained principally in the engine's high-pressure cycle.

The installation of a small restriction valve in the bypass to the exhaust valve permits an increase in braking power. This valve is actuated by compressed air, in the same way as in the servo-cylinder of the exhaust-brake flap. During exhaust-brake operation the valve can remain open, thus providing a constant throttle cross-section (Fig. O).

Principle of operation of exhaust (engine) braking systems as illustrated by "pressure-volume" diagram (n_M = 1700 min^{-1}) *(Fig. N)*
a) Exhaust-brake flap closed, b) Constant throttle actuated,
c) Exhaust-brake flap closed and constant throttle actuated.



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

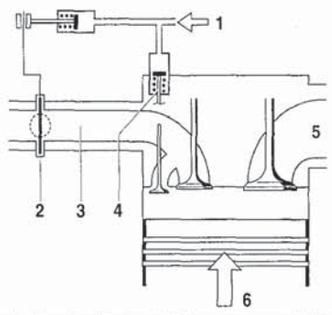
2. Retarders

Retarders are increasingly being used as wear-free additional retarding braking systems in trucks and buses. In this way, the demands of legislation are met, active vehicle safety is increased due to the reduction of the stress placed on the service-braking system, and vehicle economy is increased as a result of higher average speeds and the reduction of brake-lining wear.

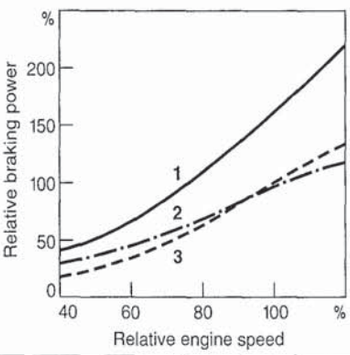
Retarders can be fitted between the engine and the transmission (primary retarders) or between the transmission and the driven axle(s) (secondary retarders). The disadvantage of primary retarders lies in the unavoidable interruption of power transmission, and thus braking effect, which occurs during gear changing with manual transmissions. Primary retarders can be employed in conjunction with power-shift transmissions, and in the case of steep downhill gradients which are negotiated at low speeds, this provides for a slight advantage in comparison to the secondary-retarder system. (Fig. R).

Currently, two basic design concepts represent the state-of-the-art:

Exhaust brake with exhaust flap and constant throttle *(Mercedes-Benz) (Fig. O)*
1 Compressed air, 2 Exhaust flap, 3 Exhaust, 4 Constant throttle, 5 Intake, 6 Piston (2^{nd} working stroke).



Braking-power curves *(V8 engine) (Fig. P)*
1 Exhaust flap and constant throttle, 2 Constant throttle, 3 Exhaust flap.



Hydrodynamic retarders: This retarder works in the same way as the Foettinger clutch (Fig. S). The rotor converts the mechanical energy supplied by the drive shaft into kinetic energy of a fluid. This kinetic energy is in turn converted into heat at the stator, which means that the fluid used must be cooled.

A hand lever or the brake pedal (in the case of an integrated retarder) transmits the driver's braking-power requirements. In conjunction with an electronic control circuitry, a defined control air pressure is set. By means of a corresponding quantity of air, this control air pressure then forces a quantity of oil into the retarder's working area between rotor and stator. The flow energy absorbed by the oil as a result of the vehicle speed and the associated rotor motion is braked by the stator's fixed blades. This in turn effects braking of the rotor and thus of the entire vehicle. Characteristics are:

- Adequate cooling-circuit dimensioning is necessary in order to dissipate to the engine cooling circuit the heat generated by braking. An oil/water heat exchanger is used,
- Relatively complex design,
- Low weight of the hydrodynamic retarder which is integrated directly into the transmission,
- High specific braking powers,
- Very sensitive control of applied braking torque,
- Fan losses occurring when the retarder is not running must also be taken into consideration in retarder design.

In the hydrodynamic secondary retarder, an almost constant braking torque is available over a broad propshaft-

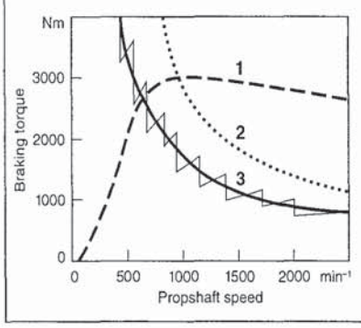
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

speed range (Fig. T). Below approx. 1,000 min^{-1} the braking torque drops steeply. As a result of this characteristic, conventionally designed hydrodynamic retarders are particularly suited to high-speed transport vehicles (overland transport).

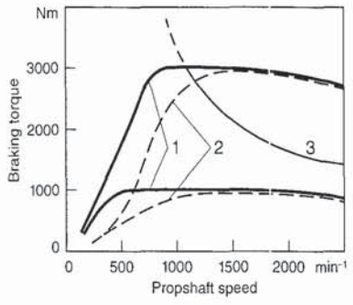
Modern retarder designs rectify the unfavorable braking torque characteristic of the secondary retarder design described above by providing high braking torques even at still low propshaft speeds. A spur-gear stage with a transmission ratio of approx. 1 : 2 drives such "boost retarders", which are fitted to the side of the transmission (Fig. S). Even in the propshaft lower speed range, a microprocessor control ensures acceptable braking-torque levels via a proportional valve.

Hydrodynamic retarders can only be used as continuous-operation braking systems in certain situations for limited

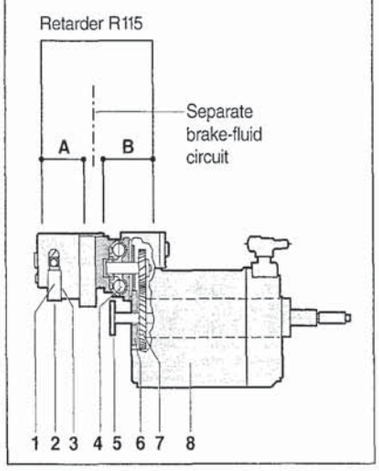
Braking-torque characteristics of primary and secondary retarders *(Fig. R)*
1 Secondary retarder, 2 Limit of cooling effect under continuous load (300 kW), 3 Primary retarder on input side of 16-speed gearbox.



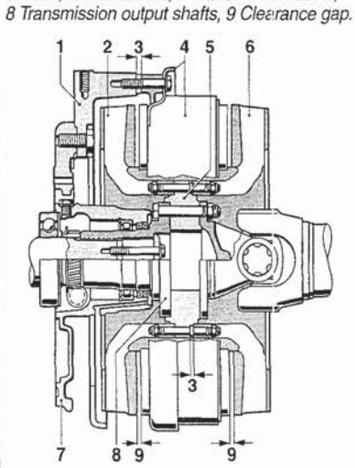
Hydrodynamic retarder performance characteristics *(Fig. T)*
1 Boost retarder, 2 Conventional retarder, 3 Cooling-power limit at continuous load (300 kW).



Boost retarder *(Fig. S)*
1 Transmission, 2 Spur gears (transmission ratio), 3 Gearbox flange, 4 Rotor, 5 Stator, 6 Compressed-air cylinder, 7 Proportional valve, 8 Wiring connector.



Electrodynamic retarder *(Fig. U)*
1 Star-shaped bracket, 2 Rotor, transmission side, 3 Spacers (for adjusting clearance), 4 Stator with coils, 5 Intermediate flange, 6 Rotor, rear-axle side, 7 Transmission cover, 8 Transmission output shafts, 9 Clearance gap.



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

periods. The maximum cooling power of modern diesel engines is approx. 300 kW. Thus, as a result of the coupling of the engine and retarder cooling circuits, there exists a risk for both engine and retarder if additional safety measures are not implemented. For this reason, thermo switches are used to restrict the retarder's braking power so that thermal equilibrium is ensured.

Electrodynamic retarders: Currently common electrodynamic retarders have a mounting in the form of a stator, on which field coils are mounted (Fig. U). The rotors mounted on both sides of the drive shaft are ribbed for better heat dissipation. In order to brake the vehicle, voltage is applied to the field coils (from the battery or alternator) which thus generate a magnetic field which induces eddy currents in the rotors as they pass through the field. This generates a braking-torque level which is dependent on the stator excitation and on the air gap between rotor and stator.

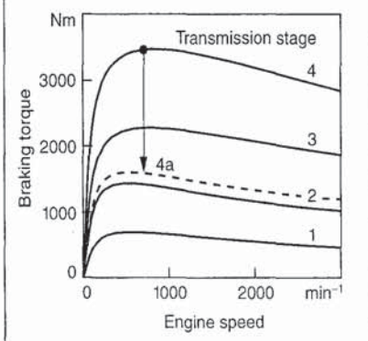
Characteristics are:
- Dissipation to the atmosphere of the heat produced,
- Relatively simple design,
- Relatively heavy construction,
- Trouble-free operation only with adequate current supply,
- Heating of the retarder leads to a reduction in braking torque,
- High braking powers even at low vehicle speeds,
- Braking power influenced by rotor blading, air-flow conditions around the eddy-current brake, and by ambient temperature.

In contrast to the conventional hydrodynamic secondary retarders, electrodynamic retarders provide relatively high braking torques at low driveshaft speeds (Fig. V).

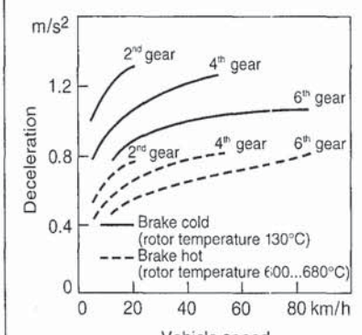
The significant reduction in braking torques of the electrodynamic retarder as the rotor temperature increases result from the thermal safeguard (Fig. W). Vehicle deceleration is reduced as thermal stress on the electrodynamic retarder increases.

In order to prevent temperature-related destruction of the retarder when the vehicle is being braked, a bi-metal switch restricts the current supply to half of the eight coils when the stator temperature reaches approx. 250 °C (Fig. W).

Braking-torque characteristic of an electrodynamic retarder *(Fig. V)*
4a Braking power when the cooling power limit has been reached (switching stage 4).

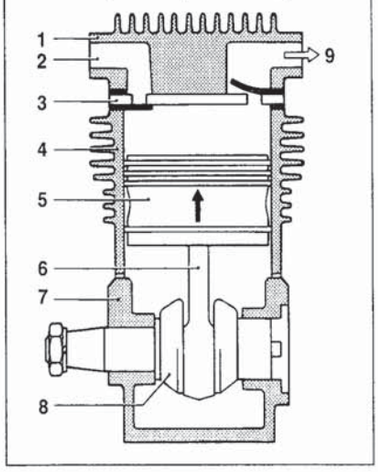


Influence of transmission ratio and rotor temperature on the performance of electrodynamic retarders *(17 t commercial vehicle, laden) (Fig. W).*

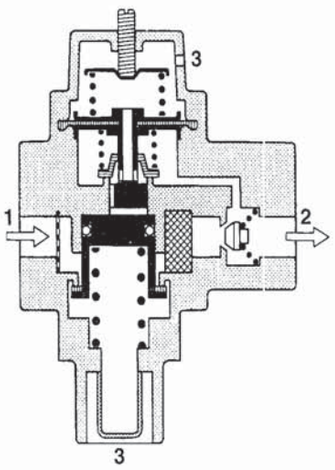


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Air compressor (compression and discharge)
1 Cylinder head, 2 Air intake, 3 Intermediate plate (with intake and outlet valve), 4 Cylinder, 5 Piston, 6 Connecting rod, 7 Crankcase, 8 Crankshaft, 9 To compressed-air system.



Pressure regulator
1 From air compressor, 2 To air reservoirs, 3 Blow-off.



Components for compressed-air brakes

Energy-supplying device

The energy-supplying device comprises the following:
- Energy source
- Pressure regulator
- Air conditioning

Energy source: The energy source is a continuously running air compressor which is driven by the engine via V-belts or toothed gears. It consists of:
- Crankcase with crankshaft (driver for power-steering pump at the free end of the shaft), bearing assembly and connections for circulating engine lubrication;
- Cylinder with piston and connecting rod;
- Intermediate plate with intake and outlet valves;
- Cylinder cover with suction and pressure connections for air and, if appropriate, the fittings required for liquid-cooled versions.

Energy-economy controls are increasingly being used in order to reduce the losses during idle operation (opening and flow resistances in the valves, lines, and pressure regulator). These are integrated in the valve plate and actuated pneumatically via an actuator. At idle, either a bypass from the compressor's pressure chamber to the input side is opened, or the intake bore is opened by rotating/shifting the intake valve.

The air compressor is usually mounted on the vehicle engine by means of base or flange attachment. In some cases it is integrated in the engine block.

During its downward stroke, the piston draws in air after the intake valve has automatically opened as a result of the vacuum. The intake valve closes at the beginning of the return movement of the piston. The air is now compressed and, after reaching a set pressure, it is conveyed via the outlet valve, which also opens automatically, into the downstream compressed-air system.

In terms of delivery rate, the aim is a volumetric efficiency of 70 % and in terms of oil consumption a maximum of 0.5 g/h is desirable.

Pressure regulation: The pressure regulator ensures that the desirec pressure level is maintained. Two principal types of regulation are used:

1. Regulation in which the pressure regu-

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

lator has no influence on the energy source (in compressors with maximum speeds >2,500 min^{-1}).

The pressure regulator switches off when the desired maximum operating pressure is reached, and returns the air supplied by the compressor to atmosphere during the subsequent no-load period. If the pressure in the air reservoirs reaches the lower operating-pressure limit the pressure regulator switches on again and supplies the air delivered by the compressor to the air reservoirs.

2. Regulation in which the pressure regulator influences the energy source (in compressors with maximum speeds <2,500 min^{-1}).

When the desired maximum operating pressure is reached, the regulator applies pressure to a plunger in the compressor and opens its intake valve. Without being supplied to the air reservoirs, the intake air is expelled through the intake fitting. When the pressure in the air reservoirs reaches the lower operating-pressure limit, the regulator switches and the intake valve can again automatically open and close, and the air reservoirs are filled.

Pressure level: In towing vehicles, values between 7 and 12 bar (low pressure) and between 14 and 20 bar (high pressure) are used. In the two-line braking system, the pressure in the lines connecting towing vehicle and trailer is between 6 and 8 bar.

Compressed-air conditioning: The air must be conditioned in order to ensure proper operation of the downstream braking-system components. Impurities in the air can cause leaks in the control valves, and water in the compressed air leads to corrosion or icing-up during frost. To combat these problems, an air drier is connected downstream of the air compressor. Such a configuration makes it unnecessary to add antifreeze to the system.

Single-box air drier

Basically, an air drier consists of a desiccant box and a housing. The housing incorporates the air passage, a bleeder valve, and a control element for granulate regeneration. Normally, the granulate is regenerated by switching in a regeneration air reservoir with integral regenerating throttle.

Function: When the bleeder valve is closed, the compressed air from the air compressor flows through the desiccant box and from there to the supply-air reservoirs. When flowing through the desiccant box, water is removed from the moist compressed air by means of condensation and adsorption. At the same time a regeneration-air reservoir with a volume of approx. 4...6 liters is filled with dry compressed air.

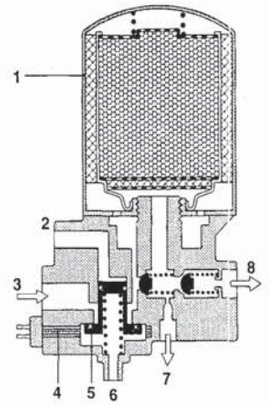
The granulate in the desiccant box has a limited water absorption capacity and must therefore be regenerated at regular intervals. In the reverse process, dry compressed air from the regeneration-air reservoir is reduced to atmospheric pressure via the regenerating throttle, flows back through the moist granulate from which it draws off the moisture, and flows as moist air via the opened bleeder valve into the atmosphere. On air driers with an integrated pressure regulator, its control element is fitted to port 4 of the air-drier valve body.

Control device

Normally, the control device comprises the brake pedal and all devices up to the point where influence is exerted on the control units.

Single-box air drier

1 Desiccant box, 2 From pressure regulator, 3 From air compressor, 4 Heating element, 5 Bleeder valve, 6 Exhaust, 7 To regeneration-air reservoir, 8 To supply-air reservoir.



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

Transmission device

The transmission device comprises the following:

- Circuit isolation (e.g., multiple-circuit protection valve),
- Energy storage (e.g., air reservoirs),
- Control units (e.g., brake valves),
- Load-sensitive braking-force metering device (e.g., automatic load-sensitive braking-force control), and
- Brake cylinders or servo cylinders.

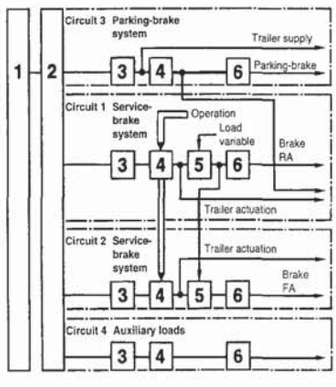
These components work together as shown in the block diagram below of a power-braking system with dual-circuit service-braking system (see also the braking-system diagram on P. 676). Functions and design of components:

Circuit isolation: Separation of the circuits with respect to one another in the event of damage in one circuit, as well as preservation of the operational integrity of the intact circuits.

Circuit isolation is primarily achieved by a combination of overflow valves grouped together as a unit; the operation of these valves is ensured at both low and high delivery rates.

Energy storage: Provision of the required volume of energy for all circuits in the braking system, including provision of energy in the event of failure of the energy source. Commercially available air reservoirs are used for this purpose; these have corresponding safety allowances for excess pressure and rust.

Transmission device in a power-braking system *(block diagram)*
1 Energy supply, 2 Circuit isolation, 3 Energy storage, 4 Control equipment, 5 Automatic load-sensitive braking-force metering, 6 Brake or servo cylinder, VA Front axle, HA Rear axle.



Control equipment

This equipment is used to control the metering of the required pressure to the corresponding parts of the system. Mechanically, hydraulically or pneumatically actuated or controlled reaction valves are used to control the pressure at the output of each valve as a function of the input variable. Due to the wide range of applications, a correspondingly large number of different components are in use. Dual-circuit control valves are also required for dual-circuit service-braking systems. Proper braking-system operation requires good control behavior, good pressure-metering capability, fast reaction times and low braking-system hysteresis.

Automatic load-sensitive braking-force metering (ALB)

Automatic braking-pressure control as a function of vehicle load. Load is often determined by spring compression (in the case of steel-spring suspension) and bellows pressure (in the case of pneumatic suspension). A control valve with a variable reaction-surface area reduces the output pressure in the valve in relation to the input pressure as a function of spring compression or bellows pressure.

Brake cylinders or servo cylinders

Convert the pressure applied to the braking system into braking force. Both plunger- and diaphragm-type cylinders are used. Diaphragm-type cylinders are primarily used for the service-braking system, while spring-brake actuators are used for the parking system. In the case of axles which are acted upon by both the service-braking system and the parking-brake system, combined single-chamber spring-brake actuators (so-called combination cylinders) are used in braking systems without hydraulic force transmission.

Wheel brakes (see P. 678)

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

Service-brake valve

Two tandem-arranged control valves are actuated by a common device (brake pedal with transmission). The synchronized opening of both circuits is ensured by identical spring and valve sealing forces as well as by the mechanical overcoming of the opening forces in both control valves. In the braking position, the rocking piston between the control circuits is subjected at its two ends to the currently applied braking pressure and thus guarantees that the circuits are synchronized. The preloaded travel spring provides small response travels of the service-brake valve. The interaction of the force of the reaction piston with the travel spring enables the system to execute the necessary control travels independently. Dual-circuit sealing of the rocking piston ensures the required safety.

Parking-brake valve

Today's compact design of the parking-brake valve is a direct result of the lack of installation space at the instrument panel (where it used to be fitted). The parking-brake valve always actuates the brake cylinders via relay valves.

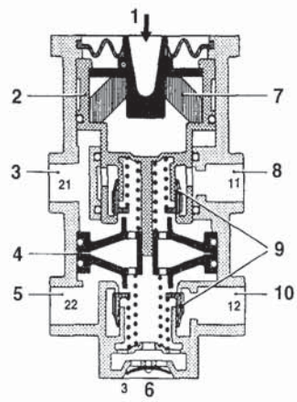
A hand lever (actuating lever) adjusts an internal valve seat by means of an eccentric and a linking strap. In doing so, it controls a double-seat valve in which compressed air from above and the force of compression springs from below act on a valve piston. In the brake position the actuating lever latches into position automatically, and the space above the valve piston is purged of air. As many intermediate settings between the drive and brake settings as desired are possible.

If the actuating lever is moved beyond the brake position, the auxiliary (test) valve is actuated and compressed air flows from the supply-air reservoir into the connecting line to the trailer-control valve. This leads to the towing-vehicle braking effect being retained, although it is cancelled for the trailer.

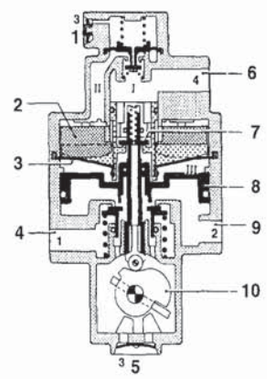
Automatic load-sensitive braking-force regulator

This device is connected between the service-brake valve and the brake cylinders. Depending on the vehicle load, it regulates the applied braking pressure. The device has a reaction diaphragm with variable active area. The diaphragm is held in two radially arranged and interlocking rakes. Depending on the position of the control-valve seat in the vertical direction, there is a large reaction area

Service-brake valve
1 Actuation, 2 Reaction piston, 3 Brake circuit 1, 4 Rocking piston, 5 Brake circuit 2, 6 Exhaust, 7 Travel spring, 8 Supply circuit 1, 9 Control valves, 10 Supply circuit 2.



Automatic load-sensitive braking force regulator
1 Exhaust, 2 Rake, 3 Reaction diaphragm, 4 From air reservoir, 5 Exhaust, 6 From service-brake valve, 7 Control valve, 8 Relay piston, 9 To brake cylinders, 10 Rotary cam.



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

(valve position at bottom) or a small reaction area (valve position at top). Consequently, the brake cylinders are supplied via an integrated relay valve with a pressure which is lower than (unladen), or which is the same as (fully laden), that coming from the service-brake valve. The regulator is mounted on the vehicle frame and senses the compression position of the axle by a rotary lever via linkages. The rotary cam moves the valve rod accordingly in the vertical direction and thus determines the valve position. The pressure limiter which is integrated into the device at the top allows a small partial pressure to flow in on the top side of the diaphragm. Thus, up to this pressure there is no reduction in the brake-cylinder pressure. This results in the synchronous application of the brakes on all vehicle axles. If the rotary lever breaks, the applied pressure flows to the brake cylinders at a ratio of 2:1.

Combination brake cylinder for wedge brakes

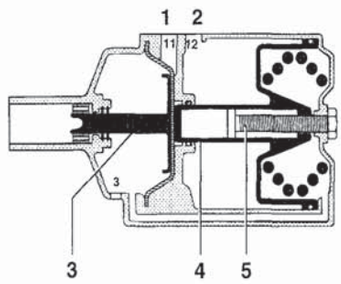
The combination brake cylinder consists of a single-chamber diaphragm cylinder for the service brakes and a spring-brake actuator for the parking brakes. The cylinder and spring-brake actuator are in tandem and act on a common pressure rod. They can be actuated independently of each other. Simultaneous actuation results in the addition of their forces. The central release screw permits tensioning the spring of the spring-brake actuator without compressed air having to be applied. This is the setting when installed in the vehicle. Following installation, the release screw is screwed into the spring-actuator cylinder, and the spring acts via the piston rod on the wedge mechanism. The entry of compressed air into the spring-actuator cylinder (when parking brake is released) forces the piston back against the action of the spring, loads the spring and releases the brake (position illustrated). When the service brakes are operated, compressed air flows into the diaphragm cylinder, actuating the wedge mechanism by way of the diaphragm and the thrust rod. A drop in air pressure releases the brake.

The principle described above is modified for cam-operated brakes and for disc brakes.

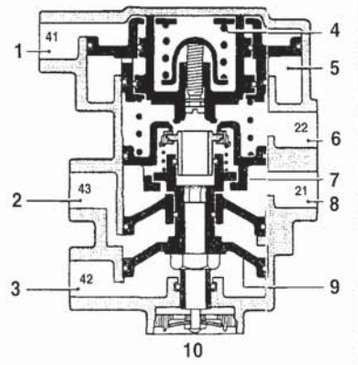
Trailer-control valve

In two-line braking systems, the trailer-control valve which is installed in the towing vehicle controls the trailer's service

Combination brake cylinder for wedge brakes
1 Single-chamber cylinder control line,
2 Spring-brake actuator control line,
3 Pressure rod, 4 Piston rod, 5 Release screw.



Trailer-control valve
1 Service-brake circuit 1, 2 Parking-brake circuit, 3 Service-brake circuit 2, 4 Pilot spring, 5 Control piston 1, 6 Control line to trailer, 7 Control-piston unit, 8 Supply line to trailer, 9 Control piston 2, 10 Exhaust.



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

brakes. This multi-circuit relay valve is triggered by both service-brake circuits and by the parking-brake system.

In the driving position, the supply chamber as well as the chamber of the parking-brake circuit are each subjected to equal pressure, and the trailer-control line is exhausted through the central exhaust port. A rise in pressure upstream of the control piston of brake circuit 1 (top) and/or of brake circuit 2 (bottom) leads to a corresponding rise in pressure in the trailer-control line. Brake circuit 1 is equipped with a larger control piston than brake circuit 2, which means that it has priority over the control piston of circuit 2. This priority ends when the pilot pressure is reached (pilot-spring force is exceeded). A reduction in pressure in the service-brake circuits leads to the same reduction in the trailer-control line. The exhausting of the parking-brake circuit (braking) increases the pressure in the chamber to the trailer-control line. The application of air to the parking-brake circuit (releasing) again exhausts the trailer-control line.

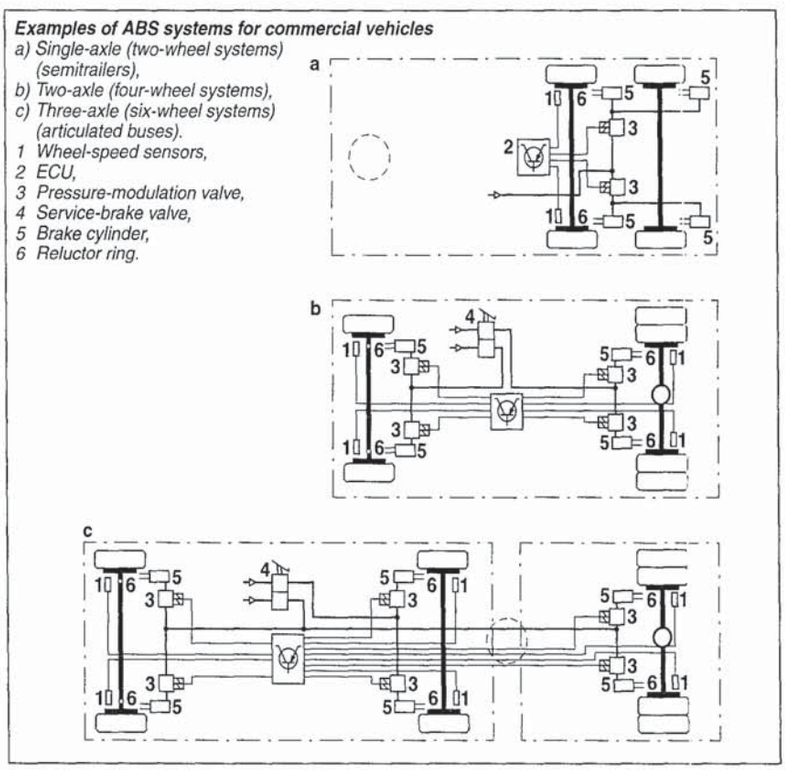
Mufflers

Current and future legislation stipulates the reduction of compressed-air valve exhaust noise. Absorption-principle mufflers are used whose size depends on the exhaust-air quantity, air pressure, exhaust duration, and required noise level.

The muffler is a cylinder with radial and axial slits, and is filled with insulating material. Noise damping is due to inflow geometry, the insulation cartridge, and the exhaust slits with spherical exhaust flow. Mufflers are attached to the compressed-air valves via threaded, snap-action, bayonet, or pipe connections. Some versions fulfill the "Low-Noise Vehicle" conditions [72 dB(A)].

Examples of ABS systems for commercial vehicles

a) Single-axle (two-wheel systems) (semitrailers),
b) Two-axle (four-wheel systems),
c) Three-axle (six-wheel systems) (articulated buses).
1 Wheel-speed sensors,
2 ECU,
3 Pressure-modulation valve,
4 Service-brake valve,
5 Brake cylinder,
6 Reluctor ring.



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

Antilock braking systems (ABS) for commercial vehicles

The ABS prevents the wheels from locking when the vehicle is overbraked. The vehicle therefore retains its directional stability and steerability even under emergency braking on a slippery road surface. The stopping distance is often shorter than with locked wheels. ABS prevents the danger of jackknifing in the case of vehicle combinations.

In contrast to passenger cars, commercial vehicles have pneumatic braking systems. Nevertheless, the functional description of the ABS control circuits for passenger cars (see P. 659) also applies in principle to commercial vehicles.

The antilock braking system as used in commercial vehicles consists of wheel-speed sensors, an electronic controller (ECU) and pressure-modulation valves. The ABS regulates the brake pressure in each brake cylinder by increasing the pressure, holding it constant or reducing it by exhausting to atmosphere.

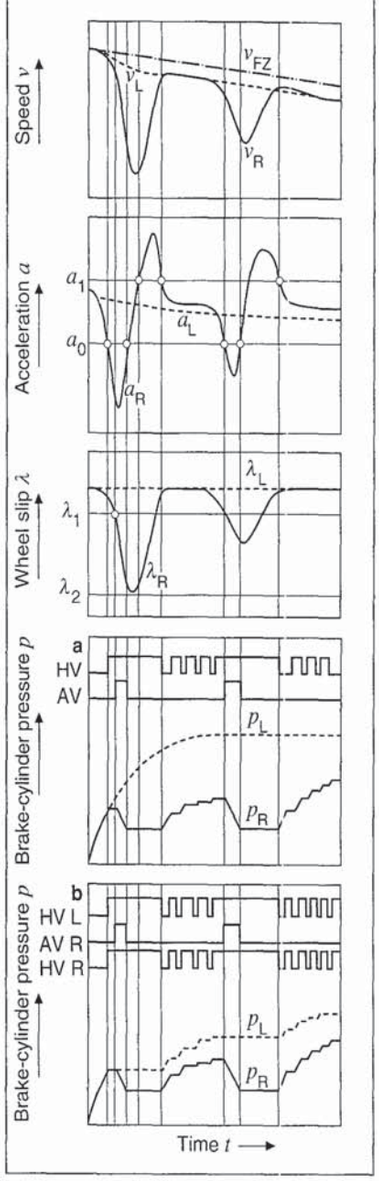
Individual control (IR)

This process, which sets and controls the optimum brake pressure individually for each wheel, produces the shortest braking distances. Under μ-split conditions (different friction coefficients between right-hand and left-hand wheels, e.g., black ice at edge of road surface, good grip at center of road surface) braking produces a high yawing moment about the vertical axis of the vehicle, thus making short-wheelbase vehicles difficult to control. In addition, this is coupled with a high steering moment as a result of the positive steering roll radii in commercial vehicles.

Select-low control (SL)

This process reduces the yawing and steering moments to zero. This is achieved by applying the same brake pressure to both wheels on the same axle. This requires only one pressure-control valve for each axle. The pressure applied is chosen to suit the wheel with less grip (select low), the wheel with more grip is braked less heavily compared to the individual control (IR) method. Under

ABS control processes
Example: Braking on μ-split.
a) IR individual control (rear axle), b) IRM individual control modified (steering axle).
HV = Holding valve, AV = Outlet valve.
Subscripts: FZ vehicle, R Right wheel, L Left wheel, 0, 1, 2 thresholds.



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

μ-split conditions, braking distances are longer but steering control/directional stability of the vehicle is better. If grip conditions (coefficients of friction) are the same on both sides, braking distances, steering control and directional stability are virtually identical with systems which control each wheel individually (IR).

In the case of similar control principles with higher pressure levels than that in the SL method, the wheel running with the lower friction coefficient is forced to run with higher slip until it eventually locks up. Under μ-split conditions, braking distances are shorter compared with pure SL control systems. Steering control and directional stability of the vehicle may be very slightly worse. Normally, due to the lower frictional coefficient, there is no tire damage at the wheel which locks up.

Individual control modified (IRM)
This process necessitates a pressure-modulation valve at each wheel of the axle. It reduces yawing and steering moments only as far as necessary, and limits brake-pressure difference between left and right sides to a permissible level. This leads to the wheel which is running at the high friction coefficient being braked less strongly. This compromise results in a braking distance which is only a little longer than that for individual control (IR), but it does ensure the safe control of vehicles which tend to handle critically.

Commercial-vehicle ABS versions
Since 1 October 1991, within the area covered by the EU member states, ABS has been prescribed by law for the initial registration of commercial vehicles intended for trailer operation, and of semitrailer tractors (> 16t), as well as trailers (> 10t), and busses (> 12t). This regulation has been extended so that since 1/10/1998 all busses and since 1/10/1999 all trucks and trailers (> 3.5t) have had to be fitted with ABS.

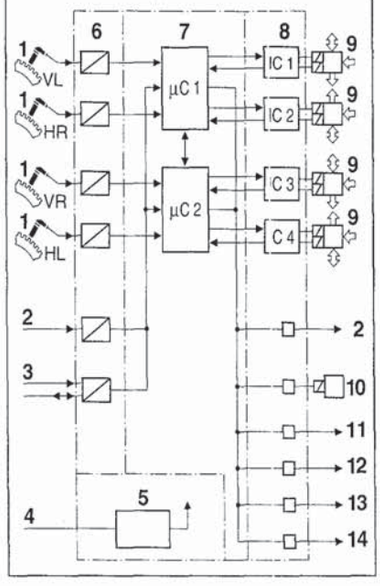
The law stipulates 3 categories of ABS which differ from each other with respect to their specifications regarding retardation and the wheel and vehicle behavior on μ-split road surfaces. Most European vehicle manufacturers only use ABS systems in category 1. Only those have to conform to all specifications of Directive 71/320/EEC.

All ABS installations must be equipped with a warning lamp which must light up for at least 2 secs after switching on the driving switch. This lamp is to be referred to by the driver as a form of visual inspection. If it lights up while the vehicle is being driven, this indicates that the installation's continuous self-testing facility has detected a fault. This can result in the ABS being switched off completely.

Towing vehicles and trailers with ABS systems from different manufacturers may be combined as desired provided there is an ABS plug and socket connection between the two vehicles in accordance with ISO 7638.

On all vehicle combinations (semitrailer tractors, truck tractor/trailer combinations), optimum control of braking at the physical limits is only guaranteed when both tractor vehicle and trailer are equipped with ABS. However, even with-

ABS/TCS control unit (ECU)
1 Wheel-speed sensor, 2 TCS engine-management interface, 3 Self-diagnosis, 4 Vehicle power supply, 5 Power supply, safety unit, 6 Input stages, 7 Microcomputers 1 and 2, 8 Output stages, 9 Pressure-control valve, 10 TCS solenoid valve, 11 Warning lamp, 12 TCS Indicator lamp, 13 Retarder relay, 14 Valve relay.



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

out ABS throughout (only on tractor unit or only on trailer) there are significant improvements compared to a vehicle combination which has no ABS at all.

In order to be able to provide the optimum and cost-effective equipment for the very wide range of commercial vehicles on today's roads, single-axle, 2-axle, and 3-axle ABS systems are available in accordance with the number of axles which are to be controlled. The single-axle systems as used primarily on semitrailers, individually control the wheels on a given axle. The remaining axles are supplied with the same brake pressures as the controlled axle.

2-axle systems are mainly fitted to two-axle buses, trucks, and trailers. Three-axle vehicles can also be equipped with a 2-axle ABS system insofar as two of the axles are in close vicinity to each other and can be provided with the same brake pressure (as for the single-axle ABS systems). The 3-axle systems are mainly intended for installation in long-wheelbase vehicles (e.g. articulated buses). In the case of 2-axle and 3-axle ABS installations, the steered axle uses either the IRM control method or, if this axle is only provided with a single pressure-control valve, the SL control method. Individual control (IR) is always used on commercial-vehicle rear axles.

The range of available ECU's permits further control combinations (not described here in detail). Example: If both axles of a semitrailer have wheel-speed sensors, but each side of the vehicle is only equipped with a single pressure-modulation valve, the wheels of one side of the vehicle are SL-controlled. In this case, one axle may be a lifting axle, which is automatically excluded from the control process when lifted.

All ABS systems can be equipped with single-channel pressure-modulation valves. ABS trailer systems can also be fitted with relay-type pressure-modulation valves (see Fig.).

In light commercial vehicles with pneumatic/hydraulic converters, ABS intervenes in the pneumatic brake circuit via single-channel pressure-modulation valves and defines the hydraulic brake pressure. In other versions, an ABS pressure modulator with integral solenoid valves is connected in parallel to the pneumatic/hydraulic converter. The modulators are controlled by the same ECUs as the single-channel pressure-modulation valves.

When the vehicle is running on a low-friction-coefficient road surface, the operation of an additional retarding brake (engine brake or retarder) can lead to excessive slip at the driven wheels. This would impair vehicle stability. ABS therefore monitors the brake slip and controls it to permissible levels by switching the additional retarding brake on and off.

ABS components

Wheel-speed sensor

For most applications nowadays, an application-engineered inductive sensor attached to the axle tube is used (for description of function, refer to P. 103). In contrast with car applications (rigidly attached sensors), on commercial vehicles the sensor is held in a spring sleeve. When the vehicle is in motion, the action of the wheel-bearing play and the flexing of the axle moves the sensor along its axis, thereby automatically adjusting the clearance between the sensor and the reluctor ring. If, under exceptional circumstances, the clearance gap becomes excessive, the ECU switches off the control for the wheel in question.

In the future, inductive sensors integrated in the wheel bearings and semiconductor speed sensors will be used more and more frequently due to economic considerations.

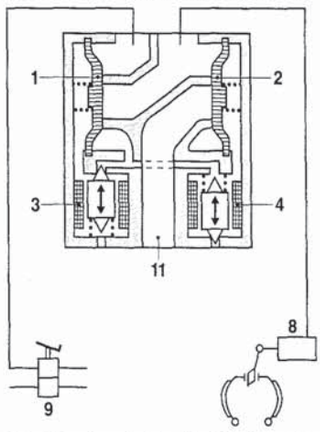
Electronic control unit (ECU)

The ECU's input stages convert the incoming sinusoidal signals from the wheel-speed sensors into square-wave signals. The wheel speeds are calculated from the frequency of the square-wave signals by (redundant) microcomputers. These speeds are used to estimate a vehicle reference speed. The brake slip for each wheel is calculated using this reference speed and the individual wheel speed. If a wheel has a tendency to lock, this is determined from the "wheel-acceleration" and "wheel-slip signals". In such a case,

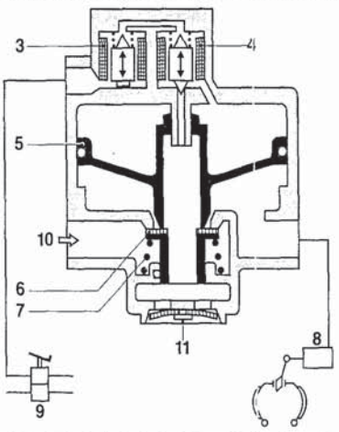
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Pressure-modulation valve (schematic)
1 Holding valve, 2 Outlet valve, 3 Solenoid valve for "Maintain pressure", 4 Solenoid valve for "Reduce pressure", 5 Control piston, 6 Valve plate, 7 Compression spring, 8 Brake cylinder, 9 Service-brake valve, 10 Supply air, 11 Exhaust.

Single-channel pressure-modulation valve



Pressure-modulation valve with relay action



the microcomputer energizes (via the ECU output stages) the solenoids of the pressure-modulation valves which control the brake pressure in the individual wheel-brake cylinders.

The ECU contains a comprehensive program for the detection of faults throughout the entire antilock system (wheel-speed sensors, ECU, pressure-modulation valves, wiring harness). If a fault is detected, the ECU switches off the defective part of the system and stores a code detailing the faulty signal path. That code can be retrieved by a service technician with the aid of the warning lamp (flashing signal) or using an intelligent testing device (e.g. personal computer) via a standardized serial interface.

The ECU's of some European ABS manufacturers include not only the ABS function but also functions for TCS traction control and in some cases for cruise control (see also page 611). The most important factor is that depending upon the model, the ECU automatically configures itself to the required function. In other words, if the vehicle concerned is only ABS-equipped, the ECU only carries out the ABS function; if the vehicle has TCS components the ECU also controls wheel slip automatically.

Pressure-modulation valve

Single-channel pressure-modulation valves are available with and without relay action. The relay-action valves are installed in semitrailers and drawbar trailers. The standard trailer-braking system often includes relay valves which can then be replaced by ABS relay-action valves. Non-relay-action ABS valves are used in all other vehicles, i.e. in buses, trucks and tractor-trailer rigs, as well as in trailers and special vehicles. Both types of valve have 3/2 pilot valves. The non-relay-action valves thereby control 2/2 diaphragm valves, which have a sufficiently large cross-section for almost all applications. In the case of the relay-action valves, the 3/2 solenoid valves affect the pressure in the pilot chamber of a relay valve. The electronics control the solenoid valves in the appropriate combination so that the required function is performed (pressure retention or pressure release). If no pilot-valve actuation takes place, "pressure build-up" is the result.

When braking normally (that is, without ABS response = no locking tendency of a wheel), the air flows through the pressure-modulation valves unhindered in both directions when pressure is applied to or removed from the brake cylinders. This ensures fault-free functioning of the service-braking system.

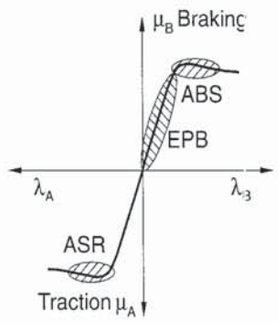
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Electronically controlled braking system (ELB) for commercial vehicles

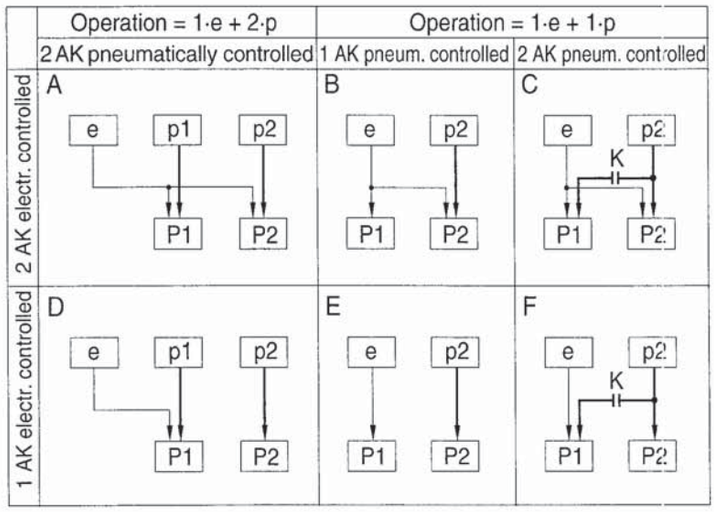
Assignment

The aim of the electronically controlled braking system (ELB) for commercial vehicles is to optimize the braking process and, in certain cases, the power transmission process. The ELB system also supports the driver and the service technician during monitoring and servicing of the braking system, as well as contributing to an increase in economic efficiency. ELB comprises the areas of ABS (Antilock Braking System), EPB (Electropneumatic Brake), and TCS (Traction Control System). Within an electronic vehicle-management system, the ELB utilizes the information available from the data bus network to produce easy-to-control and

Adhesion-slip diagram, scope of ELB
λ Slip, μ Adhesion coefficient.
Indices: A Traction, B Brake.



Structure of the operating and working circuits
e/p Electrical/pneumatic operation, P Pneumatic working circuit (AK),
1, 2 Compressed air from reservoir 1, 2,
K Valve for circuit isolation (decoupling),
A...F variants.



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

directionally stable braking and power transmission, and to provide information for other systems. Compared with conventional braking systems, an ELB system can be simpler in design. In the ELB, complex functions are processed electronically.

Function blocks

An ELB encompasses at least the following function groups:
- Electropneumatic braking system (EPB),
- Antilock braking system (ABS)
- Traction control system (TCS).

ABS and TCS are already in use on commercial vehicles (see PP. 693 and 610) and in the ELB are up-graded by the availability of additional information such as brake pressures and axle loads. Under stable adhesion/slip range (see Adhesion-Slip Curve) the action of the brakes is controlled electronically by the EPB. In this process, the effect of pressure control on the wheels, axles and the tractor and trailer units over the EPB range as a whole, is designed to comply with a variety of different targets. Thus, for light braking operations, the control-system objective may be even brake-lining wear, for medium to heavy braking it may be precise balancing of braking forces, and for emergency braking the aim may be maximum possible braking effect.

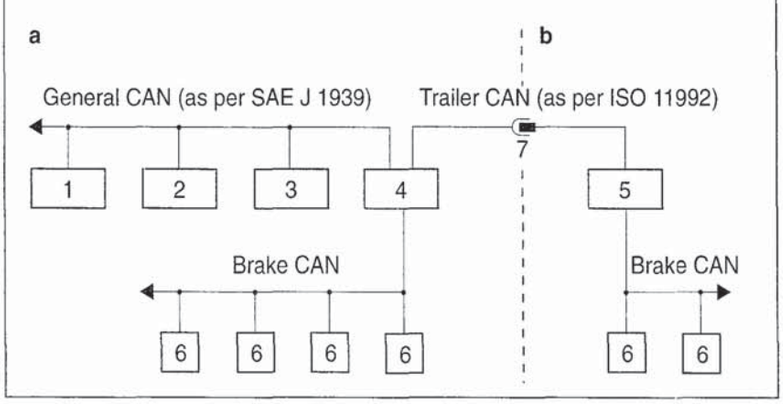
Design

Compressed-air supply, circuit isolation, energy storage and brake cylinders are the same as in conventional braking systems. The additional components include: pressure-control modules in the vicinity of the wheels for adjusting the brake pressure in the wheel cylinders as required, and an ECU. The system may also include a trailer control module the main function of which is to brake a conventional trailer.

Today, ELB systems with pneumatic retention circuits are available in the form of back-up systems at the safety level. Tomorrow's vehicle generations will be able to provide adequate safety while featuring electrically controlled multiple circuits without retention circuits. Normally, the pneumatic working circuits for operation of the brake cylinder in the tractor vehicle are of the dual-circuit design (II braking-force distribution, see P. 654) and in the trailer they are single circuit. The Figure

CAN networking of the brake components and their networking to other systems in the vehicle

a) Tractor vehicle, b) Trailer.
1, 2, 3 CAN stations (e.g. information, chassis, drivetrain),
4, 5 CAN stations (ELB control unit),
6 CAN stations (ELB pressure-control module),
7 Plug connection ISO 7638 (7-pole).



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

"Structure of the operating and working circuits" shows combinations of electrical and pneumatic control of two working circuits. For example, electrical operation of all axles is possible with Variant A which also features separate pneumatic retention circuits. Trailers are controlled via a standardized CAN data bus (ISO 11 992) (see P. 884). The pneumatic control circuit is retained in order to cope with tractor/trailer rigs using conventional vehicles and the stipulated control for all braking circuits. However, this function too can be performed by an electronically controlled trailer control module.

Apart from the CAN data bus connecting it to the trailer, an ELB has at least two more: One bus links it to the ECUs for the drivetrain (e.g. EDC and/or retarder ECUs, transmission ECU, etc.) and one internal bus to the system for communicating with the pressure-control modules and the trailer control module (see diagram "CAN Networking"). The ELB is thus able to exchange information with other systems in order to optimize vehicle management functions.

Functional sequence EPB

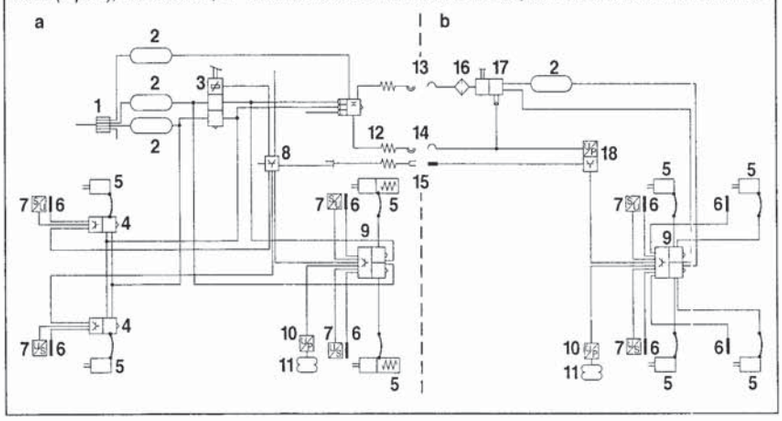
A single-circuit ELB with 2-circuit retention circuit (1e + 2p) is shown in the Fig. "Service-brake installation of an ELB". In addition to a conventional pneumatic trailer control, this ELB also features an electrical control.

After the driving switch is turned, the ELB is initialized and subjected to a self-test. If no faults are detected on the ELB, the warning lamps go out and electrically controlled braking can now take place. Redundant principles are applied in the registration of the brake-pedal position. This is used by the ELB control unit to calculate the optimum pressure level for each control channel. The data is transmitted to the pressure-control modules (located near to the wheels) via the braking-system CAN. At the same time, the brake values are sent to the trailer via CAN. The pressure-control modules (DRM) on the tractor unit and trailer automatically adjust the brake pressure to the required level. Sensor signals from the wheels for variables such as wheel speed, brake lining thickness, etc. are sent by the pressure control modules via the CAN to the ELB control unit. The system's rapid reaction with simultaneous pressure regulation on all axles produces a direct braking feel similar to that in a passenger car.

Service-brake installation of an ELB

a) Tractor vehicle, b) Trailer.

1 Four-circuit protection valve, 2 Air reservoir, 3 Service-brake valve with braking-value sensor (1e+2p), 4 Single-channel pressure-control module (DRM), 5 Wheel-brake cylinder, 6 Wheel-speed sensor, 7 Lining-wear sensor, 8 ELB control unit in the tractor vehicle, 9 Two-channel pressure-control module (2K-DRM), 10 Pressure sensor, 11 Air-suspension bellows, 12 Trailer control valve, 13 Supply coupling head (glad-hand), 14 Brake coupling head (glad-hand), 15 Plug-in connection ISO 7638 (7-pole), 16 Line filter, 17 Trailer brake valve with release device, 18 ELB control unit in the trailer.



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

Trailers equipped with ELB which are towed by tractor vehicles having a 5-pole ABS plug-in connection generate their electrical brake value from the pressure in the pneumatic trailer brake line.

When the driving switch is at "Off", or if pressure control is deactivated in the event of a fault, the solenoid valves in the pressure-control modules revert to the mechanically held normal position. In that position, the pneumatic retention circuits from the service brake valve apply the brake pressure to the wheel cylinders unmodified (back up braking).

Extended functions

ELB incorporates EPB, ABS and TCS as standard functions. Other functions for automatic brake balancing and functions which require interaction with other systems are already available fur use on production models or are in the course of development.

A few examples are given below:

Brake management

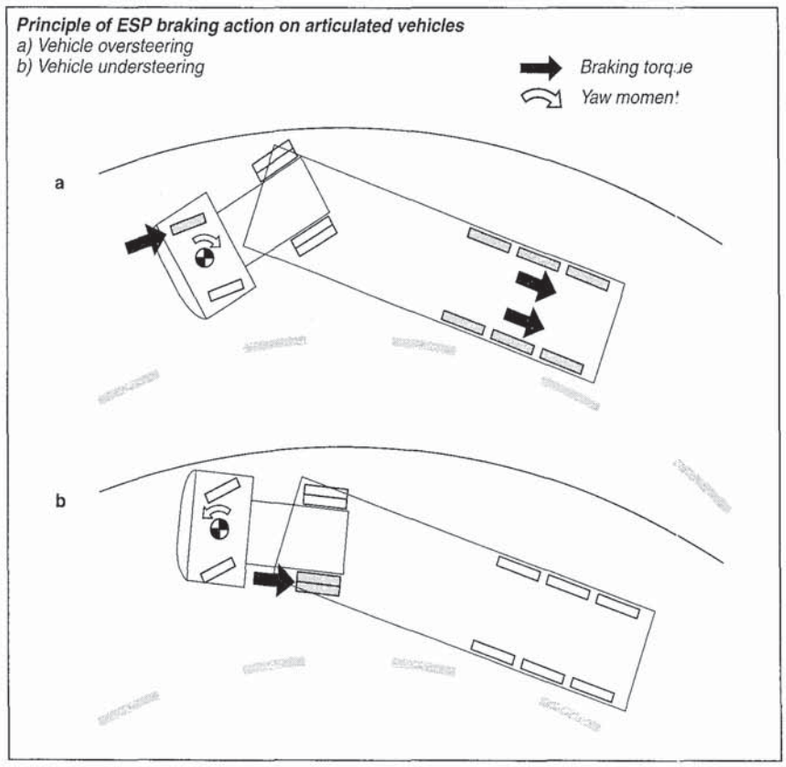
The braking effect desired by the driver can be achieved by means of either the retarder and/or the engine brake and/or the service brakes. The ELB control unit can perform the task of allocating the braking function to the appropriate braking system or systems.

Braking regulation

Vehicle deceleration is performed according to the driver's command, i.e. the position of the footbrake valve, regardless of whether the vehicle is loaded or empty. An automatic brake monitoring system prevents overload.

Brake-lining wear control

The brake-lining thickness is detected by sensors. Under normal braking with low levels of deceleration, the brake-lining



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

wear between the wheels on the same axle is equalized by slight adjustment of the brake balance.

Brake balancing between tractor unit and trailer

The aim of automatic balancing of the braking force of the tractor unit and the trailer is to generate optimum trailer-coupling forces between the two units when braking. For articulated vehicles, the optimum trailer-coupling force is equal to the coupling load; for truck-and-trailer combinations it is zero. Each unit is then braked individually according to its own mass. Assuming appropriate braking-system design and choice of brake linings, this then generally leads to equalization of temperatures and therefore of wear between the brake linings on the tractor unit and the trailer.

Brake monitoring

The energy generated in a brake is dependent on the vehicle's speed and the braking torque, while the temperature of the brakes is also dependent on the dissipation of the heat produced by friction. Using those variables, the ELB can estimate the temperature of the brakes and then take action to prevent overloading.

Inappropriate reduction of braking torque on one or more wheels can be detected by ECU analysis of the vehicle behaviour under braking.

Rollback limiter/"Bus-stop brake"

The use of information that is normally available from other electronic systems via the SAE J1939 CAN enables automatic application of the brakes shortly after the vehicle starts to roll with the drive disengaged, e.g. when stopping at traffic lights. In the same way, the brake is automatically released when the vehicle starts to pull away. On public transport busses, this function can replace the so-called "bus-stop brake".

Electronic stability program (ESP)

ESP is an extension of the ABS system and controls not only longitudinal dynamics (like ABS) but also actively responds to the vehicle's transverse dynamics at the limits of adhesion (e.g. in the event of a skid). This requires a yaw-rate sensor and a lateral-acceleration sensor for determining the actual vehicle behaviour, as well as a steering-angle sensor for detecting the driver's intentions. If there are inconsistencies between the driver's intentions and the vehicle's behaviour, e.g. if the tractor unit starts to understeer or oversteer, the ESP modifies the vehicle behaviour by automatic braking of individual wheels to reflect the intentions of the driver. The physical processes involved are explained in the description of ESP for cars (see P. 704). The same basic principles apply to commercial-vehicle ESP systems with the exception of the braking strategy. This is modified to suit commercial vehicles in their various forms. For example, as well as braking of individual wheels on the tractor unit, correction of oversteer can be assisted by braking the trailer to tension the tractor-and-trailer combination (see diagram "Principle of ESP braking action on articulated vehicles"). The trailers do not normally have sensor systems for detecting handling dynamics and are therefore not involved to any greater degree in the control of vehicle directional stability.

It is clear that the risk of overturning is considerably greater with commercial vehicles than with cars. For that reason, the commercial-vehicle ESP also incorporates functions for reducing the likelihood of vehicle overturn. This applies to ELB systems both on the tractor unit and on the trailer. From the available signals, critical vehicle conditions are detected and the vehicle or vehicle combination automatically braked as required by the particular situation. The behaviour of trailers without ELB is estimated by the tractor unit's ECU. It then instigates appropriate braking operations as required to avert hazardous situations.

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

Brake test stands

The brakes are of decisive importance in maintaining high technical standards of vehicle safety; it is therefore imperative that the brake system be inspected on a regular basis. The German motor vehicle inspection prescribed by Paragraph 29 of the StVZO Road Licensing Regulations (FMVSS/CUR) employs brake test stands (roller dynamometers) for this purpose, as do automotive service centers for inspections and repairs. The braking forces monitored at the wheel's circumference provide the basis for evaluating the operation and effectiveness of the brake system. Brake stands employed for the inspections stipulated in Paragraph 29 must conform to the "Regulations governing use, design and testing of brake test stands" as administered by the Federal Transport Minister.

Design

The brake test stand's main components are two roller sets, for the left and right sides of the vehicle respectively. The vehicle is driven onto the test stand so that the wheels of the axle being tested rest upon the rollers.

A stable frame supports the roller sets, which assume the form of a drive roller and a secondary roller in a parallel layout, while a drive chain provides the positive dynamic connection between the two rollers. An AC motor powers the drive roller through a gear set with an upward conversion ratio, while the drive unit itself is suspended on an extension of the drive roller's shaft. Pressure exerted against a torque lever flanged onto the gear-drive unit is transferred through the load sensor, with the frame providing positive support for the entire assembly. The braking force F_{Br} is actually measured by monitoring the reaction torque M_R. The electric motors set the rollers in motion and then maintain an almost constant rotational speed against the opposing forces that occur when the vehicle's brakes are applied. The suspended drive unit with torque lever transmits the braking forces to the load-sensing device. The load-sensing device is designed as a flexural sensor with wire strain gauge.

The system's computer employs digital technology in the subsequent evaluation of the various data derived from braking-force testing, such as fluctuations or differences in braking force. Once processed, the information is presented in either analog or digital form, depending upon the specific system, while a printer can be connected to provide a hardcopy test protocol.

Operation

The drive motors for the roller sets may be activated in one of two ways, either by remote control or with an integral automatic on/off switch. An automatic-activation test stand is distinguished by the pressure-sensitive rollers located between the main test rollers on each roller set. When the vehicle is driven onto the test stand, it pushes down the pressure-sensitive rollers and activates the stand. When the vehicle leaves the stand the pressure-sensitive rollers are released and the unit is switched off. Should the applied braking force start to exceed the available traction between tires and test rollers, the wheel will respond by starting to slip and will then lock. Tire slip, however, makes it impossible to perform useful measurements of braking force. Under these conditions, it is the slip resistance between tire and roller (as a function of wheel load) that is measured and this is of no use. Here, assistance is provided by an automatic override device which recognizes this kind of slip by monitoring the test-roller speed, and which responds to it by switching off the test unit when a given maximum figure is exceeded. This avoids both false measurements and possible tire damage. The display, meanwhile, continues to show the maximum braking force achieved before the override device was activated. An electronic memory circuit ensures that the final display remains in place long enough to be recorded by the operator.

In addition, the vehicle and/or axle weight can also be measured at the test stand or entered remotely; the test unit can then use this information to calculate the effective retardation.

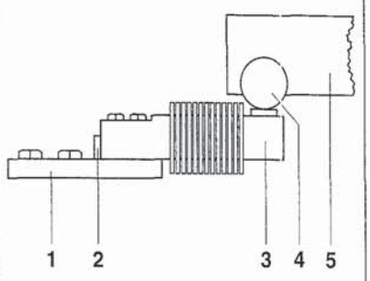
The brake test stand employs specific test sequences to provide extremely rationalized examination procedures, allowing

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

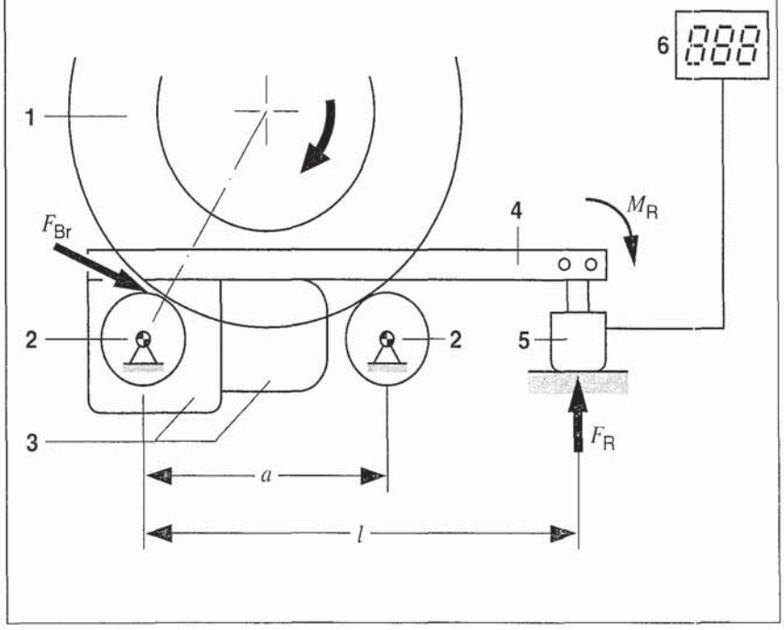
the operator to carry out complete testing of both front and rear brakes without leaving the vehicle.

Vehicles with permanent 4-wheel drive and variable torque distribution are tested on special stands, which are constructed to prevent the forces generated at the test axle from being transferred to that axle which is at rest.

Brake test stand: Measurement sensor
1 Adjustment plate, 2 Alignment pin,
3 Flexural sensor with wire strain gauge,
4 Thrust block, 5 Torque lever.



Determining braking force F_{Br} via measurement of reaction torque M_R
1 Vehicle tire,
2 Roller set with spacing a,
3 Motor with gear set,
4 Torque lever with length l,
5 Measurement sensor,
6 Display.



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

Electronic Stability Program (ESP) for passenger cars

Quantities and terms

a	Distance of front wheels from center of vehicle mass
a_x	Estimated longitudinal acceleration of vehicle
a_y	Measured lateral acceleration of vehicle
A_0, A_1, A_2	Parameters for calculation of tire operating point
c	Distance of rear wheels from center of vehicle mass
C_p	Brake-torque ratio
C_λ	Longitudinal tire stiffness
D_T	Sampling time of the controller
D_λ	Tolerance band of drive-slip difference
F_B	Brake force on the tire
F_{BF}	Steady-state (filtered) brake force on the tire
F_N	Normal force on the tire
F_R	Resultant force on the tire
F_S	Lateral force on the tire
J_{Mot}	Moment of inertia of the engine
J_{Whl}	Moment of inertia of the wheel
K_p, K_d, K_i	Controller gains for the P-, D- and I-parts
M_{Dif}	Local brake-torque difference between the driven wheels
M_{DR}	Engine torque requested by driver
M_{YwNo}	Nominal yaw moment on the vehicle
ΔM_{YwNo}	Small change in the nominal yaw moment on the vehicle
M_{CaHalf}	Half of the torque on the cardan axle
M_{Ca}	Torque on the cardan axle
M_{Mot}	Actual engine torque
M_{WhlNo}	Nominal brake torque
M_{NoMot}	Nominal engine torque
M_{NoLock}	Nominal brake-torque difference between the driven wheels
M_{NoSPR}	Nominal engine-torque reduction by spark retard
p_{Circ}	Brake circuit pressure induced by the driver
p_{Whl}	Pressure in wheel brake cylinder
p_{WhlPre}	Nominal pressure in wheel brake cylinder
R	Wheel radius
T_{iOFF}	Time during which the fuel injection is shut off
$\ddot{U}_{Tr}$	Transmission ratio
U_{val}	Actuation mode of solenoid valve
υ_{CH}	Characteristic velocity of the vehicle
υ_{Dif}	Difference between driven-wheel velocities
υ_V	Vehicle velocity
υ_{Ca}	Cardan-axle speed
υ_{Whl}	Measured wheel speed
υ_{Whl3}	Measured wheel speed, rear left
υ_{Whl4}	Measured wheel speed, rear right
υ_{WhlFre}	Wheel speed (free-rolling)
υ_{NoDif}	Nominal difference between wheel velocities
υ_{NoCa}	Nominal velocity of the cardan axle
υ_x	Vehicle speed in the longitudinal direction
υ_y	Vehicle speed in lateral direction
x_1, x_2	Parameters of the inverse hydraulic model
α	Slip angle of the tire
α_0, λ_0	Arbitrary operating point of the tire
β	Slip angle of the vehicle
β_{No}	Nominal slip angle of the vehicle
δ	Steering-wheel angle
δ_W	Front-wheel steering angle
λ	Tire slip
λ_{No}	Nominal tire slip
λ_{Ma}	Nominal average drive slip of the driven wheels
μ_{HF}	Coefficient of friction between tires and road
μ_{Res}	Resultant coefficient of friction between tire and road
$\dot{\psi}$	Yaw rate
$\dot{\psi}_{No}$	Nominal yaw rate
m	Minimum value of the nominal driven-wheel brake torque
MIN	Minimum-value operator
SUM	Event-driven integration
ZWV	Spark retard (SPR)

Assignment

The Electronic Stability Program ESP (vehicle dynamics control) system is a closed-loop control system which prevents lateral instability of the vehicle. It is integrated within the vehicle's brake system and dri-

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

vetrain. While ABS prevents wheel lockup when braking and TCS prevents spin of the driven wheels, ESP prevents the vehicle from "pushing out" of the turn or spinning out of the turn when it is steered.

Further to the advantages inherent in ABS and TCS, ESP improves the active driving safety in the following points:

- Provides the driver with active support, even in laterally critical dynamic situations.
- Enhances vehicle stability and tracking performance even in limit situations in all operating modes such as full braking, partial braking, coasting, accelerating, engine drag, and load shift.
- Enhances directional stability even during extreme steering maneuvers (panic reactions), resulting in a drastic reduction in the danger of skidding.
- Improved handling behavior also in limit situations. For the driver, this behavior becomes predictable as a function of his (or her) experience. The vehicle remains fully under control even in critical traffic situations.
- Depending upon the situation, even better utilization of the friction potential between the tires and the road when ABS and TCS intervene, and therefore improved traction and stopping distances in addition to improved steerability and stability.

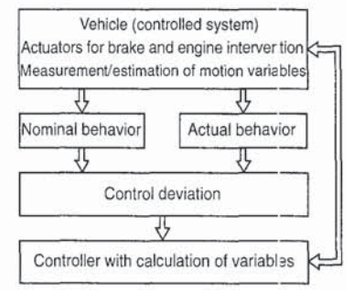
Vehicle handling

The vehicle's steering properties are defined in the description of the vehicle's lateral dynamics (P. 350). This description is derived from steady-state cornering and shows the dependence of the tire slip angle α on the lateral vehicle acceleration a_y and therefore on the lateral tire forces. Furthermore, the description of ABS (P. 659) and TCS (P. 606) also underlines the dependence of the lateral tire forces on the tire slip. This means that the vehicle's steering properties can be influenced by means of the tire slip. ESP utilizes this tire characteristic in order to effect servo-control for vehicle handling.

It is important for good vehicle handling that the vehicle remains safely on a track which corresponds as far as possible to the course of the steering-angle (see Fig. "Lateral dynamics of a vehicle", Curve 2). During steering maneuvers, this is the case if the lateral tire forces remain considerably below the friction potential between the tire and the road surface. The yaw-rate curve then corresponds to that of the steering angle.

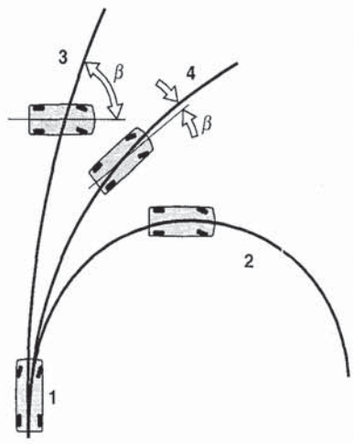
For ESP though, the mere control of the yaw rate according to the steering angle proves to be inadequate and the vehicle

Block diagram of ESP controller



Lateral dynamics of a vehicle

1 Step input at steering wheel, steering-wheel angle fixed, 2 Track on high-μ road, 3 Track on low-μ road with "open-loop" steering correction and yaw-rate control, 4 Track on low-μ road when the slip angle is also controlled (ESP).



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

can become instable (see Fig., Curve 3). The ESP therefore controls not only the yaw rate but also the vehicle's sideslip angle.

The ESP vehicle-handling control is not restricted to ABS and TCS/MSR operations, but also extends to cover the area in which the vehicle is rolling freely, and also comes into action during partial braking if the vehicle is moving at the physical driving limits.

ESP control systems

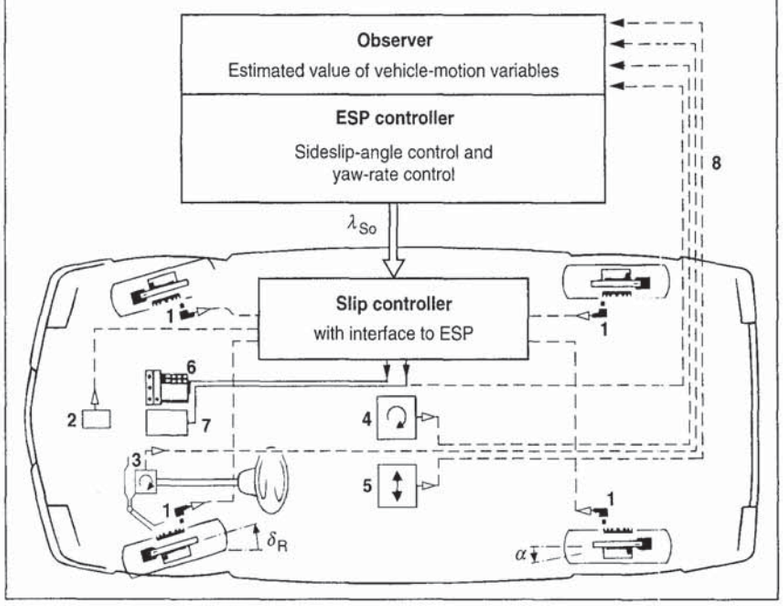
Control

The control of the vehicle's behavior at the physical driving limit must influence the vehicle's three degrees of freedom in the plane of the road (longitudinal and lateral velocities, and yaw moment about the vertical axis) so that vehicle handling is in line with the driver's input and with the prevailing road conditions. In this respect, as shown in the block diagram, it must first of all be defined how the vehicle is to behave at the physical driving limit in accordance with the driver's input (nominal behavior), and how it actually behaves (actual behavior). In order to minimize the difference between nominal and actual behavior (deviation), the tire forces must in some way be controlled by actuators.

The overall system (Fig. "Overall control system of ESP" below), shows the vehicle as the controlled system, with sensors (1...5) for defining the controller input variables, and actuators (6 and 7) for influencing the tractive force and the braking force. Also shown are the hierarchically structured controller comprising the higher-level vehicle dynamics controller, and the lower-level slip controllers. The higher-level controllers input the nominal values to the lower-level controllers in the form of a nominal slip. The "observer" determines the controlled state variable (vehicle slip angle β).

In order to determine the desired performance, the signals are evaluated which

Overall control system of ESP
1 Wheel-speed sensors, 2 Brake-pressure sensor, 3 Steering-wheel sensor, 4 Yaw-rate sensor, 5 Lateral-acceleration sensor, 6 Pressure modulation, 7 Engine management, 8 Sensor signals for ESP. α Tire slip angle, δ_W Steering angle of the wheel, λ_{No} Nominal tire slip.



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

define the driver's input. These comprise the signals from the steering-wheel sensor (3, driver's steering input), the brake-pressure sensor (2, desired deceleration input), and the engine management (7, desired drive torque). Apart from the vehicle speed, the calculation of the desired performance also takes the coefficients of friction between the tires and the road into account. These are calculated from the signals outputted by the wheel-speed sensors (1), the lateral-acceleration sensor (5), the yaw-rate sensor (4), and the brake-pressure sensor (2). Depending upon the control deviation, the yaw moment which is necessary to make the actual-state variables approach the desired-state variables is then calculated.

In order to generate the required yaw moment, it is necessary for the changes in desired slip at the wheels to be determined by the vehicle dynamics controller. These are then set by means of the lower brake-slip controller and traction controller together with the "brake-hydraulics" actuator (6), and the "engine-management actuator" (7).

The system relies on tried and proven ABS and TCS components. The TCS hydraulic modulator (6), which is described elsewhere, permits high levels of dynamic braking of all wheels throughout the complete temperature range encountered.

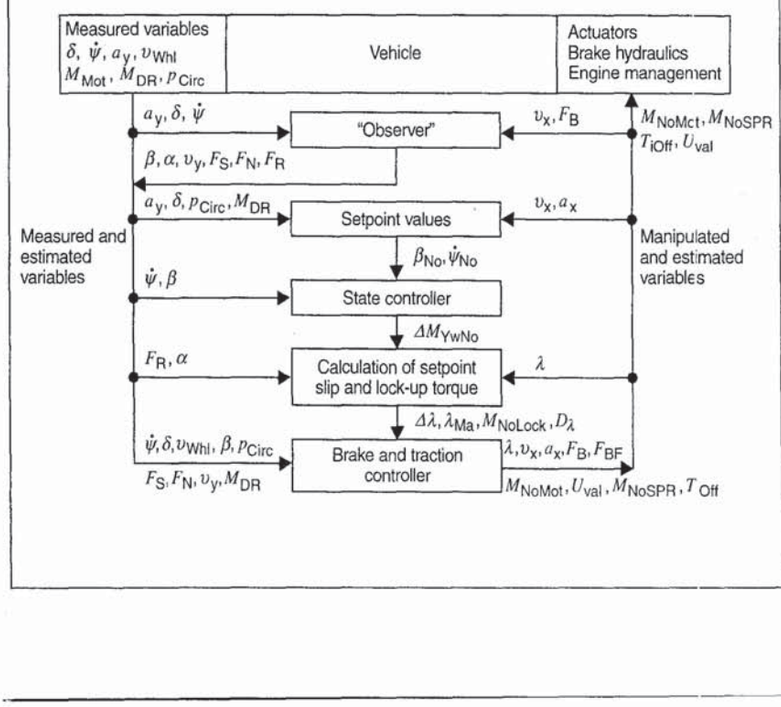
The necessary engine torque can be set by means of the engine management (7) and the CAN interface, so that the traction-slip values at the wheels can be adjusted accordingly.

System components

Vehicle dynamics controller

The relationship between steering angle, vehicle speed, and yaw rate during steady-state driving on a circular course (P. 355), is taken as the basis for the desired vehicle motion during steady-state driving, and when braking and/or accelerating. By applying the "Single-track (bicycle) model": the nominal yaw rate is cal-

Block diagram of ESP vehicle dynamics controller with input and output variables



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

culated from the vehicle speed and the steering angle:

$$\dot{\psi}_{No} = \frac{v_x \cdot \delta_W}{(a+c)\left(1+\frac{v_x^2}{v_{CH}^2}\right)}$$

For the sideslip-angle control, this value is first of all limited according to the road-surface coefficient of friction:

$$|\dot{\psi}_{No}| \leq \mu_{HF} \cdot g / v_V$$

whereby g is the acceleration due to gravity, and the coefficient of friction μ_{HF} and the vehicle speed v_V are estimated values.

No attempt is made to directly influence the lateral speed, and with it the sideslip angle, by means of changes in the lateral forces. It is better to adjust the lateral motion indirectly by means of changes in the slip angle, whereby the vehicle's rotation is initiated by the generation of yaw moments.

A simplified block diagram is used to demonstrate the structure of the vehicle dynamics controller. Using the measured variables (nominal yaw rate $\dot{\psi}_{No}$, steering-wheel angle δ, and the vehicle lateral acceleration a_y), together with the estimated variables (vehicle longitudinal speed v_x, and braking forces F_B), a so-called "Observer", using a simple vehicle model, determines the slip angle β, the sideslip angle α, the vehicle lateral speed v_y, the wheel forces in the lateral and vertical directions F_S and F_N, and the resulting wheel forces F_R in the plane of the road.

The nominal sideslip-angle β_{No}, and the nominal yaw rate $\dot{\psi}_{No}$, are determined from the following driver inputs: steering-wheel angle δ, engine-torque input M_{DR} (accelerator-pedal position), and the brake pressure p_{Circ}, together with the estimated vehicle longitudinal speed v_x, and the coefficient of friction μ_{HF} which is determined using the estimated longitudinal acceleration a_x and the measured lateral acceleration. In the process, the vehicle's dynamic response, and special situations such as inclinations, banks, and/or μ-split road surfaces (different coefficients of friction between tires and road on the left and right side of the vehicle) are taken into account.

The vehicle dynamics controller is designed as a state controller. The controlled-state variables are the sideslip angle and the yaw rate. The more the sideslip angle increases, the more it is taken into account by the vehicle dynamics controller. The state controller's output variable corresponds to a yaw moment M_{YwNo}.

Together with the actual slip values λ, the resultant wheel forces F_R, and the slip angles α, the linearized vehicle model is now also applied to convert this yaw moment into changes of the nominal slip at the appropriate wheels. For instance, presuming that the vehicle is rolling freely and oversteers in a right-hand bend so that the nominal yaw-rate is exceeded, among other things a nomina brake slip is requested at the front left wheel. This subjects the vehicle to a counterclockwise change in yaw moment which reduces the excessive yaw rate. The nominal slip is changed by the lower-level ABS or TCS wheel controller. If the brakes have not been applied, or the driver's brake-pressure input does not suffice to set the required nominal slip (partial-braking range), the pressure in the brake circuits is actively increased.

When TCS is operative, in order to set the vehicle's nominal yaw moment M_{YwNo}, the vehicle dynamics controller outputs a mean absolute drive slip $\lambda_{M\varepsilon}$, a drive-slip tolerance band D_λ, and a nominal brake locking torque M_{NoLock}. In order to achieve distinct improvements for the ABS and TCS basic functions with regard to their utilization of the adhesion potential in line with the driving situation, all available measurement quantities and estimated values are also applied to the full in the slip controllers.

Lower-level brake-slip controller (ABS) and engine drag-torque controller (MSR)

In order to be able to control the wheel slip to a definite level, it must be possible to evaluate it with an adequate degree of accuracy. The vehicle's longitudinal speed is not measured, but is determined from the wheel speeds v_{Whl}. To do so, individual wheels are "under-braked" during ABS application. In other words, slip control is interrupted, and the instantaneous wheel

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

brake torque is reduced by a defined amount and held constant for a given period of time. Assuming that the wheel speed is stable toward the end of this period, the zero-slip (free-rolling) wheel speed v_{WhlFre} can be calculated from the momentary braking force F_B and the tire stiffness C_λ.

$$v_{WhlFre} = v_{Whl} \cdot \frac{C_\lambda}{C_\lambda - \frac{F_B}{F_N}}$$

Using the yaw rate $\dot{\psi}$, the steering angle δ_W, and the lateral velocity v_y, together with the vehicle geometry, the (free-rolling) wheel speed is transformed into the center of gravity in order to generate the center-of-gravity velocity v_x in the vehicle's longitudinal direction. Finally, v_x is transformed back to the four wheel positions in order to evaluate the free-rolling speed of all four wheels. This enables the actual slip λ to be calculated for the control of the three remaining wheels.

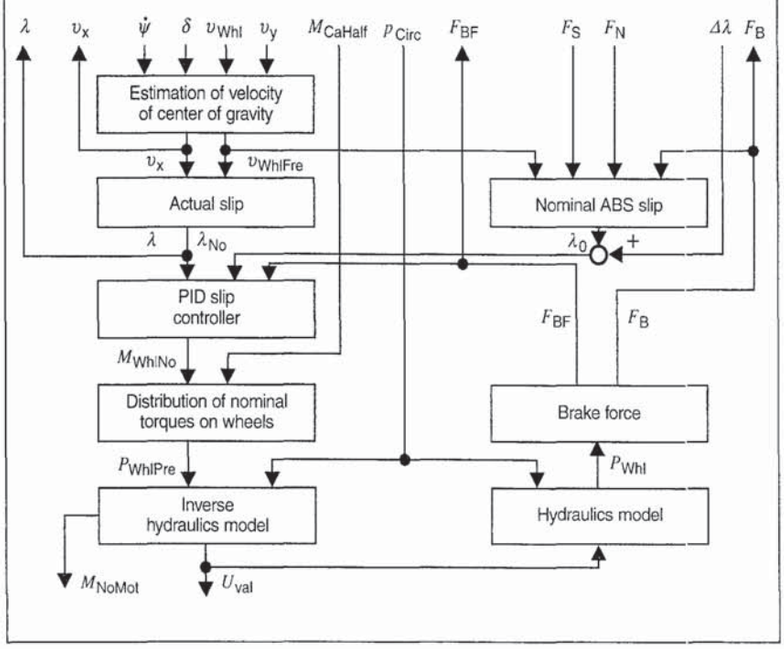
$$\lambda = 1 - \frac{v_{Whl}}{v_{WhlFre}}$$

Starting from the stationary brake force F_{BF}, using a PID control law the nominal torque at the wheel can be calculated as a function of the slip deviation.

$$M_{WhlNo} = F_{BF} \cdot R + K_p(\lambda_{No} - \lambda)R + K_d\left(\frac{d}{dt}v_{Whl} - \frac{d}{dt}v_{WhlFre}\right)\frac{J_{Whl}}{R} + K_i \cdot C_p \cdot \text{SUM}\{(\lambda_{No} - \lambda) \cdot D_T\}$$

In the case of the driven wheels, in order to implement an engine drag torque control (MSR) the nominal braking torque M_{WhlNo} can be partially set by the engine (or completely when the brakes are not applied). The driven wheel with the lower nominal wheel torque is controlled within the permissible limits by engine intervention.

Block diagram of the brake-slip controller for ABS and MSR with input and output quantities



The following applies for rear-wheel drive:

$$M_{NoMot} = -\frac{2m}{\ddot{U}_{Tr}} + \frac{J_{Mot} \cdot \ddot{U}_{Tr}}{R} \cdot \frac{d}{dt} v_x$$

$$m = MIN\ (M_{Whl3}, M_{Whl4})$$

For negative values, the nominal engine torque M_{NoMot} is limited by the maximum engine drag torque, and in the driven case (positive values) it is limited to the maximum dynamic drive torque as permitted by the manufacturer. In case of a positive nominal brake torque M_{WhlNo}, the remaining braking torque must be adjusted through the brake pressure.

$$p_{WhlPre} = \frac{M_{WhlNo} + M_{CaHalf}}{C_p}$$

The pressure p_{WhlPre} applied to the wheel-brake cylinders by the controller, is adjusted by the braking hydraulics and relevant valve-triggering mode U_{val}. The required valve time is calculated using an inverse "hydraulic model", whose parameters x_1, x_2 have been defined beforehand and stored in the controller. Essentially, the model uses the Bernoulli theorem for incompressible media, and a pressure/volume characteristic.

$$U_{val} = \frac{p_{WhlPre} - p_{Whl}}{(x_1 + x_2 \cdot p_{Whl}) \sqrt{|p_{Circ} - p_{Whl}|}}$$

$U_{val} > 0$ Build up pressure,
$U_{val} = 0$ Hold pressure,
$U_{val} < 0$ Reduce pressure.

Since the valve-control mode U_{val} is limited by the sampling time and quantified, the adjusted pressure p_{Whl} that has actually been set must be calculated using the hydraulic model. By means of the dynamic wheel equations, taking the known (estimated) wheel brake pressure and the measured wheel speeds, the actual tire braking force F_B and the steady-state braking force F_{BF} can now be calculated:

$$F_B = C_p \cdot \frac{p_{Whl}}{R} - \frac{M_{CaHalf}}{R} + \frac{J_{Whl}}{R^2} \cdot \frac{d}{dt} v_{Whl}$$

$$F_B = T_1 \cdot \frac{d}{dt} F_{BF} + F_{BF}$$

The steady-state (filtered) braking force F_{BF} now serves as the reference variable for the PID controller. Using the calculated operating point λ_0, and the change in slip stipulated by the vehicle dynamics controller, the ABS controller calculates the nominal tire slip λ_{No}.

$$\lambda_0 = A_0 \cdot \mu_{Res} + \frac{A_1}{v_{WhlFre}} + A_2$$

$$\mu_{Res} = \frac{\sqrt{F_B + F_S}}{F_N}$$

Traction controller (TCS)

On rear-drive vehicles, the traction controller is used for slip control of the driven wheels only. Active intervention at the front wheels is through the brake-slip controller. Unlike ABS, the traction controller receives from the vehicle dynamics controller the nominal mean traction-slip value λ_{Ma} of both driven wheels and a nominal brake-locking torque value M_{NoLock} to be used as reference variables for directly influencing the yaw moment. The nominal value for the differential speed of the two driven wheels v_{NoDif} is the difference in their (free-rolling) speeds, whereby the vehicle dynamics controller also stipulates a tolerance band D_λ for the difference between the two drive-slip values. This difference represents a dead zone for the control deviation in order that a nominal brake-locking torque M_{NoLock} can be generated.

The TCS module calculates the nominal braking torque M_{WhlNo} for both driven wheels, the nominal engine torque M_{NoMot} to be set by throttle-valve intervention, the nominal value M_{NoSPR} for engine-torque reduction using ignition timing (SPR = spark retard) and, as options, the length of time T_{iOFF} during which the EFI is to be cut off and the number of cylinders this cutoff is to be applied to.

The nominal values for the crankshaft and wheel differential speeds (v_{NoCa} and v_{NoDif}) are calculated from nominal slip values together with the (free-rolling) wheel speeds v_{WhlFre}. The controlled variables v_{Ca} and v_{Dif} are calculated from wheel speeds v_{Whl3} and v_{Whl4}:

$$v_{Ca} = \frac{1}{2}(v_{Whl3} + v_{Whl4})$$

$$v_{Dif} = v_{Whl3} - v_{Whl4}$$

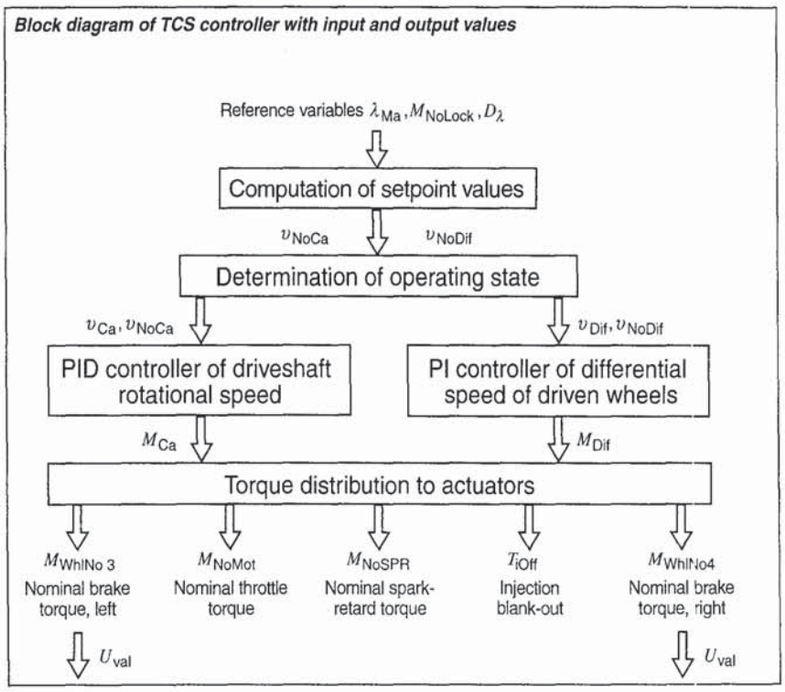
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

The dynamic response depends on the highly differing operating modes of the controlled system. It is therefore necessary to determine the operating mode in order to be able to adapt the controller parameters to the controlled system's dynamic response and to the non-linearities. The large moment of inertia of the complete drivetrain (engine, gearbox, cardan axle, and driven wheels) has an influence on the cardan-axle speed υ_{Ca} which is therefore characterized by a relatively large time constant (low dynamic response). On the other hand, the time constant of the wheel differential speed υ_{Dif} is relatively small since the dynamic response of υ_{Dif} is determined almost completely by the small moments of inertia of the two wheels. Apart from this, υ_{Dif} in contrast to υ_{Ca} is not directly influenced by the engine. υ_{Dif} and υ_{Ca} are used therefore as controlled variables because they permit the separation of the drivetrain system (measured wheel speed, rear left and rear right, υ_{Whl3} and υ_{Whl4} respectively) into two subsystems with distinct dynamic response and distinct engine influence. The engine intervention and the "symmetrical" part of the brake intervention represent the controlled variables of the cardan-axle speed controller υ_{Ca}. The "asymmetrical" portion of the brake intervention is the actuating signal for the differential wheel-speed controller υ_{Dif}.

The cardan-axle speed is controlled by means of a non-linear PID controller, whereby in particular the gain of the I-component (dependent upon operating mode) can vary over a wide range. At steady state, the I-component is a measure for the torque which can be transferred to the road surface. The cardan-axle torque M_{Ca} is the controller output.

A non-linear PI controller is used for controlling the wheel differential speed υ_{Dif}, the controller parameters being dependent upon the engaged gear and upon influences from the engine. From the tolerance band D_λ for the differential slip of the driven wheels, which is output by the vehicle dynamics controller, a dead zone is calculated for the control deviation from υ_{Dif}. For

Block diagram of TCS controller with input and output values



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

"μ-split", in order to ensure adequate traction, the vehicle dynamics controller specifies a relatively narrow dead zone. In doing so it increases the sensitivity of the controller for the wheel differential speed υ_{Dif}. If the nominal brake-locking torque M_{NoLock} is to be reduced, or in case of the optional Select-Low control, the vehicle dynamics controller defines a wider tolerance band. In these cases, the controller for the differential wheel speed υ_{Dif} permits larger differences between the rotational speeds of the rear wheels. The controller output is the differential nominal torque M_{Dif}.

The cardan-axle torque M_{Ca} and the nominal torque differential M_{Dif} are distributed between the actuators. A corresponding valve-triggering mode U_{val} in the hydraulic modulator adjusts the differential nominal torque M_{Dif} via the braking-torque difference between the left and right driven wheels. The nominal cardan-axle torque M_{Ca} is achieved by engine intervention and by means of symmetrical brake intervention. There is a relatively long delay (dead time and transient response of the engine) before throttle-valve intervention comes into effect. For rapid-acting engine intervention, if optionally available, the ignition is retarded, and the fuel injection is cut off. The symmetrical brake intervention provides short-term support for the reduction of engine torque.

By means of this module, the traction controller can be relatively easily adapted to the various engine-intervention types.

System realization

The hydraulic modulator and the wheel-speed sensors are suitable for operation in underhood conditions. The yaw-rate sensor, the lateral-acceleration sensor, the steering-wheel-angle sensor, and the ECU are designed for installation in the passenger compartment or in the trunk. An example of the in-vehicle installation of the components, together with their electrical and mechanical connections, is given on the opposite page.

Sensors

Interface monitoring is a necessity, and can be implemented efficiently and at low cost in modern-day ECUs. It has a decisive effect upon the architecture of the sensor interfaces (for sensors, see P. 94).

The demands reflected in the sensor requirements were ascertained by evaluating simulation studies together with an extensive program of road tests. The consequences of side-effects on ESP operation were also investigated (influence of positioning tolerances, cross-couplings, and other sensor malfunctions). The result was a multi-level, and thus very dense monitoring network which incorporates the aspects of analytical redundancy. In order to be able to master with the necessary reliability those complex systems which are relevant from the safety viewpoint, the aspects of analytical redundancy must be incorporated if reasons of cost forbid the application of redundant sensors.

ECU

The ECU is constructed in conventional (4-layer) pcb technology, and in addition to two partially redundant computers, it incorporates all drivers for valve and lamp triggering, as well as the semiconductor relays for valve and pump triggering, the interface circuits for sensor-signal conditioning, and the appropriate switch inputs for auxiliary signals such as those from the brake-light switch. Furthermore, a CAN interface is integrated in order to facilitate communication with other systems in the vehicle (e.g. engine management and transmission control). The large number of additional signal inputs requires the use of a special plug and socket connection in order that the size of the ECU housing can be kept to a minimum.

Monitoring system

A comprehensive safety-monitoring system is of fundamental importance for the ESP's reliable functioning. The system used encompasses the complete system together with all components and all their functional interactions. The safety system is based on safety methods such as e.g. FMEA, ETA and error-simulation studies.

From these, measures are derived for avoiding errors which could have safety-related consequences. Extensive monitoring programs guarantee the reliable detec-

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

tion of all sensor errors which cannot be prevented completely. These programs are based upon the well-proven safety software from the ABS and ABS/TCS systems which monitor all the components connected to the ECU together with their electrical connections, signals, and functions. The safety software was further improved by fully utilizing the possibilities offered by the additional sensors, and by adapting them to the special ESP components and functions.

The sensors are monitored at a number of stages:

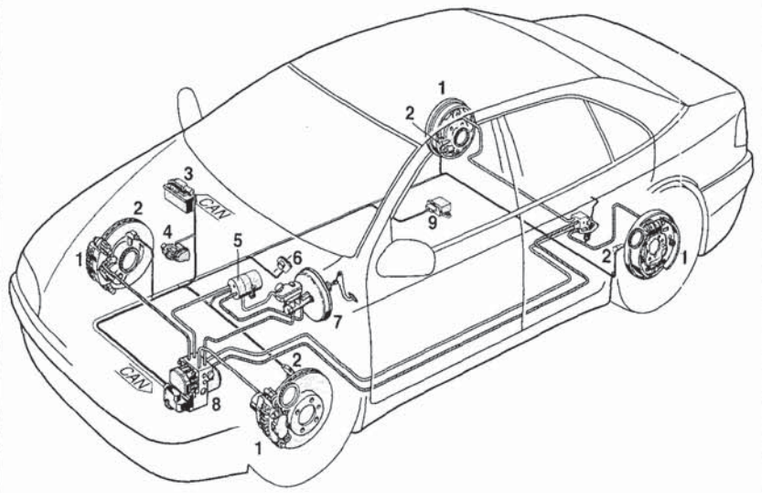
In the first stage, the sensors are continuously monitored for cable open-circuit, and signal implausibility (out-of-range check, detection of interference, physical plausibility).

In a second stage, the most important sensors are tested individually. The yaw-rate sensor is tested by intentionally detuning the sensor element and then evaluating the signal response. Even the acceleration sensor has internal background monitoring. When activated, the pressure-sensor signal must show a predefined characteristic, and the offset and amplification are compensated for internally. The steering-wheel angle sensor is provided with "local intelligence" and has its own monitoring functions which directly deliver any error message to the ECU. In addition, the digital signal transmission to the ECU is permanently monitored.

In a third stage, analytical redundancy is applied to monitor the sensors during the steady-state operation of the vehicle. Here, a vehicle model is used to check that the relationships between the sensor signals, as determined by the vehicle motion, are not violated. These models are also frequently applied to calculate and compensate for the sensor offsets as long as they stay within the sensor specifications.

In case of error, the system is switched off either partially or completely depending upon the type of error concerned. The system's response to errors also depends upon whether the control is activated or not.

The ESP system with its electrical connections in the vehicle
1 Wheel brakes, 2 Wheel-speed sensors, 3 Engine-management ECU with CAN interface, 4 Throttle-valve actuator, 5 Precharging pump with admission-pressure sensor, 6 Steering-wheel angle sensor, 7 Brake booster with master cylinder, 8 Hydraulic system with brake-pressure sensor and attached ECU, 9 Yaw sensor with integrated lateral-acceleration sensor.



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

Adaptive Cruise Control (ACC)

Operation

The basic function of Adaptive Cruise Control relies on the conventional cruise-control system (vehicle-speed controller), which maintains a desired speed specified by the driver. In addition, ACC can adapt vehicle speed to changing traffic conditions by means of automatic acceleration, deceleration or braking. This system thus maintains the vehicle's distance to the vehicle driving in front as a function of road speed.

Distance sensor

The most important component in an ACC system is a sensor which measures the distance, the relative speed and the relative position of the preceding vehicles. Maximum performance is achieved – even in poor weather conditions – with a radar sensor.

The radar sensor (P. 101) operates at a frequency of 76 ... 77 GHz which was specially allocated for ACC. Three beams are emitted simultaneously for measurement purposes. The beams reflected by the preceding vehicles are analyzed regarding their propagation time, Doppler shift and amplitude ratio, and from these factors the distance, relative speed, and relative position are calculated (for details, refer to PP. 101 ... 103).

Course setting

To ensure reliable ACC operation, no matter what the situation – e.g. also on curves/bends – it is essential that the preceding vehicles are allocated to the correct lane(s). For this purpose, the information from the ESP sensor system (yaw rate, steering-wheel angle, wheel speeds and lateral acceleration) is evaluated with regard to the ACC-equipped vehicle's actual curve status. Further information on the traffic flow is obtained from the radar signals.

Video imaging and navigation systems are also being considered for future assistance in defining the courses taken by the vehicles.

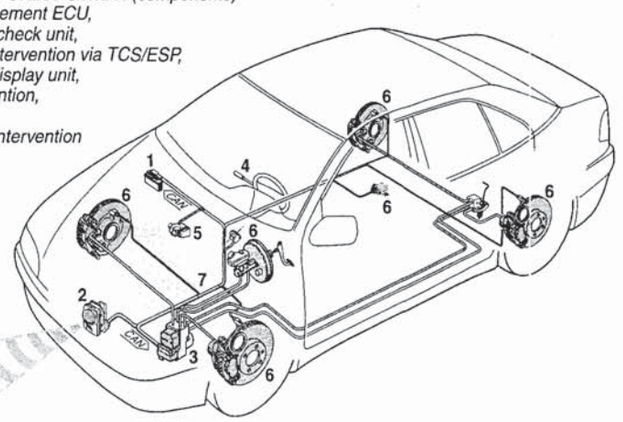
Engine intervention

Speed control requires an electronic engine-power control system (ETC or EDC). Such a system enables the vehicle to be accelerated to the desired speed or, if an obstacle appears, to be decelerated by means of automatic throttle closing.

Active brake intervention

Experience has shown that deceleration by means of throttle closing is not sufficient for ACC operation. Only the inclusion of brake intervention makes it possible for longer follow-on control operations

Bosch Adaptive Cruise Control *(components)*
1 Engine-management ECU,
2 Radar-sensor check unit,
3 Active brake intervention via TCS/ESP,
4 Controls and display unit,
5 Engine intervention,
6 Sensors,
7 Transmission intervention (optional).



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

with ACC without the need for frequent driver interventions. ESP provides the possibility of braking without driver intervention.

ACC permits only "soft" brake interventions. Emergency braking due to the sudden appearance of obstacles (e.g. the slow-moving vehicle in front suddenly changing its lane) is therefore not possible.

Setting options
The driver inputs the desired speed and the desired time gap; values of 1 ... 2 s are offered for the latter.

Display elements
The driver must be provided with at least the following information:
- indication of the desired speed,
- indication of the switch-on status,
- indication of the desired time gap selected by the driver,
- indication of the follow-on mode, which informs the driver as to whether the system is controlling the distance to a detected target object or not.

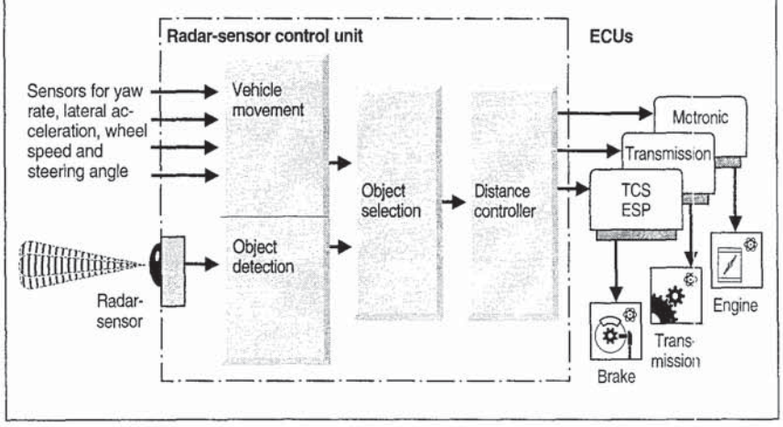
Aim of ACC
The aim of ACC is to relieve the driver of the stress associated with "mindless" driving tasks such as maintaining speeds and driving behind other vehicles in heavy traffic. This system helps to improve road safety as well as driver comfort.

System limits
Even with this form of driver support, the driver remains fully responsible for controlling the vehicle. He/she continues to remain responsible for complex decisions relating to straight-ahead driving and control of the vehicle – and obviously for steering as well. The alignment of the functions to emphasize the comfort aspect for the driver, means that a clear boundary has been defined between the tasks which are the responsibility of ACC and those which are the responsibility of the driver. Safety functions such as emergency braking and forced spacing are thus not featured in this system. These functions, together with selecting the desired speed and the desired time gap, are the sole responsibility of the driver.

ACC does not yet permit control operations in urban environments. This system can only be activated at speeds in excess of 30 km/h.

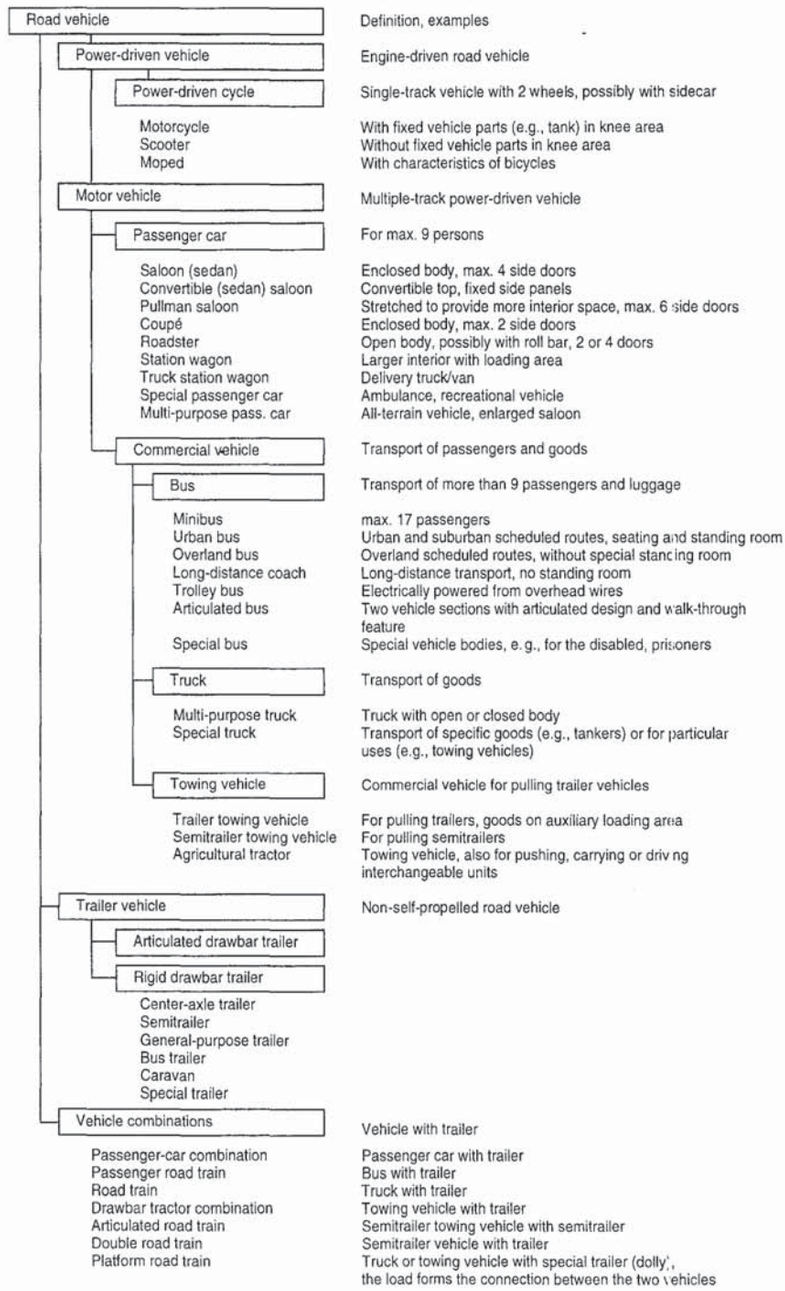
Expanding functions for operation in urban areas would require considerably higher performance on the part of the sensors responsible for monitoring the environment. Such performance cannot be achieved by the 76.5 GHz radar alone.

Basic structure of ACC control



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

Road-vehicle systematics



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

Classification[1])

Category L
Motor vehicles with fewer than 4 wheels, motorized two-wheeled and three-wheeled vehicles.

Category	Design	Piston displacement	Top speed
L_1	two-wheeled	≤ 50 cm³	≤ 50 km/h
L_2	three-wheeled	≤ 50 cm³	≤ 50 km/h
L_3	two-wheeled	> 50 cm³	> 50 km/h
L_4	three-wheeled asymmetrical to longitudinal vehicle axis	> 50 cm³	> 50 km/h
L_5	three-wheeled symmetrical to longitudinal vehicle axis	> 50 cm³ ≤ 1 t Total weight	> 50 km/h

Category M
Passenger vehicles with at least 4 wheels or with 3 wheels and an overall weight > 1 t.

Category	Driver's seat + passenger seats	Total weight
M_1	1 ≤ 9	
M_2	> 9	< 5 t
M_3	> 9	> 5t

Category N
Goods transport vehicles with at least 4 wheels or with 3 wheels and a laden weight > 1 t.

Category	Total weight
N_1	≤ 3.5 t
N_2	> 3.5 t ≤ 12 t
N_3	> 12 t

Category O
Trailers and semitrailers

Category	Total weight
O_1 only single-axle trailers	≤ 0.75 t
O_2	> 0.75 t ≤ 3.5 t
O_3	> 3.5 t ≤ 10 t
O_4	> 10 t

[1]) Vehicle classification in accordance with the Directives of the European Community (71/320/EEC) and ECE Regulation No. 13 with regard to brake equipment.

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

Vehicle bodies, passenger cars

Main dimensions

Interior-dimensions

Dimensional layout depends upon body shape, type of drive, scope of aggregate equipment, desired interior size, luggage compartment volume and other considerations such as driving comfort, driving safety and operating safety. Seating positions are designed in accordance with ergonomic findings and with the aid of templates or 3D CAD dummy models (DIN, SAE, RAMSIS): Body template as per DIN 33 408 for men (5th, 50th, and 95th percentile) and women (1st, 5th and 95th percentile). For example, the 5th percentile template represents "small" body size, i.e., only 5 % of the population have smaller bodies, and 95 % have larger body dimensions.

SAE H-point template in accordance with SEA J826 (May 1987): 10th, 50th and 95th percentile thigh segments and lower leg segments. For legal reasons, motor-vehicle manufacturers in the USA and in Canada must use the SAE H-point template for determining the seating reference point. Body templates in accordance with DIN 33408 in accelerated form are particularly well suited to the dimensional design of seats and passenger compartments. Most motor-vehicle manufacturers round the world use the 3D CAD dummy model "RAMSIS" in development (RAMSIS: computer-aided anthropological-mathematical system for passenger simulation).

The hip point (H-point) is the pivot center of torso and thigh, and roughly corresponds to the hip joint location. The seating reference point (in accordance with ISO 6549 and US legislation) or R-point (ISO 6549 and EEC Directives/ECE Regulations) indicates the position of the design H-point in the rearmost normal driver seating position in the case of adjustable seats. In determining the design H-point position, many vehicle manufacturers use the 95th percentile adult-male position or, if this position is not reached, the position with the seat adjusted to its rearmost setting. In order to check the position of the measured H-point relative to the vehicle, a three-dimensional, adjustable SAE H-point machine weighing 75 kg is used. The seating reference point, heel point, vertical and horizontal distance between these two points, and body angles specified by the vehicle manufacturer form the basis for determining the dimensions of the driver's seating position.

The seating reference point is used

- to define the positions of the eye ellipse (SAE J941) and the eye points (RREG 77/649) as a basis for determining the driver's direct field of view;
- to define hand reach envelopes in order to correctly position controls and actuators;
- to determine the accelerator heel point (AHP) as a reference point for positioning the pedals.

The space required by the rear axle as well as location and shape of the fuel tank primarily determine the rear seating arrangement (height of the seating reference point, rear seating room, head-room) and thus the shape of the roof rear portion. Depending on the type of vehicle being developed, the projected main dimensions and the required passenger sizes, there are different body angles for the 2D templates or body postures (RAMSIS) and different distances between the seating reference points of the driver's and rear seats. The longitudinal dimensions are greatly influenced by the height of the seating reference point above the heel point. Lower seats require a more stretched passenger seating position, and thus greater interior length.

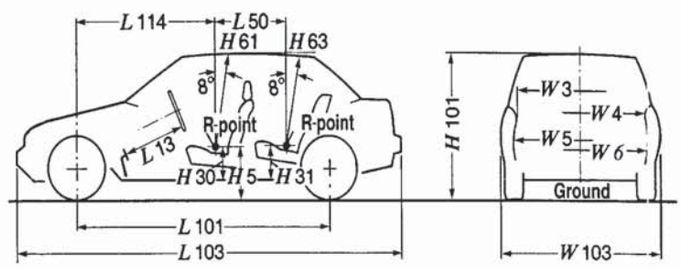
The passenger-compartment width is dependent on the projected exterior width, the shape of the sides (curvature) and the space required for door mechanisms, passive restraint systems and various assemblies (propellor-shaft tunnel, exhaust system etc.).

Luggage-compartment dimensions

The size and shape of the luggage compartment are dependent on the design of the rear of the vehicle, the position of the fuel tank and its volume, the position of the spare wheel and the location of the main muffler.

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

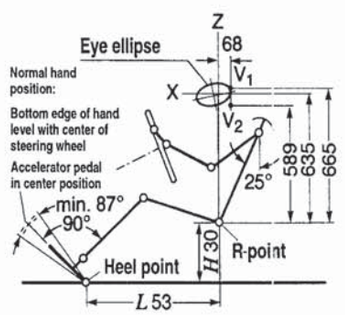
Typical internal and external dimensions *(as per DIN 70020, Part 1)*



Dimension			Subcompact car mm	Long car mm
H	5	R-point to ground, front	460	510
H	30	R-point to accelerator heel point, front	240	300
H	31	R-point to accelerator heel point, rear	300	310
H	61	Effective headroom, front	940	980
H	63	Effective headroom, rear	920	950
H	101	Vehicle height	1360	1400
L	13	Steering wheel to brake pedal	480	630
L	50	R-point distance (front to rear seat)	710	830
L	101	Wheelbase	2430	2880
L	103	Vehicle length overall	3840	4930
L	114	Front wheel center to R-point	1250	1590
W	3	Shoulder room, front	1310	1430
W	4	Shoulder room, rear	1290	1420
W	5	Hip room, front	1260	1430
W	6	Hip room, rear	1240	1470
W	103	Vehicle width overall	1620	1820

Luggage-compartment capacity is determined in accordance with DIN-ISO 3832 or, more commonly, with the VDA method using the VDA unit module (a right parallelepiped with dimensions of 200 x 100 x 50 mm – corresponds to a volume of 1 dm^3).

Parameters which determine passenger-car driver's seat location



Exterior dimensions

The following factors must be taken into consideration:

- Seating arrangement and luggage compartment,
- Engine, transmission, radiator,
- Auxiliary and special equipment,
- Space required by sprung and turned wheels (allowance for snow chains),
- Type and size of drive axle,
- Position and volume of fuel tank,
- Front and rear bumpers,

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

- Aerodynamic considerations,
- Ground clearance (approx. 100...180 mm),
- Effect of body structure width on windshield wiper system (ADR 16, FMVSS 104).

Vision

A compromise must be found between optimum vision and the functional layout of components which tend to obstruct the field of vision.

The following influencing factors must be taken into consideration:

- Obscuration by pillars, the roof, the hood and the luggage-compartment lid. The eye ellipse in accordance with SAE J941 and the "eye points" in accordance with RREG 77/649[1]) are the basis for assessing the field of vision,
- Location, size and shape of the rear-view mirror in accordance with RREG 79/795.
- Windshield wiper pattern in accordance with FMVSS 104[2]) and RREG 78/318,
- Windshield curvature,
- View of instruments (obstruction of vision by steering wheel, ADR 18 A[3])).

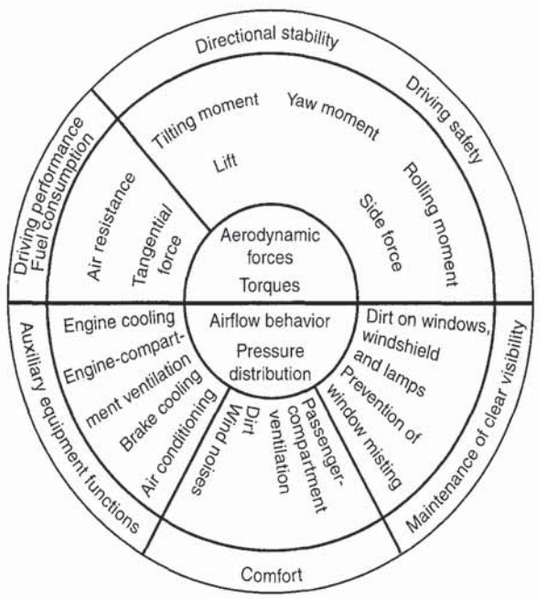
Body design

The following technical requirements must be met in interior and exterior body design:

- Mechanical functions (lowering of side windows, opening of the hood, luggage-compartment lid and sunroof, positions of lamps),
- Manufacturability and ease of repair (gap widths, bodywork assembly, window shape, protective molding rails, paint feature lines),
- Safety (position and shape of bumpers, no sharp edges or points),
- Aerodynamics (air resistance, dirt on the vehicle body, wind noises, ventilation openings, windshield-wiper operation),
- Optics (distortion caused by window type and slope, glare due to reflection),
- Legal requirements (position and size of lamps, rear-view mirror, license plates),

[1]) Directives of the Council of the European Union.
[2]) Federal Motor Vehicle Safety Standard (USA).
[3]) Australian Design Rule.

Aerodynamic effects on vehicle functions



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

– Design and layout of controls (positions, shapes and surface contours),
– Clear layout (parking).

Aerodynamics

Aerodynamics deals with all processes which are observed as air flows through and around a vehicle.
Aerodynamic drag $W = c_W \cdot A \cdot v^2 \cdot \frac{\varrho}{2}$

where c_W = drag coefficient,
A = cross-sectional area,
v = driving speed,
ϱ = air density.

Table 1.
c_w values for various vehicles

Vehicle (Examples)	c_W –	A m²
Audi A8	0.29	2.25
Porsche 911	0.29	1.95
Mercedes C 200 D	0.30	2.05

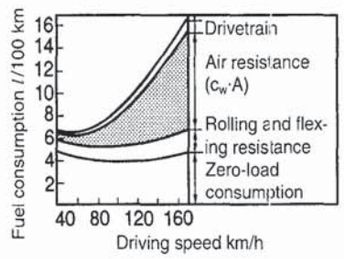
The factors to be influenced by the vehicle manufacturer are the drag coefficient c_W as a measure of the aerodynamic quality of the vehicle shape, and the projected vehicle cross-sectional area A.
Attempts to reduce the c_W value by adding spoilers, underbody panels, etc. are not practical, since their effect depends upon the aerodynamic characteristics of the basic vehicle body (see Table 2 for effects of individual modifications on drag coefficient). These types of modifications in optimized form are standard features of modern vehicle design. This means that the fitting of supplementary devices to further improve the c_W value and the axle lifting-force coefficient can only result in very minor improvements. Often, such modifications result in the impairment of the vehicle's day-to-day capabilities due to reduced overhang angle or reduced ground clearance. In other words, such add-on parts serve more for improving the vehicle's appearance than for improving its performance.

The c_W value can be influenced by individual aerodynamic or design measures. Airflow through the vehicle as well as roof-mounted fixtures will always increase the c_W value. Examples (– = better, + = worse). Examples are given in Table 2.

Table 2.
c_w values for vehicle modifications

Effect of	Δc_W in %
Lowering vehicle height by 30mm	approx. –5
Smooth wheel covers	–1...–3
Wide tires	+2...+4
Windows flush with exterior	approx. –1
Sealing body gaps	–2...–5
Underbody panels	–1...–7
Concealed headlamps	+3...+10
Outside rear-view mirrors	+2...+5
Airflow through radiator and engine compartment	+4...+14
Brake cooling devices	+2...+5
Interior ventilation	approx. +1
Open windows	approx. +5
Open sunroof	approx. +2
Roof-mounted surfboard rack	approx. +40

Effect of $c_W \cdot A$ on fuel consumption (mid-sized vehicle)



Effect of windshield slope α on the c_W value
(– = better, + = worse)



α	c_W	Δc_W in %
50°	0.345	–
55°	0.342	–0.8
65°	0.340	–1.4
40°	0.349	+1.1
30°	0.349	+1.1
0°	0.369	+7.0

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

Body structure

Unitized (self-supporting) body
(Standard design)
The conventional unitized (self-supporting) body is built up of hollow sheet-steel components onto which body panels are welded by welding robots or in multi-spot welding units. Individual parts can also be glued in position.

Depending upon vehicle type, roughly 5000 spot welds must be made along a total flange length of 120...200 m. The flange widths are 10...18 mm. Other parts (front fenders, doors, hood and luggage-compartment lid) are bolted to the supporting structure of the body. Other types of body construction include frame and sandwich designs.
General requirements:

Rigidity
Torsional and bending rigidity should be as high as possible in order to minimize elastic deformation of the apertures for the doors, hood and luggage-compartment lid. The effect of body rigidity on the vibrational characteristics of the vehicle must be taken into consideration.

Vibrational characteristics
Body vibrations as well as vibrations of individual structural components as a result of excitation by the wheels, suspension system, engine and drivetrain can severely impair driving comfort if resonance occurs.

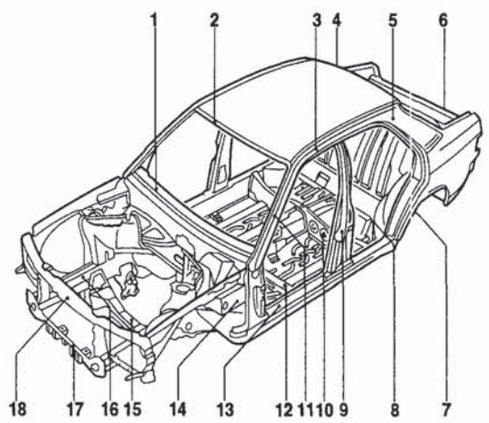
The natural frequency of the body, and of those body components which are capable of vibration, must be detuned by means of creasing and changing the wall thicknesses and cross sections, such that resonance and its consequences are minimized.

Operational integrity
Alternating stresses which can affect the body as the vehicle is driven can lead to incipient structural cracks or weld failure. Areas which are particularly susceptible are the bearing points of the running gear, the steering system and engine units.

Body stresses due to accidents
In the event of a collision, the body must be capable of transforming as much kinetic energy as possible into deformation work while minimizing deformation of the vehicle interior.

Ease of repair
Those components which are most susceptible to damage as a result of minor accidents ("fender-benders") must be easily replaceable or repairable (access

Body structure
1 Cross member under windshield,
2 Roof frame, front,
3 Roof frame, side,
4 Roof frame, rear,
5 C-pillar,
6 Rear-facing panel,
7 Rear floor and spare-wheel pan,
8 Side member, rear,
9 B-pillar,
10 Cross member under rear seat,
11 A-pillar,
12 Cross member under driver's seat,
13 Side member,
14 Wheel well,
15 Engine-support cross member,
16 Side member, front,
17 Cross member, front,
18 Radiator cross member.



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

to exterior body panels from inside, access to bolts, favorable location of joints, feature lines for the repainting of individual components).

Body materials

Sheet steel

Sheet steel of various grades (see table on P. 197) is customarily used for the vehicle body structure.

Sheet thicknesses range from 0.6 to 3.0 mm, with most pieces being between 0.75 and 1.0 mm thick. Due to the mechanical properties of steel with regard to stiffness, strength, economy and ductility, alternative materials for the vehicle body structure are not yet available.

High-strength, low-alloy (HSLA) sheet steel is used for highly-stressed structural components. The resulting high strength of these components allows their thickness to be reduced.

Aluminum

In order to reduce weight, aluminum can be used for separate body components such as the hood, luggage-compartment lid, etc.

Since 1994, an aluminum body has been in use for one of the German luxury-class cars. The vehicle's frame is constructed from aluminum extruded sections, and the sheet components are self-supporting in integrated form (ASF Audi Space Frame). The realization of this principle necessitated the employment of suitable aluminum alloys, as well as new production processes and special repair facilities. According to the manufacturers, the rigidity and deformation characteristics are identical to those of steel or are even superior.

Plastics

Plastics as materials for separate body components are used in a limited number of cases in place of steel (see Table below).

Table 3. Examples of alternative materials

Examples of application	Material	Abbreviation	Processing method
Load-bearing components, e.g. bumper beam	Thermoplastics reinforced by glass-fiber mats	PP-GMT	Injection pressure
Moldings/covers, e.g. front apron, spoiler, front section, radiator grill, wheel-well liners, wheel covers Separate vehicle-body components, e.g. hood, fender, luggage-compartment lid, sunroof	Thermoplastics reinforced by glass-fiber mats	PP-GMT	
	Polyurethane	PUR	RIM (Reaction-Injection-Molding) RRIM (Reinforced-Reaction-Injection-Molding)
	Polyamide Polypropylene Polyethylene Acrylonitrile-butadiene-styrene copolymeres Polycarbonate (with Polybutadiene theraphthalate mod.)	PA PP PE ABS PC-PBT	Injection-molding, glass-fiber constituent determines elasticity
Protective molding rails	Polyvinylchloride Ethylene-Propylene-Terpolymers Elastomer-modified polypropylene	PVC EPDM PP-EPDM	Injection-molding/extrusion
Energy-absorbing foam	Polyurethane Polypropylene	PUR PP	Reaction foaming

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

Body surface

Corrosion protection
Allowance must be made for corrosion protection as early as during the body design phase ("Anti-Corrosion Code", Canada).
Corrosion protection measures:
- Minimize flanged joints, sharp edges and corners,
- Avoid areas where dirt and humidity can accumulate,
- Provide holes for pretreatment and electrophoretic enameling,
- Provide good accessibility for the application of corrosion inhibitor,
- Allow for ventilation of hollow spaces,
- Prevent the penetration of dirt and water to the greatest extent possible; provide water drain openings,
- Minimize the area of the body exposed to stone-chip throw,
- Prevent contact corrosion.

Precoated sheet steel (inorganic zinc, electrolytically galvanized, hot-dip galvanized) is often used for those components which are particularly endangered, such as doors and load-bearing members at the front of the vehicle. Particularly inaccessible structural areas are coated with spot-welding paste (PVC or epoxy adhesive, approx. 10 ... 15 m seam length per vehicle) prior to assembly.

Painting (P. 228)
Measures subsequent to electrophoretic enameling:
- Covering the spot-welded seams (up to 90 ... 110 m), folds and joints with PVC sealing compound,
- Coating the underbody with PVC underseal (0.3 ... 1.4 mm thick, 10 ... 18 kg per vehicle) to protect against damage due to stone chips. Plastic trim panels can be used as an alternative.
- Preservation of hollow parts with penetrating, non-aging water-based wax,
- Use of corrosion-resistant, separate plastic components in highly susceptible areas such as the front wheel wells (PVC coating is not suitable here).
- Preservation of underbody and engine compartment after final assembly.

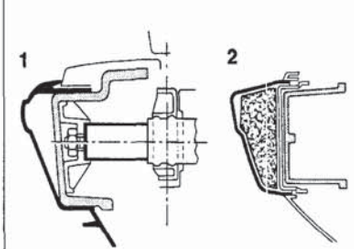
Table 4. Paint/coating thicknesses

Coating system, overall thickness	≈ 120 µm
Zinc-phosphate coating	≈ 2 µm
Electrophoretic enameling (cathodic)	13 ... 18 µm
Filler	≈ 40 µm
Top-paint coat	35 ... 45 µm
Varnish coat (only for metallic paint)	40 ... 45 µm

Body finishing components

Bumpers
The front and rear of the vehicle should be protected in such a manner that low-speed collisions will only damage the vehicle slightly, or not at all. Prescribed bumper evaluation tests (US Part 581, Canada CMVSS 215, and ECE-R 42) specify minimum requirements in terms of energy absorption and installed bumper height. Bumper evaluation tests in accordance with US Part 581 (4 km/h barrier collision, 4 km/h pendulum tests) must be passed by a bumper system whose energy absorber is of the no-damage absorber type. The requirements of the ECE standard are satisfied by plastically deformable retaining elements located between the bumper and the vehicle body structure. In addition to sheet steel, many bumpers are manufactured using fiber-reinforced plastics and aluminum sections.

Bumpers
1 Shock-absorber system, 2 Energy-absorbing PUR-foam system



VW EX1012 Part IV
U.S. Patent No. 6,557,540

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

Exterior trim, impact strips

Plastics have become the preferred materials for external impact strips, trim, skirts and spoilers, and particularly for those components whose purpose is to improve the aerodynamic characteristics of the vehicle. Criteria used in the selection of the proper material are flexibility, high-temperature shape retention, coefficient of linear expansion, notched-bar toughness, resistance to scratches, resistance to chemicals, surface quality and paintability.

Glazing

The windshield and rear window are usually held in rubber strips and sealed or bonded in place.

The total weight of the windows in a vehicle ranges from 25 to 35 kg. Due to a number of inherent disadvantages, weight considerations have not yet led to plastics (PC, PMMA) being introduced as the substitute for glass. Due to its heat-insulation and noise-damping properties, 2-layer insulating glass has come into use for door windows.

Door latches

Door latches are of great importance with regard to passive accident safety (pertinent regulations: ECE-R 11 and FMVSS 206, among others):

- Fully latched and secondary latched positions,
- Complete integrity under a longitudinal load of up to 12 kN and a transverse load of up to 10 kN (fully latched position),
- Complete integrity under a longitudinal or transverse inertia load of up to $30 \cdot g$.

Individual manufacturers have varying solutions with regard to ease of operation, anti-theft protection and child-proof operation.

Seats

The strength requirements which must be met by the seats in a collision pertain to the seat cushion and backrest, the head restraints, the seat adjustment mechanism and the seat anchors (pertinent regulations: FMVSS 207, 202; ECE-R 17, 25; RREG 74/408, 78/932 and others). One component of active safety is seating comfort. Seats must be designed such that vehicle occupants with different body dimensions do not suffer from driving fatigue. Parameters:

- Support of individual body areas (distribution of pressure),
- Lateral support when cornering,
- Seating ambience,
- Freedom of movement so that an occupant can change his/her sitting position without having to readjust the seat,
- Vibrational and damping characteristics (matching of the natural frequency with the excitation frequency band),
- Adjustability of seat cushion, backrest and head restraint.

The above parameters are affected by the following:

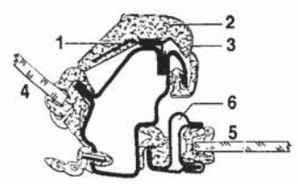
- Dimensions and shapes of the upholstery in the seat cushion and backrest,
- Distribution of the spring rates of individual cushioned zones,
- Overall spring rate and damping capacity, of the seat cushions in particular,
- Thermal conductivity and moisture-absorption capacity of the covers and upholstery,
- Operation and range of the seat adjustment mechanisms.

Interior trim

A section of trim consists of a dimensionally stable core (sheet steel, sheet aluminum or plastic) with mounting hardware, and energy-absorbing cushion made of foam material (e.g. PUR) and a flexible surface layer. One-piece plastic trim sections made of injection-molded thermoplastic material are also used.

The headliner is made either as a stretched liner or finished liner. The ma-

Section through an A-pillar with trim *(Principle)*
1 Core, 2 Foam, 3 Film, 4 Windshield, 5 Side window, 6 Door frame.



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

terials used must be flame-retardant and slow burning (FMVSS 302).

Safety

Active safety:
Prevention of accidents
Passive safety:
Reduction of accident consequences

Active safety

Driving safety is the result of a harmonious chassis and suspension design with regard to wheel suspension, springing, steering and braking, and is reflected in optimum dynamic vehicle behavior.

Conditional safety results from keeping the physiological stress that the vehicle occupants are subjected to by vibration, noise, and climatic conditions down to as low a level as possible. It is a significant factor in reducing the possibility of misactions in traffic.

Vibrations within a frequency range of 1 to 25 Hz (stuttering, shaking, etc.) induced by wheels and drive components reach the occupants of the vehicle via the body, seats and steering wheel. The effect of these vibrations is more or less pronounced, depending upon their direction, amplitude and duration.

Noises as acoustical disturbances in and around the vehicle can come from internal sources (engine, transmission, propshafts, axles) or external sources (tire/road noises, wind noises), and are transmitted through the air or the vehicle body. The sound pressure level is measured in dB(A) (see also PP. 52).

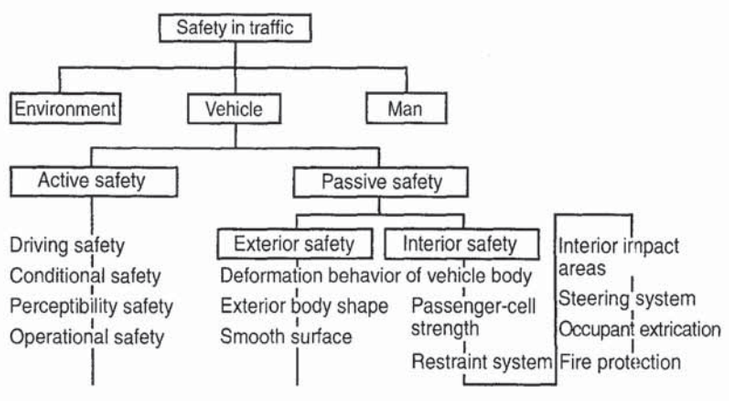
Noise reduction measures are concerned on the one hand with the development of quiet-running components and the insulation of noise sources (e.g., engine encapsulation), and on the other hand with noise damping by means of insulating or anti-noise materials.

Climatic conditions inside the vehicle are primarily influenced by air temperature, air humidity, rate of air flow through the passenger compartment and air pressure (see PP. 364 for additional information).

Perceptibility safety
Measures which increase perceptibility safety are concentrated on
- Lighting equipment (see P. 738),
- Acoustic warning devices (see P. 766),
- Direct and indirect view (see P. 720) (Driver's view: The angle of obscuration caused by the A-pillars for both of the driver's eyes – binocular – must not be more than 6 degrees).

Operating safety
Low driver stress, and thus a high degree of driving safety, requires optimum design

Safety in traffic. *Terms and influencing factors*



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

of the driver's surroundings with regard to ease of operation of the vehicle controls.

Passive safety

Exterior safety
The term "exterior safety" covers all vehicle-related measures which are designed to minimize the severity of injury to pedestrians and bicycle and motorcycle riders struck by the vehicle in an accident. Those factors which determine exterior safety are:
– Vehicle-body deformation behavior,
– Exterior vehicle-body shape.

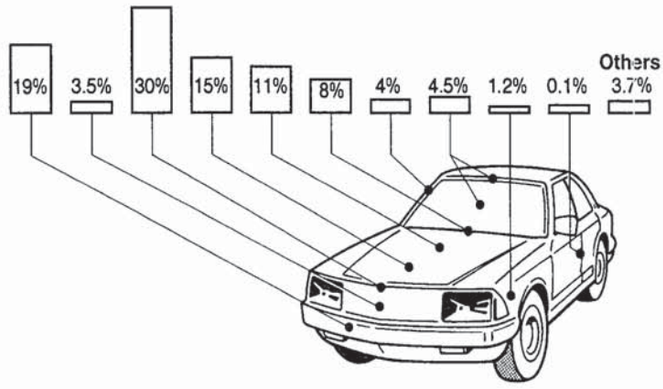
The primary objective is to design the vehicle such that its exterior design minimizes the consequences of a primary collision (a collision involving persons outside the vehicle and the vehicle itself).

The most severe injuries are sustained by passengers who are hit by the front of the vehicle, whereby the course of the accident greatly depends upon body size. The consequences of collisions involving two-wheeled vehicles and passenger cars can only be slightly ameliorated by passenger-car design due to the two-wheeled vehicle's often considerable inherent energy component, its high seat position and the wide dispersion of contact points. Those design features which can be incorporated into the passenger car are, for example:
– Movable front lamps,
– Recessed windshields wipers,
– Recessed drip rails,
– Recessed door handles.
See also ECE-R26, RREG 74/483

Interior safety
The term "interior safety" covers vehicle measures whose purpose is to minimize the accelerations and forces acting on the vehicle occupants in the event of an accident, to provide sufficient survival space, and to ensure the operability of those vehicle components critical to the removal of passengers from the vehicle after the accident has occurred.
The determining factors for passenger safety are:
– Deformation behavior (vehicle body),
– Passenger-compartment strength, size of the survival space during and after impact,
– Restraint systems,
– Impact areas (vehicle interior), (FMVSS 201),
– Steering system,
– Occupant extrication,
– Fire protection.

Laws which regulate interior safety (frontal impact) are:
– Protection of vehicle occupants in the event of an accident, in particular restraint systems (FMVSS 208, ECE R94, injury criteria),
– Windshield mounting (FMVSS 212),

Risk to pedestrians in event of collisions with passenger cars
as a function of impact frequency and seriousness of injury (based on 246 collisions)



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

- Penetration of the windshield by vehicle body components (FMVSS 219),
- Parcel-shelf and compartment lids (FMVSS 201).

Rating-Tests:
- New-Car Assessment Program (NCAP, USA, Europe, Japan, Australia),
- IIHS (USA, insurance test),
- ADAC, ams, AUTO-BILD.

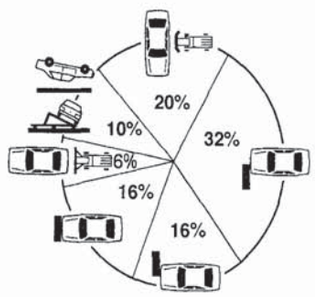
Deformation behavior of vehicle body

Due to the frequency of frontal collisions, an important role is played by the legally stipulated frontal impact test in which a vehicle is driven at a speed of 48.3 km/h (30 mph) into a rigid barrier which is either perpendicular or inclined at an angle of up to 30° relative to the longitudinal axis of the car.

Because 50 % of all frontal collisions in right-hand traffic primarily involve the left-hand half of the front of the vehicle, manufacturers worldwide conduct left asymmetrical front impact tests on LHD vehicles covering 30...50 % of the vehicle width.

In a frontal collision, kinetic energy is absorbed through deformation of the bumper, the front of the vehicle, and in severe cases the forward section of the passenger compartment (dash area). Axles, wheels (rims) and the engine limit the deformable length. Adequate deformation lengths and displaceable vehicle aggregates are necessary, however, in order to minimize passenger-compartment acceleration. Depending upon vehicle design (body shape, type of drive and engine position), vehicle mass and size, a frontal impact with a barrier at approx. 50 km/h results in permanent deformation in the forward area of 0.4...0.7 m. Damage to the passenger compartment should be minimized. This concerns primarily
- dash area (displacement of steering system, instrument panel, pedals, toe-panel intrusion),
- underbody (lowering or tilting of seats),
- the side structure (ability to open the doors after an accident).

Distribution of accidents by type of collision
Symbolized by test methods yielding equal results



Acceleration measurements and evaluations of high-speed films enable deformation behavior to be analyzed precisely. Dummies of various sizes are used to simulate vehicle occupants and provide acceleration figures for head and chest as well as forces acting on thighs.

Head acceleration values are used to determine the head injury criterion (HIC). The comparison of measured values supplied by the dummies with the permissible limit values as per FMVSS 208 (HIC: 1000, chest acceleration: 60 *g*/3 ms, upper leg force: 10 kN) are only limited in their applicability to the human being.

The side impact, as the next most frequent type of accident, places a high risk of injury on the vehicle occupants due to the limited energy absorbing capability of trim and structural components, and the resulting high degree of vehicle interior deformation.

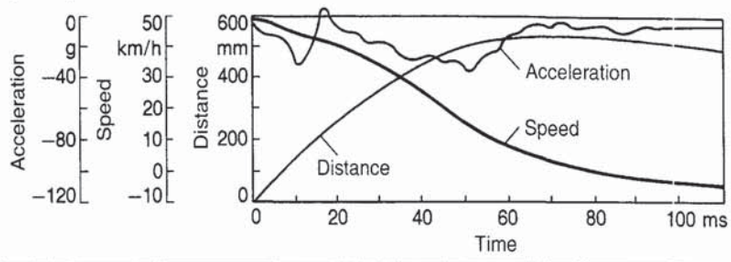
The risk of injury is largely influenced by the structural strength of the side of the vehicle (pillar/door joints, top/bottom pillar points), load-carrying capacity of floor cross-members and seats, as well as the design of inside door panels (FMVSS 214, ECE R95, Euro-NCAP, US-SINCAP).

In the rear impact test, deformation of the vehicle interior must be minor at most. It should still be possible to open the doors, the edge of the trunk lid should not penetrate the rear window and enter the vehicle interior, and fuel-system integrity must be preserved (FMVSS 301).

Roof structures are investigated by means of rollover tests and quasi-static car-roof crush tests (FMVSS 216).

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

Acceleration, speed and distance traveled, of a passenger compartment when impacting a barrier at 50 km/h



In addition, at least one manufacturer subjects his vehicles to the inverted vehicle drop test in order to test the dimensional stability of the roof structure (survival space) under extreme conditions (the vehicle falls from a height of 0.5 m onto the left front corner of its roof).

Steering system

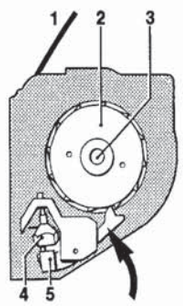
Legal requirements (FMVSS 203 and 204) regulate the maximum displacement of the top end of the steering column toward the driver (max. 127 mm, frontal impact at 48.3 km/h) and the limit of the impact on the steering system of a test piece (maximal 1111 daN at an impact speed of 24.1 km/h). Slotted tubes, corrugated tubes and breakaway universal joints (among others) are used in the design of the lower section of the steering column spindle so that it can be deformed both longitudinally and transversely.

Passenger restraint systems (P. 803)

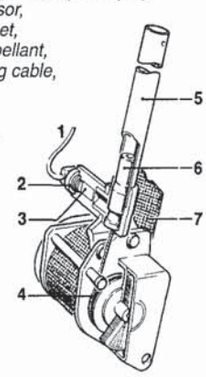
Automatic seat belt (manual systems)
The most frequently installed three-point seat belt with retractor mechanism ("automatic seat belt") represents a good compromise between effective safety, ease of buckling, comfort and cost. When a specific vehicle-deceleration value is reached, a built-in, quick-response interlock inhibits the seat-belt roller.

Seat-belt tightener systems
Seat-belt tightener systems represent a further development and improvement of the three-point automatic seat-belt systems. By reducing seat-belt slack, they eliminate excessive forward passenger movement in serious accidents. This in turn reduces the differential speed between the vehicle and passengers, and thus also reduces the corresponding

Inertia-reel seat-belt system
1 Seat belt, 2 Ratchet wheel, 3 Inertia-reel shaft, 4 Pendulum, 5 Pawl (in locked position).



Seat-belt tightener (Example)
1 From sensor,
2 Firing pellet,
3 Solid propellant,
4 Tensioning cable,
5 Cylinder,
6 Piston,
7 Seat belt.



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

forces acting on the passengers.

Integrated belt-force limiters ensure that controlled give of the belt takes place after it has been tightened, so as to prevent potential overloading in the chest area.

Airbag systems

Airbags (frontal airbags, side bags, window bags) serve to prevent or reduce the impact of the occupant against interior vehicle components (steering wheel, instrument panel, doors, windows, roof pillars).

Calculations

Finite-Element Method

The Finite-Element Method (FEM) can be used to calculate static, dynamic and acoustic characteristics of components and complete bodies. In finite-element analysis, a support structure of any degree of complexity is broken down into simple structural elements (beams, shells and solid elements etc.), of which the elastic behavior is known and can be easily defined. These elements are then assembled to form the overall structure, taking into account compatibility conditions.

This enables a mathematical model to be constructed in such a manner that it sufficiently corresponds to the actual body in terms of its elastic characteristics.

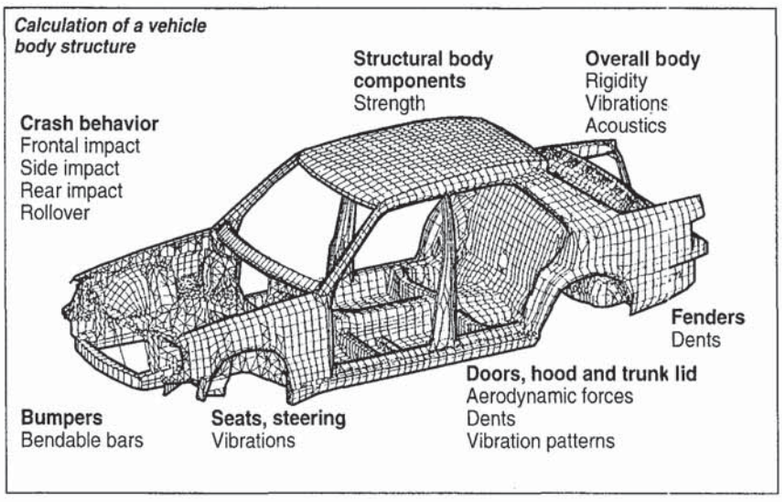
A number of systems are available for practical FE calculation, such as PERMAS, NASTRAN, ABAQUS and DYNA3D.

Advantages of FEM:
- Characteristics of structures of any level of complexity can be calculated,
- Anisotropic and non-linear material properties can be taken into account,
- Variations can be rapidly examined,
- Tried and tested program systems are available (easy to incorporate into the CAD/CAM chain.

Limits of FEM:
- Accuracy is dependent on element type and precision of element distribution within the structure,
- Changes in sheet-metal thicknesses and material characteristic values resulting from the deep-drawing process are not taken into account,
- Welding joints cannot be precisely replicated in the model.

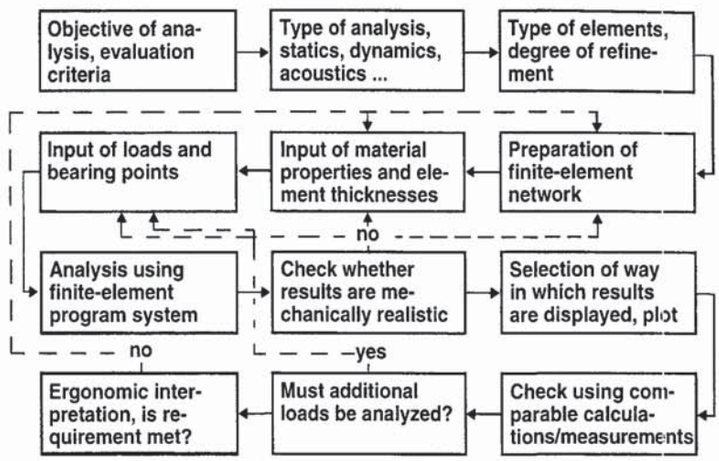
Complete body calculation

For the calculation, the bodywork structure is broken down into elements with the required level of precision depending on the problem to be solved (as at 1999: up to approx. 300,000 elements with over 1.8 million unknowns). Results under static



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

The structural analysis process using the finite-element method



load are supplied in the form of deformations, stresses and deformation work.

Strength analysis
Detailed analyses are carried out for individual parts and body sections which are exposed to special stresses caused by factors such as e.g. restraint systems or towed loads. The aim of these analyses is to furnish proof of adequate strength or to reduce unacceptably high stresses by modifying the design.

Analysis of dynamic behavior
Dynamic analyses are carried out both for the complete body and for the individual components. In these analyses, the natural vibration (frequencies, forms of vibration) and the system's response to periodic or generally time-dependent excitation is determined. In this way, critical resonances can be identified and the loads which determine operational integrity can be defined.

For the examination of ride comfort and acoustical behavior in the vehicle interior, FE models of the chassis, engine, doors etc., as well as a model of the interior, are added to the body model.

Analysis of crash behavior
Accident tests carried out by automobile manufacturers (frontal, rear and side impacts, rollover and drop tests) as well as traffic accidents, are dynamic, to a large degree non-linear processes which cannot be described using the current FE programs. Special FE program systems (e.g., DYNA3D, PAM-CRASH) have been developed for numerical simulation of these processes, and are proving successful in the field. These systems include analysis of severe plastic deformations as well as recording of the contact areas arising between various vehicle parts during crash processes.

Analysis of occupant-protection systems
The following main tasks are carried out with the aid of computer simulation:
- Design/optimization of restraint systems with regard to front- and rear-end impacts by means of crash-test sled simulations in the cases in which the interaction between structure and dummy is negligible. The tool for this purpose is a multibody system (e.g. Madymo 3D) in conjunction with an FE

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

program system (e.g. LS-DYNA-3D).
- Design of protective components with regard to side impacts in integrated simulations, i.e. complete-vehicle simulations with dummy, seat and moldings. Calculation with FE program system (LS-DYNA-3D).
- Design and optimization of cushioning measures (in accordance with FMVSS 201) with regard to satisfying protective criteria. Calculation with FE program system (LS-DYNA-3D).

Recycling, environmental protection

The automobile manufacturers are making progress in their endeavors to maintain clean water and air, prevent noise pollution and recycle raw materials:
- The recycling quota for metallic materials is 95%.
- The recycling quota for plastics is approximately 14%. In cooperation with the chemical industry and the suppliers of plastic components, intensive efforts are being made to further improve this figure.
- Exhaust-gas purification and recovery of high-value catalyst materials.
- Recycling of battery materials.
- Chlorofluorocarbons (CFCs) are no longer used as refrigerants or as expanding agents in the manufacture of plastics.
- Solvents for body degreasing are almost entirely free of chlorinated hydrocarbons; water-based paints are used in dip-priming.
- Water-based paints for top coating are in use.
- Reprocessing of manufacturing agents, e.g. oil, coolant, antifreeze.
- Recycling of some 60% of residual materials (e.g. scrap metal, waste paper, leather, textile and wood waste).

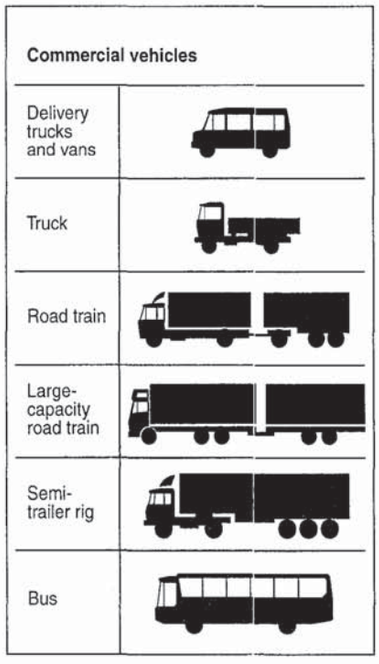
Vehicle bodies, commercial vehicles

Commercial vehicles

Commercial vehicles are used for the safe and efficient transportation of persons and goods. In this respect, the degree of economic efficiency is determined by the ratio of usable space to overall vehicle volume, and of useful load to laden vehicle weight. Dimensions and weights are limited by legal regulations.

From the design-concept viewpoint, a distinction must be made between cab-over-engine (COE) and cab-behind-engine (CBE) vehicles.

A wide variety of vehicle types meet the demands of local and long-distance transportation, as well as the demands encountered on building sites and in special applications.



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

Delivery trucks and vans

These are light-duty trucks (2...7 t) used in the transportation of persons and in local goods distribution. In fulfilling this function stringent demands are made on the vehicle in terms of mobility, maneuverability, performance, operating comfort and safety. The design concepts are based on front-mounted engine, front or rear-wheel drive, independent suspension or rigid axle and, from 3.5 t laden weight, twin tires on the rear axle.

The product range includes enclosed-body multi-purpose vehicles and vans, as well as low-bed and high-bed platform-body vehicles with special superstructures and double cabs.

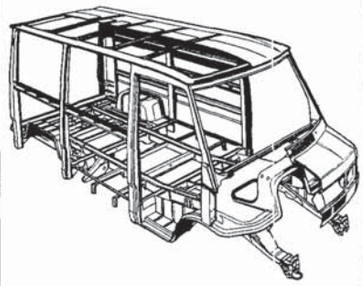
In small delivery trucks and vans, the bodies form an integral load-bearing unit together with the chassis.

The body and chassis frameworks consist of sheet-metal pressed elements and flanged profiles. Platform-body vehicles have a ladder-type frame with open or closed side members and cross members as the primary load-bearing structure.

Delivery trucks and vans

Van	
Double-cab low-bed truck	
Platform-type high-bed truck	
Chassis	

Delivery-truck load-bearing unit



Large delivery trucks and vans mostly have their own framework and a separate body.

Medium- and heavy-duty trucks and tractor vehicles

The vehicles in this sector have either a load-bearing chassis or partially load-bearing body. In most cases the engine is at the front. It is seldom fitted as an underfloor engine between the axles. The vehicle is driven via the twin-tire axle(s). In individual cases, the rear axle is fitted with single tires. For building-site (off-road) use with high traction requirements, all-wheel drive with longitudinal and cross-lock technology is applied.

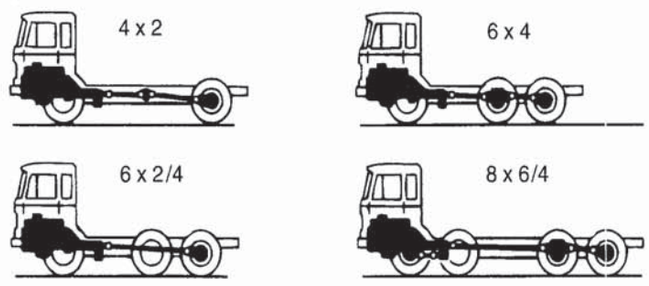
Type of truck undercarriage (see Figure below):
N x Z/L
N = Number of wheels
Z = Number of driven wheels
L = Number of steered wheels

(twin wheels count as one wheel)

Normal chassis have leaf- or pneumatically-sprung rigid front and rear axles. Pneumatic suspension facilitates the simple mounting and removal of interchangeable bodies and unhitching of semi-trailers. Three-axle vehicles (6x2) are fitted with either a leading or a trailing axle (in front of or behind the driven axle) to increase the useful load. High-traction 6x4 vehicles for use on building sites have a twin-axle configura-

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

Types of truck undercarriage (examples)



tion with axle-load compensation and center bearing point or air-sprung single axles.

Chassis frames

The chassis frame is the commercial vehicle's actual load-bearing element. It is designed as a ladder-type frame, consisting of side and cross members. The choice of profiles decides the level of torsional stiffness. Torsionally flexible frames are preferred in medium- and heavy-duty trucks because they enable the suspension to comply better with uneven terrain. Torsionally stiff frames are more suitable for smaller delivery vehicles and vans.

Apart from the force introduction points, critical points in the chassis-frame design are the side-member and cross-member junctions. Special gusset plates or pressed cross-member sections form a broad connection basis. The junctions are riveted, bolted and welded. U- or L-shaped side-member inserts provide increased framework flexural strength and reinforcement at specific points.

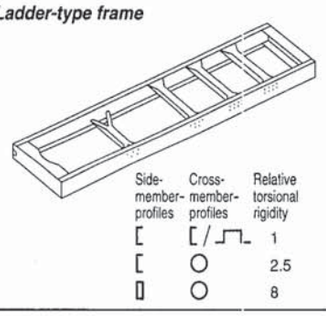
Driver's cab

There are a variety of cab designs available depending on the vehicle concept. In delivery vehicles and vans, low, convenient entrances are an advantage, whereas in long-distance transport space and comfort are more important. Modular design concepts allow for short, medium and long cab versions while retaining the same front, rear and doors.

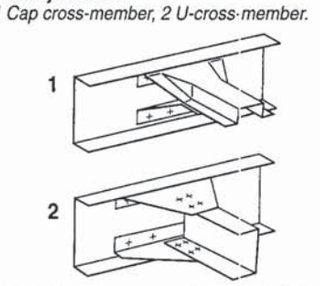
In the case of cab-over-engine (COE) vehicles, the steering system is positioned right at the front of the vehicle. The engine is located under the cab or under an engine tunnel between the driver and the co-driver. The entrance is positioned in front of or above the front axle. A mechanical (pretensioned torsion bar) or hydraulic cab-tipping mechanism ensures good access to the engine.

In cab-behind-engine (CBE) vehicles, the engine/transmission assembly is mounted ahead of the cab firewall beneath a steel or plastic hood (which is usually tiltable for reasons of accessibility). The driver enters the cab behind the front axle.

Ladder-type frame



Frame junctions
1 Cap cross-member, 2 U-cross-member.



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

Bodies

Specific body structures such as flatbeds, standard vans, box vans, dump-truck deep-beds, tankers, concrete mixers etc. permit the economical and efficient transportation of a wide variety of goods and materials. Connection between body and load-bearing chassis frame is effected in part by means of auxiliary frames with non-positive or positive attachments.

Road trains and semitrailer rigs are used in long-distance transport. As the size of the transportation unit increases, the costs relative to the freight volume decrease.

Load volume is increased by reducing the empty spaces between cab, cargo area and trailer (high-capacity road train). Advantages of semitrailer rigs lie in the greater uninterrupted loading length of the cargo area and the shorter inoperative times of the tractor units. Measures to improve aerodynamics, such as front and side trim on the vehicle and specially adapted air deflectors from the cab to the body, are applied to minimize fuel consumption.

Buses

The bus market offers a specific vehicle for practically every application. This has resulted in a wide range of bus types, which differ in their overall dimensions (length, height, width) and appointments (depending on the application).

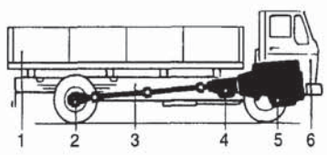
Microbuses

Microbuses carry up to approx. 19 passengers. These vehicles have been developed from delivery trucks or vans weighing up to approx. 4.5 t.

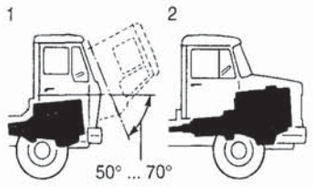
Minibuses

Minibuses carry up to approx. 25 passengers. These vehicles have been developed from delivery trucks or vans weighing up to approx. 7.5 t. They are occasionally built on the ladder-type chassis of light-duty trucks. A modified suspension design and special measures carried out on the body result in optimum ride comfort and noise levels.

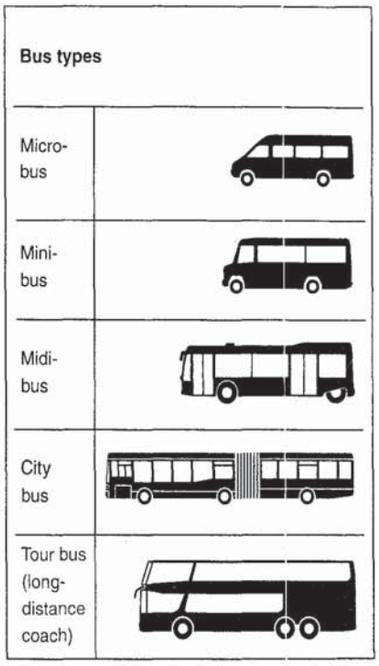
Truck assemblies
1 Body, 2 Axle, 3 Chassis frame, 4 Transmission, 5 Engine, 6 Cab.



Driver's cab
1 Cab over engine (COE), 2 Cab behind engine (CBE).



Bus types



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

Midibuses
Depending on the application, midibuses can carry up to approx. 35 passengers (in tour buses) and up to approx. 65 passengers (in city buses). These vehicles weigh up to approx. 12.5 t and are predominantly built on the ladder-type chassis of light-duty trucks. There are also integral-framework designs in operation. A modified suspension design and special measures carried out on the body result in optimum ride comfort and noise levels.

City buses
City buses are equipped with seating and standing room for scheduled routes. The short intervals between stops in suburban passenger transportation operations necessitate a rapid passenger turnover. This is achieved by wide doors that open and close swiftly, low boarding heights (approx. 320 mm) and low floor heights (approx. 370 mm).

Main specifications for a 12 m standard public-service bus:
Vehicle length approx. 12 m,
Total weight 18.0 t,
Number of seats 32...44,
Total passenger capacity approx. 105 persons.

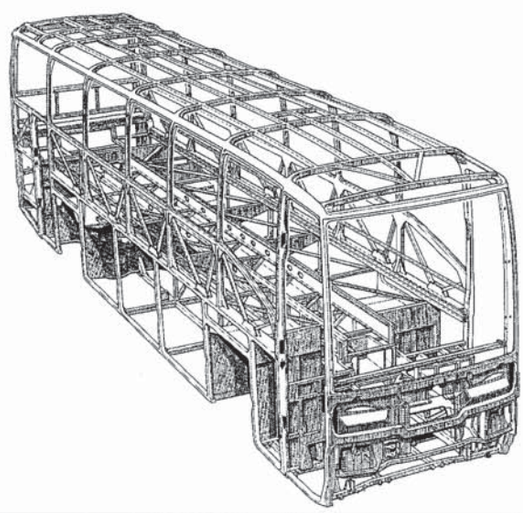
The use of double-decker buses (length 12 m carrying up to approx. 130 passengers), three-axle rigid buses (length up to 15 m carrying up to approx. 135 passengers) and articulated buses (approx. 160 passengers) provides increased transport capacity.

Intercity buses or touring coaches
Depending on the application (standing passengers are not permitted at $v >$ 60 km/h), either low-floor designs featuring the low boarding and floor heights of public-service buses are used, or buses are employed which, with their higher floors and small luggage compartments, are already very much like tour buses. Overland buses come in lengths of 11...15 m as rigid vehicles or in lengths of 18 m as articulated vehicles.

Tour buses (long-distance coaches)
Tour buses are designed to provide comfortable travel over medium and long distances. They range from the low, two-axle standard bus through to the double-decker luxury bus and come in lengths of approx. 10...15 m.

Body structure
Light design based on an integral body.

Integral bus body



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

The body and base frames, which are firmly welded together, consist of pressed grid-type support elements and rectangular tubes.

Undercarriage
The horizontally or vertically mounted engine drives the rear axle. Pneumatic suspension at all axles permits ride-level stabilization and a high degree of ride comfort. Intercity buses and touring coaches are mainly equipped with independent wheel suspension on their front axles. Disk brakes, frequently supported by retarders, are used on all the axles.

Passive safety in commercial vehicles

Passive safety is intended to limit the consequences of accidents and to protect other road users. Systematic recording of accidents, accident tests with complete commercial vehicles and intensive computer optimization help to devise safety measures.

In the event of a collision, the driver's cab and the passenger compartment must maintain the amount of room necessary for occupant survival, while at the same time deceleration must not be excessive. Depending upon vehicle design, there are a variety of solutions to this problem.

In delivery trucks and vans, front-section design is energy-absorbing as in passenger cars. In spite of shorter deformation routes and higher levels of released energy, the physiologically permissible limits are not exceeded in the case of virtually all passenger-car crash-test standards (legal requirements and rating tests).

In the case of trucks, the side members extend up to the front bumper and can absorb high longitudinal forces. Such passive-safety measures are based on accident analyses and are intended to improve the structural design of the cab. Static and dynamic stress and impact tests at the front and rear of the cab, as well as on its roof, simulate the stresses involved in a frontal impact and in accidents in which the vehicle overturns or rolls over, as well as in which the load shifts.

Statistical analyses have proved that the bus is one of the safest means of passenger transportation. Static roof-load tests and dynamic overturning tests provide evidence of body strength The use of flame-retardant and self-extinguishing materials for the interior of the vehicle minimizes the risk of fire.

Because road traffic involves many different kinds of vehicles, collisions between light and heavy vehicles are unavoidable. As a result of the differences in vehicle weight, and incompatibility in terms of vehicle geometry and structural stiffness, the risk of injury in the ighter vehicle is greater. The formulas below define the change in speed during a normal (non-oblique) plastic impact for frontal or rear collisions between two vehicles:

$$\text{Vehicle 1 } \Delta c_1 = \frac{\mu \cdot \Delta v}{1 + \mu}$$

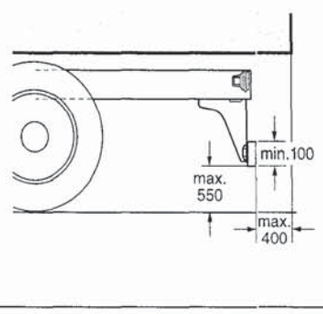
$$\text{Vehicle 2 } \Delta c_2 = \frac{\Delta v}{1 + \mu}$$

where $\mu = m_2/m_1$

m_1, m_2 = masses of the vehicles involved,
v relative speed prior to impact.

Side, front and rear underride guards help to reduce the danger of the lighter vehicle driving under the heavier vehicle in the event of a collision. In other words, they serve to protect other road users.

Rear underride guard for commercial vehicles



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

Lighting

Functions

Vehicle front end
The primary function of the headlamps at the vehicle front end is to illuminate the roadway so that the driver can register the traffic conditions and recognize any obstacles and hazards in good time. They also serve to identify and mark out the vehicle to oncoming traffic. The turn-signal lamps serve to show the driver's intention to change direction or to indicate a hazardous situation. The headlamps and lights at the front end include the following:
- Low-/high-beam headlamps,
- Fog lamps,
- Auxiliary driving lamps,
- Turn-signal lamps,
- Parking lamps,
- Side-marker/clearance lamps (wide vehicles) and
- Daytime running lamps (if required by law in individual countries).

Vehicle rear end
Lights are turned on at the vehicle's rear end in accordance with the weather conditions and indicate the vehicle's position. They also indicate how the vehicle is moving and in which direction, e.g. whether it is traveling unbraked straight ahead, or whether the brakes are applied or the driver is intending to change direction, or whether a hazardous situation exists. The backup lamps illuminate the roadway while the vehicle is backing up/reversing. The lamps/lights at the rear end include the following:
- Stop lamps,
- Tail lamps,
- Fog warning lamps,
- Turn-signal lamps,
- Parking lamps,
- Clearance lamps (wide vehicles),
- Backup lamps and
- License-plate lamps.

Vehicle interior
In the vehicle interior, priority over all other functions is given to the ease and reliability with which the switch elements can be reached and operated and to provide the driver with sufficient information on the vehicle's operating states (while distracting him/her from driving as little as possible). A well-lit instrument panel (P. 783) and discreet lighting of the various functional groups, such as the radio or navigation system, are absolutely essential to ensure relaxed and safe driving. Optical and acoustic signals must be prioritized according to their urgency and then relayed to the driver.

Regulations

Approval codes and symbols
Automotive lighting equipment is governed by national and international design and operating regulations according to which the equipment in question must be manufactured and tested. Each class of illumination device is assigned a specific approval code. The symbol for this code must be legible e.g. on all lenses for headlights and other vehicle lamps. This also applies to approved replacement headlamps and lights.

If a device has one of these approval symbols, this indicates that it has been tested by a technical service body and approved by an official approval authority (in Germany: Federal Motor-Vehicle Agency). All units which are series-produced and assigned an approval symbol must conform in all respects to the approved unit. Examples of approval symbols:

∩∩ K National test symbol D,

(E1) ECE test symbol,

[e 1] EU test symbol.

The number 1 following each letter for example indicates that approval has been granted in Germany.

In Europe, installation of all automotive lighting and visual signaling equipment is governed not only by national guidelines but also by the higher European directives (ECE: whole of Europe, EU and Japan). In the course of the ongoing union of Europe, the implementation regulations are being increasingly simplified by the harmonization of directives and legislation.

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

Bosch headlamps conform to the applicable ECE and EU directives and can therefore be used in all ECE and EU countries regardless of the country in which they were acquired.

In the USA, lighting equipment is governed by regulations that are very different from those in Europe. The principle of self-certification compels each manufacturer as an importer of lighting equipment to ensure and in an emergency to furnish proof that his products conform 100% to the regulations of FMVSS 108 laid down in the Federal Register. There is therefore no type approval in the USA. The regulations of FMVSS 108 are partly based on the SAE industry standard.

Motor vehicles which for instance are reimported into Europe must be refitted to comply with the European directives.

Photometric terms and definitions

Headlamp range
The distance at which the headlamp beam continues to supply a specified luminous intensity: mostly the 1 lux line at the right side of the road (RH traffic).

Headlamp geometrical range
This is the distance to the horizontal portion of the light/dark cutoff line on the road surface. A low-beam inclination of 1% or 10 cm per 10 meters results in a geometric range equal to 100 times the headlamp's installation height (as measured between the center of the reflector and the road surface).

Visual range
Distance at which an object (vehicle, object etc.) within the luminous distribution field is still visible.

The visual range is influenced by the shape, size and reflectance of the objects, road-surface type, headlamp design and cleanliness, and the physiological condition of the driver's eyes. Because of this large number of influencing factors, it is not possible to quantify this range using precise numerical definitions. Under extremely unfavorable conditions (with RH traffic, on the left side of a wet road surface) the visual range can fall to below 20 m. Under optimal conditions it can extend outward to more than 100 m (with RH traffic, on the right side of the road).

Signal identification distance
Maximum distance at which a visual signal (e.g. fog warning lamp) remains just visible in fog or other inclement weather conditions.

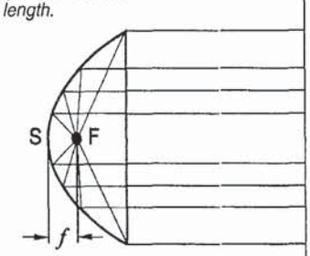
Glare, physiological
This is the quantifiable reduction in visual performance that occurs in response to light sources emitting glare. An example would be the reduction in visual range that occurs as two vehicles approach one another.

Glare, psychological
(discomfort glare)
This condition occurs when a glare source induces discomfort without, however, causing an actual reduction in visual performance. Psychological glare is assessed according to a scale defining different levels of comfort/discomfort.

Reflector focal length
Conventional reflectors for headlamps and other automotive lamps are usually parabolic in shape. The focal length f (distance between the vertex of the parabola and the focal point) is between 15 and 40 mm.

Free-form reflectors
The geometrical configurations of modern reflectors are generated using complex mathematical calculations (HNS, Homogeneous Numerically Calculated Surface). Here, the low mean focal length $\bar{f}$ is defined relative to the distance between

Parabolic reflector
F Focal point, S Vertex, f Focal length.



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

the reflector's vertex and the center of the filament. Typical values are between 15 and 25 mm.

In the case of reflectors partitioned with steps or facets (PD2 Partition Design 2), each partition can be created with its own mean focal length *f*.

Reflector illuminated area
Parallel projection of the entire reflector opening onto a transverse plane. The standard reference plane is vertically perpendicular to the vehicle's direction of travel.

Effective luminous flux, headlamp efficiency ratings
The first of the above is that portion of the light source's luminous flux able to supply effective illumination via its reflective or refractive components (for instance, as projected onto the road surface via the headlamp reflector). A reflector with a short (or limited mean) focal length makes efficient use of the incandescent filament because such a reflector extends outward to encompass the bulb, allowing it to convert a large proportion of the luminous flux into a useful beam of light.

Angles of geometric visibility
Those angles, defined relative to the axis of the lighting device, at which the illuminated surface must be visible.

Definitions of device design

Grouped design
A single housing, but with different lenses and bulbs.
Example: Multichamber rear-lamp assemblies containing different individual light units.

Combined design
A single housing and bulb assembly with more than one lens.
Example: Combined rear lamp and license-plate lamp.

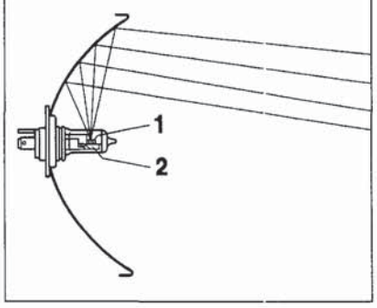
Nested design
Common housing and lens, but with individual bulbs.
Example: Headlamp assembly with built-in side-marker lamp.

Main headlamps, European system

Low beam (dipped beam)
The high traffic density on modern roads severely restricts the use of high-beam headlamps. Under most standard conditions, the low beams are the actual driving lamps. Basic design modifications have allowed substantial improvements in low-beam performance. These include:
- Introduction of the asymmetrical low-beam pattern, characterized (RH traffic) by an extended visual range along the right side of the road,
- Official approval for various types of halogen lamps, making it possible to enhance the luminous intensity at the road surface by 50...80 %.
- Introduction of innovative headlamp systems featuring complex geometrical configurations (PES, HNS, PD2) designed to improve efficiency levels by up to 50 %.
- The "Litronic" gaseous-discharge headlamp (with luminous arc) supplies more than twice the light generated by comparable halogen units.

Low-beam headlamps require a light/dark cutoff line in the light distribution. This is generated in halogen headlamps with H4 bulbs and in Litronic headlamps with a D2R bulb by reflecting the cap (H4) or the light shield (D2R). In headlamps with all-round use (H1, H7, HB4 bulbs), the light/dark cutoff line is created by

***Low beam** (projection pattern, H4 lamp)*
1 Low-beam filament, 2 Shield



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

specifically reflecting the filaments.

The "dark above/bright below" distribution pattern resulting from the light/dark cutoff line furnishes acceptable visual ranges under all driving conditions. This configuration holds the glare to which approaching traffic is exposed within reasonable limits while at the same time supplying relatively high levels of illumination in the area below the light/dark cutoff line.

The light distribution pattern must combine maximum visual ranges with minimum glare. These demands are supplemented by other requirements affecting the area directly forward of the vehicle. For instance, the headlamps must provide assistance when cornering, i.e., the light distribution pattern must extend beyond the left and right-side extremities of the road surface.

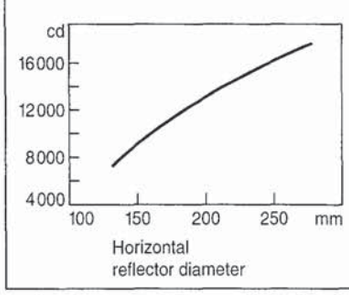
Automotive headlamp performance is subject to technical assessment and verification. Among the requirements are minimum illuminance levels, to ensure adequate road-surface visibility, and maximum intensity levels, to prevent glare (points for measuring illuminance, P. 742).

Headlamp versions

Conventional headlamps

With conventional headlamp systems, the quality of the low beam increases directly in proportion to the size of the reflector. At the same time, the geometrical range increases as a function of installation height. These factors must be balanced against the aerodynamic dictates according to which the vehicle's front-end profile must be kept as low as possible.

Luminous intensity of a headlamp for illuminating right edge of road as function of horizontal reflector diameter



These mutually antagonistic requirements are reconciled by using wider headlamps to accommodate larger reflectors.

Reflectors of a given size, but with different focal lengths, also perform differently. Shorter focal lengths produce wider light beams with better close-range and side illumination. This is of particular advantage during cornering.

Stepped reflectors

Stepped, or graduated reflectors are segmented reflectors consisting of paraboloid and/or parelliptical (combined parabola and ellipse) sections designed to provide various focal lengths. These units retain the advantages of a deep reflector in a shallow unit suitable for compact installation.

Homofocal reflector

The homofocal reflector's supplemental sectors share a single focal point to achieve a shorter focal length than is provided by a basic reflector, thus making a particularly useful contribution to the effective luminous flux. While the light from the supplemental reflectors improves close-range and side illumination, there is no improvement in range.

Multifocal reflector

The principle behind the multifocal reflector is similar to that of its homofocal counterpart. Based on mathematical definitions, the introduction of parelliptical reflector sections, which disperse the light horizontally, produces a large number of focal points.

Variable-focus (stepless) reflectors

Specially designed programs (CAL, Computer Aided Lighting) assist in designing the transitionless VF (Variable Focus Reflector) with its non-parabolic sectors. The focal points of the various reflector zones can change position relative to the light source. This principle can be applied to exploit the entire reflector surface.

Headlamps with clear lenses

Developments in the area of HNS reflector technology (Homogeneous Numerically Calculated Surface) have now made it possible for headlamps to operate at ef-

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

Perspective illustration with points for measuring illuminance in accordance with ECE Directive 8 and/or 20

Specifications in lx for headlamp with halogen lamp at distance of 25 meters.

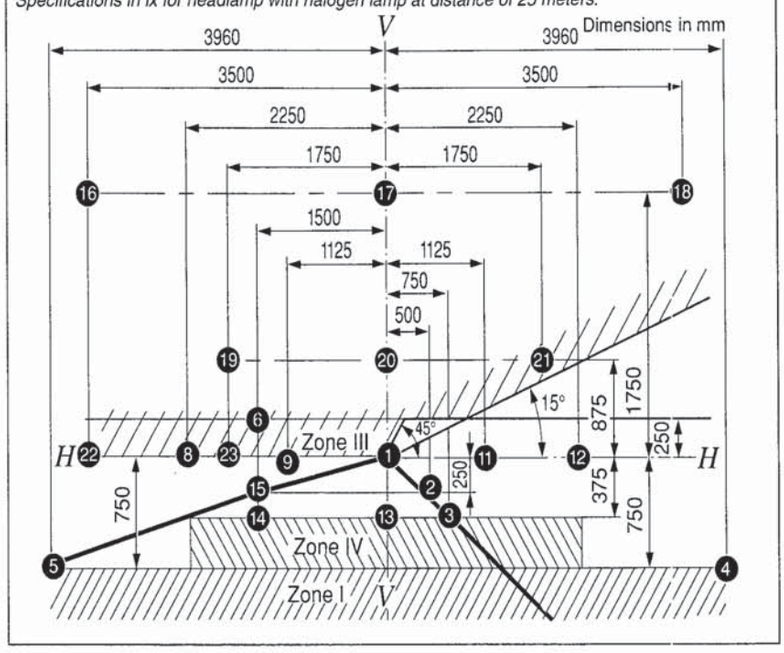


Table 1. Points for measuring low and high beams

Low beam			
Test points	Specifications in lx	Test points	Specifications in lx
1. E_{HV}	≤ 0.7	14. E_{50L}	≥ 2
2. E_{75R}	≥ 12	15. E_{75L}	≥ 12
3. E_{50R}	≥ 12	16. $E_{8L/4U}$	≥ 0.1; ≤ 0.7
4. E_{25R}	≥ 2	17. $E_{V/4U}$	≥ 0.1; ≤ 0.7
5. E_{25L}	≥ 2	18. $E_{8R/4U}$	≥ 0.1; ≤ 0.7
6. E_{B50L}	≤ 0.4	19. $E_{4L/2U}$	≥ 0.2; ≤ 0.7
Max. value in Zone I	≤ E_{50R}	20. $E_{V/2U}$	≥ 0.2; ≤ 0.7
Max. value in Zone III	≤ 0.7	21. $E_{4R/2U}$	≥ 0.2; ≤ 0.7
Min. value in Zone IV	≥ 3	22. $E_{8L/H}$	≥ 0.1; ≤ 0.7
13. E_{50V}	≥ 6	23. $E_{4L/H}$	≥ 0.2; ≤ 0.7

High beam	
Test points	Specifications in lx
7. E_{max}	> 48
	< 13 · E_{75R}
	(< 240)
8. $E_{H-5.15°}$	≥ 6
9. $E_{H-2.55°}$	≥ 24
10. E_{HV}	≥ 0.8 E_{max}
11. $E_{H+2.55°}$	≥ 24
12. $E_{H+5.15°}$	≥ 6

Test figures for test lumens of relevant lamp at approx. 12 V.

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

ficiency levels of up to 50%. The entire light-distribution pattern is generated on the lens from the reflector surface alone, without additional optical elements. This permits a new, unconventional headlamp design.

Headlamps with facet-type reflectors

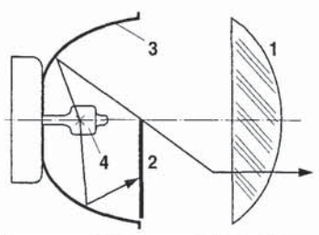
The reflector surface is partitioned with facets. The PD2 program provides the CAL and HNS modules for individual optimization of each individual segment. The important feature of surfaces developed with PD2 is that discontinuity and steps are permitted at all boundary surfaces of the partition. This results in freely shaped reflector surfaces with maximum homogeneity and side illumination.

PES headlamps

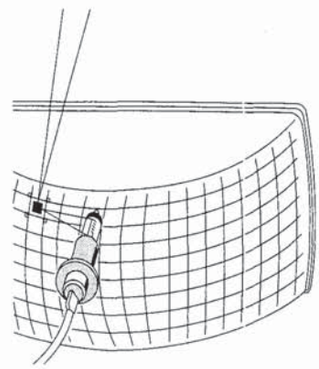
The PES headlamp system (Poly-Ellipsoid-System) employs imaging optics to improve on the technical performance provided by conventional headlamps, making it possible to obtain the light-distribution patterns associated with large-surface conventional lamps from effective projection surfaces as small as 28 cm². This result is obtained using an elliptical (CAL designed) reflector in combination with optical projection technology. A screen reflected with the objective projects precisely defined light/dark cutoffs. Depending upon specific individual requirements, these transitions can be defined as sudden or gradual intensity shifts, making it possible to obtain any desired geometry.

Together with conventional high beams, side-marker lamps and PES fog lamps, PES headlamps can be incorporated in

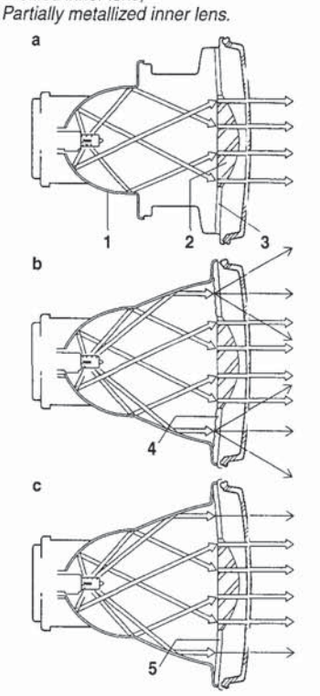
PES reflector *(optical principles)*
1 Objective, 2 Screen, 3 Reflector, 4 Lamp.



HNS or facet-type reflector
Filament pattern reflection with mirror optics.



PES reflectors
(reflection and signal patterns)
a) PES, b) PES with ring parabola and lens,
c) PES with ring parabola and partially metallized tube body.
1 Reflector, 2 Objective, 3 Screen,
4 Profiled inner lens,
5 Partially metallized inner lens.



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

light-strip assemblies to obtain a unit no higher than approximately 80 mm from top to bottom.

In PES headlamps, the beam path can be configured in such a way that the surroundings of the objective are also used in the signal image. This enlargement of the signal image is used above all with small objective diameters to reduce the psychological glare for the oncoming traffic. The annular reflector uses that portion of the light which is not detected by the PES reflector and directs it forward past the objective. An inner screen, which prevents a direct view of the lamp, can be designed as a lens or a partially metallized screen.

Litronic

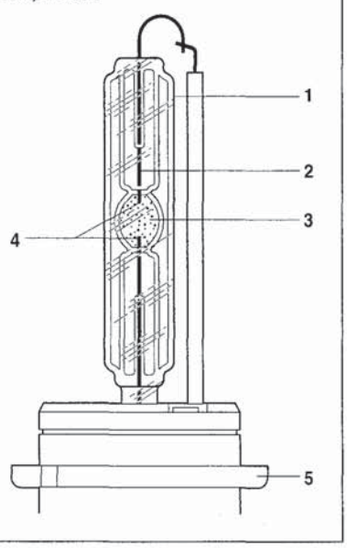
The Litronic (Light-Electronic) headlamp system with a xenon gaseous-discharge lamp as its central element generates high illumination-intensity levels with minimal front-end surface requirements. This makes it ideal for installation in vehicles with aerodynamic front-end styling exhibiting optimum c_w values.

The 35 W "D2S" bulb's arc generates a luminous flux twice as intense as that produced by the H1 bulb. At 4200 K, the color temperature[1]) is higher, which means it contains – similar to sunlight – larger components of green and blue. Maximum illumination, corresponding to approx. 90 lm/W, is available as soon as the quartz element reaches its normal operating temperature of more than 900 °C. Brief high-power operation at currents of up to 2.6 A (continuous operation: approx. 0.4 A) can be used to obtain "immediate light". The life expectancy of 1500 hours corresponds to the operating time to be anticipated during the vehicle's service life. Failure is not sudden, as with filament bulbs. Instead, gradual dimming facilitates early diagnosis and replacement.

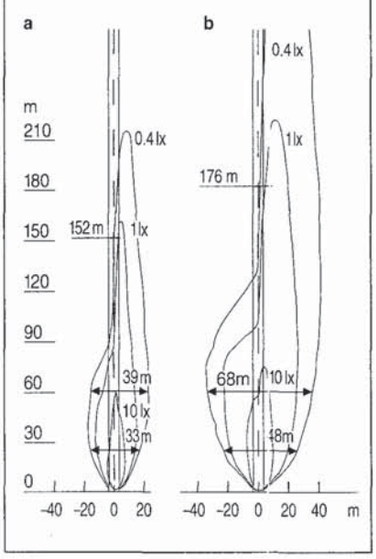
The second generation of these gaseous-discharge lamps for automotive applications features high-voltage-proof sockets and UV glass shielding elements:
– the D2S lamps for PES-design headlamps,

[1]) Temperature of the "black beam" which appears to have the same or a similar color when viewed by an observer.

Gaseous-discharge lamp D2S
1 UV inert-gas bulb, 2 Lead-in insulator, 3 Discharge chamber, 4 Electrodes, 5 Lamp holder.

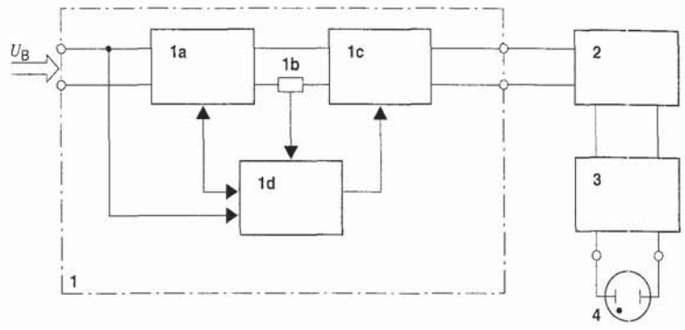


Light-distribution patterns *(road traffic)*
a) PES halogen lamp,
b) Litronic PES D2S lamp.

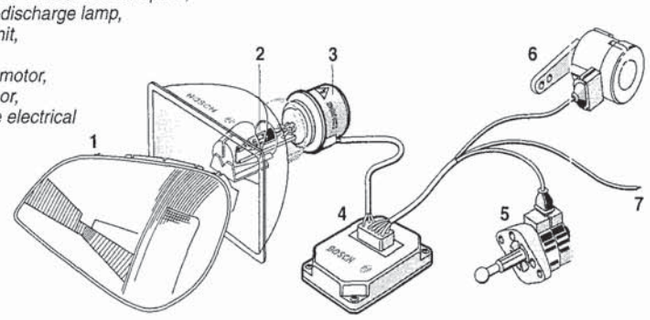


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

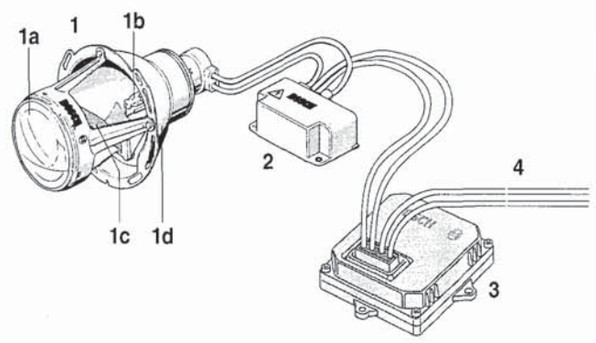
Electronic ballast unit (EVG) for 400 Hz alternating current and pulse ignition of the bulb
1 ECU (1a DC/DC converter, 1b Shunt, 1c DC/AC Converter, 1d Microprocessor),
2 Ignition unit, 3 Lamp socket, 4 D2S lamp, U_B Battery voltage.



System components for reflection-type headlamp with integrated dynamic headlight vertical-aim control
1 Lens with or without scatter optics,
2 Gaseous-discharge lamp,
3 Ignition unit,
4 ECU,
5 Stepping motor,
6 Axis sensor,
7 To vehicle electrical system.

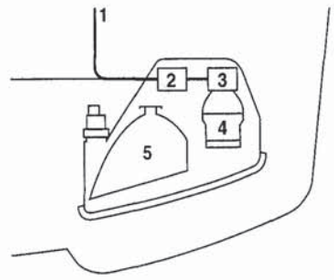


System components for PES-design headlamps
1 Headlamp
(1a Lens,
1b D2S lamp,
1c Screen,
1d Reflector),
2 Ignition unit,
3 ECU,
4 To vehicle electrical system.

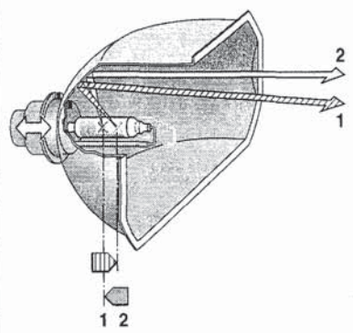


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

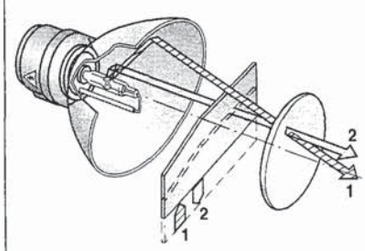
Quad-headlamp system with Litronic
1 Vehicle electrical system, 2 ECU, 3 Ignition unit with lamp connection, 4 Headlamp optics with gaseous-discharge lamp, 5 Halogen high beam.



Bi-Litronic "Reflection"
1 Low beam, 2 High beam.



Bi-Litronic "Projection"
1 Low beam, 2 High beam.



– D2R lamps for reflection headlamps; an integral light shield, comparable to the bulb cover used for H4 low beams, generates the light/dark cutoff line.

An integral part of the headlamp is the electronic ballast unit (EVG) responsible for activating and monitoring the lamp. Its functions include:
– Ignition of the gaseous discharge (voltage 10...20 kV)
– Regulated power supply in the cold lamp's warm-up phase and
– Demand-oriented supply in continuous operation.

The system furnishes largely consistent levels of illumination by compensating for fluctuations in the vehicle's electrical system. Should the lamp go out (for instance, due to a momentary lapse in the voltage supply), reignition is spontaneous and automatic.

The electronic ballast unit responds to defects (such as a damaged lamp) by interrupting the power supply to help avoid injury in the event of contact.

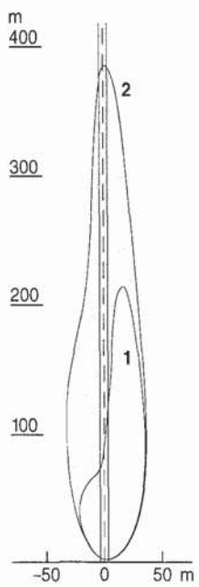
Litronic's initial area of application has been as a high-performance low-beam unit in quad headlamp assemblies, where it is designed to operate simultaneously with specially designed halogen high-beam units. This has made it possible to achieve substantially wider road-illumination patterns for lighting the edges of curves and of wide roads as effectively as a halogen unit illuminates straight stretches of road. The driver enjoys substantial improvements in both visibility and orientation in difficult operating conditions and inclement weather. Compliance with ECE-R regulations is achieved by equipping Litronic headlamps with vertical aim control and washer systems to consistently ensure optimal utilization of the extended range while at the same time maintaining excellent beam projection.

Bi-Litronic "Reflection"

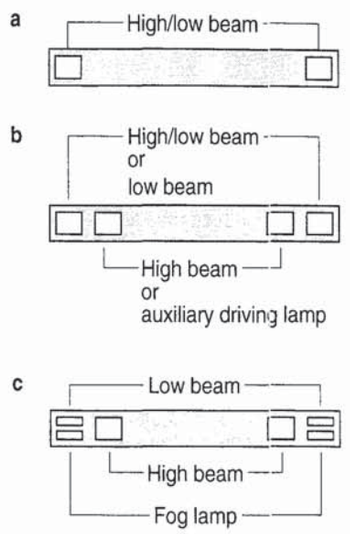
Bi-Litronic is a special system. It permits both the low and high beams to be generated by a dual-headlamp system using only one gaseous-discharge lamp. For this purpose, when the high-/low-beam switch is operated, an electromechanical

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

Light-distribution patterns of Bi-Litronic
1 Low beam, 2 High beam.



Headlamp systems
a) Dual headlamps,
b) Quad headlamps,
c) Six headlamps.



actuator moves the gaseous-discharge lamp in the reflector into the appropriate position for defining the escape of the light cone for the main and low beams. The essential advantages of Bi-Litronic "Reflection" are:

- Xenon light for high-beam operation,
- Visual guidance through continuous shifting of light distribution from close to long range,
- Clear reduction of required space compared with four-compartment systems,
- Lower cost through use of only one lamp and a ballast unit.

Bi-Litronic "Projection"

Bi-Litronic "Projection" system is based on a PES Litronic headlamp. Xenon light is made available for high-beam operation by shifting a light shield for the light/dark cutoff. With lens diameters of 60 and 70 mm, Bi-Litronic "Projection" enables the presently most compact headlamp design with combined high/low beam and at the same time outstanding luminous efficiency.

High beam

The high beam is usually generated by a light source located at the focal point of the reflector (see Fig. on P. 739). This causes the light to be reflected outward in the direction of the reflector's axis. The intensity of the high beam projected along the axial plane is largely a function of the reflector's luminous surface area. In four and six-headlamp systems, in particular, purely paraboloid high-beam reflectors can be replaced by units with complex geometrical configurations designed to supply a "superimposed" high-beam pattern.

The calculations employed to design these units seek to achieve a high-beam distribution that harmonizes with the low-beam pattern (simultaneous activation). The pure high beam is virtually "superimposed" on the low-beam projection to do away with the annoying overlap normally

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

found in the transitional area at the front of the light-distribution pattern.

Designs
Global regulations mandate two headlamps for low beam and at least two (or the option of four) high-beam units for all dual-track vehicles.

Dual headlamp system
This design utilizes bulbs comprising two separate light sources (Bilux, Duplo) to project both low and high beams via a single reflector.

Quad headlamp system
Two of the headlamps provide both high and low beam or low beam only, while the second pair only provides high-beam illumination.

Six-headlamp system
This configuration differs from the quad design by incorporating a supplementary fog lamp in the main headlamp.

Component groups:

Lens (adjustable in bodywork)
The lens and reflector are combined in a single headlamp unit. The beam is adjusted by pivoting the complete assembly. Under unfavorable circumstances, this can lead to the lens being at a slight angle relative to the car's bodywork. The headlamp assemblies are generally equipped with seals in the area adjacent to the bulb, and also feature special ventilation systems.

Lens (fixed to the bodywork)
There is no connection between the lens and the reflector which is mounted in a housing designed to move relative to the lens for adjustment (housing type). Because the reflector has no connection to the lens it remains stationary and can be fully integrated into the vehicle's bodywork. The complete headlamp is sealed or provided with ventilation elements.

Components

Reflector
Reflectors are made of sheet metal or plastic.
Sheet-metal reflectors are manufactured as follows:
- Deep-draw processing to obtain a paraboloid or more complex geometrical configuration,
- Galvanization or powder-coating to protect against corrosion,
- Paint application to obtain a smooth surface,
- Evaporative application of aluminum to form the reflective layer, and
- Evaporative application of a special protective layer onto the aluminum substrate.

This process hermetically seals the sheet metal while providing an extremely smooth reflective surface featuring a maximum residual ripple of 1/10,000 mm.

Plastic reflectors are produced by injection molding (duroplastic, thermoplastic); no special anti-corrosion treatment is required. Plastic can be shaped with much greater precision and can also be used to manufacture stepped reflectors.

Lens
A large proportion of lenses is manufactured using high-purity glass (free of bubbles and streaks). During the lens molding process high priority is assigned to surface quality in order to prevent undesirable upward light refraction in the final product – this would tend to blind oncoming traffic. The type and configuration of the lens prisms depend upon reflector size and focal depth as well as the desired light-distribution pattern. With the improvement in calculation methods, it is also possible to develop headlamps where complete light distribution is determined by the reflector. This eliminates all the diffuser elements on the lens, thus producing a "clear lens". The first plastic lens entered series production in 1992. Aside from reduced weight, plastic lenses provide other advantages for automotive applications including greater latitude in headlamp and vehicle design.

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

Main headlamps, American system

Low beam

The demands placed on light distribution in American motoring differ from those in Europe. Since 1.5.1997, however, headlamps with light/dark cutoffs have also been authorized in the USA. These though must be visually adjusted. It is thus now possible to develop headlamps which conform to both legal requirements.

High beam

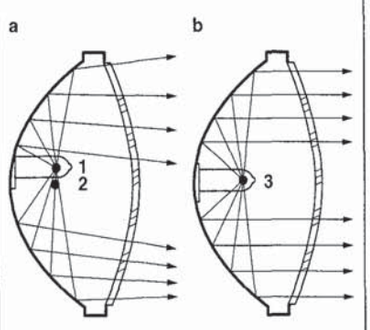
As with the European system, the light source is usually located at the focal point of the parabolic reflector. Dual, quad and six-headlamp configurations are employed.

Designs

Sealed beam

In this design which is no longer used, the aluminized glass reflector must be sealed gas-tight with the lens on account of the unencapsulated light sources. The whole unit is sealed and filled with an inert gas. Should a filament burn through, the entire unit must be replaced. Units with halogen light sources are also available. The limited range of available sealed-beam headlamps on the market severely restricted the designers' latitude for front-end styling variations.

American sealed-beam headlamps
a) Low beam, b) High beam.
1 Low-beam filament, 2 Focal point,
3 High-beam filament (at focal point).



Replaceable Bulb Headlamp (RBH)

European developments based on replaceable bulb technology also had an effect on the American system from 1983 onwards. The headlamps' size and shape can be adapted for improved vehicle design (styling considerations). The RBH design usually features plastic reflectors and lenses.

Vehicle Headlamp Aiming Device (VHAD)

This design involves RBH headlamps which are mechanically adjusted vertically with the aid of a level gauge integrated in each headlamp and horizontally by means of a system comprising needle and dial: This is in fact "on-board aiming".

Headlamp systems

As in Europe, dual-, quad- and six-headlamp configurations are used in North America.

Main headlamps, European regulations

Regulations and directives for main headlamps

76/761/EEC and ECE-R1 and R2:
Headlamps for high and low beam including their bulbs.
ECE-R8: Headlamps with H1, H2, H3, H7, H8, H9, H11, HIR1, HIR2, HB3 and HB4 bulbs.
ECE-R20: Headlamps with H4 bulbs.
StVZO §50: Headlamps for high and low beam.
76/756/EEC and ECE-R48: for installation and application.
ECE-R 98/99: Headlamps with gaseous-discharge lamps.

Low beam, installation

Regulations prescribe 2 white-light low-beam headlamps for multiple-track vehicles.

Low beam, illumination technology

The relevant ordinances governing symmetrical low-beam illumination in Germany are contained in the Technical Requirements (TA) of the StVZO (FMVSS/

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

CUR; Vehicle Homologation and Licensing Regulations). The only applicable regulations for asymmetrical low beams are international regulations and guidelines containing precise stipulations governing photometric testing of the different low-beam units (with standard or halogen bulb).

Homologation testing is carried out using test lamps manufactured to more precise tolerances than those installed in production vehicles.

Headlamp glare is evaluated based on StVZO §50 (6). Glare is considered to be eliminated when the illuminance at a height equal to that of the center of the headlamp does not exceed 1 lx at a distance of 25 m. This test is carried out with the engine running at moderate speed.

Low beam, switching

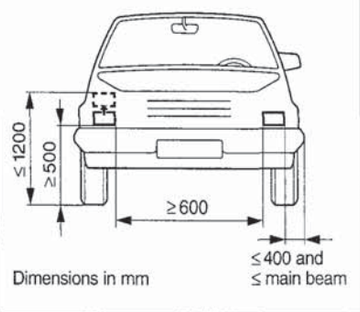
All high-beam lamps must extinguish simultaneously when the low beams are switched on. Dimming (gradual deactivation) is permitted, with a maximum dimming period of 5 seconds. A 2-second response delay is required to prevent the dimming feature from activating when the high-beam flashers are used. When the high beams are switched on, the low-beam units may continue to operate (simultaneous operation). H4 bulbs are generally designed for limited use with both filaments in operation.

High beams, installation

A minimum of two and a maximum of four headlamps are prescribed for the high-beam mode.

Prescribed instrument-cluster high-beam indicator lamp: blue or yellow.

European headlamp system *(low beam)*



Dimensions in mm

High beams, illumination technology

High-beam light distribution is defined in the regulations and guidelines together with the stipulations governing the low beams.

The most important specifications are: symmetrical distribution relative to the central vertical plane, maximum light along the headlamp's center axis.

The maximum approved luminous intensity, a composite of the intensity ratings for all high-beam headlamps installed on the vehicle, is 225,000 cd. The respective ratings are indicated by reference codes located adjacent to the homologation code on each headlamp. 225,000 cd corresponds to the number 75. The luminous intensity of the high beam could be indicated, e.g., by the number 20 stamped next to the round ECE test symbol.

If these are the only headlamps on the vehicle (no auxiliary driving lamps) then the composite luminous intensity is to be in the range of 40/75 of 225,000 cd, viz., 120,000 cd.

High- and low-beam adjustments

Conditions for aiming

- Tire pressures must conform to specifications.
- Vehicle loaded, in accordance with model type:

For passenger cars: one person or 75 kg on the driver's seat.
For trucks: unladen;
For single-track vehicles and single-axle tractors: one person or 75 kg on the driver's seat.

- The vehicle should be rolled several meters to allow the suspension to adapt to the added load.
- The vehicle must be parked on a flat, level surface.

If adjustment is carried out without a headlamp aiming device, a test surface must be set up at a distance of 10 meters from the vehicle so that the center mark is located in the direction of travel in front of the headlamp to be adjusted (see Figs.).

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

- The headlamps must be adjusted individually, with all other headlamps covered.
- If the vehicle is equipped with a manual headlamp range adjuster, the switch should be set to the position prescribed by the manufacturer.

Table 2. Setting dimension "e" for headlamp adjustment, Europe[1])

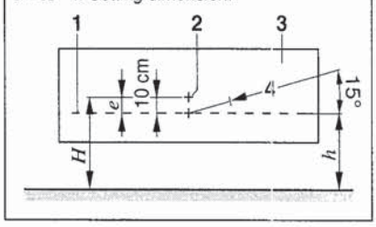
Vehicle type	Headlamp cm	Fog lamp cm
1 Motor vehicles on which the upper edge of the reflector surface is not more than 140 cm above the standing surface.		
1a Pass. cars (also station wagons/estates)	12	20
1b Vehicles with self-leveling suspension or automatic beam adjusters.[2]) 1c Multi-axle tractors and special-purpose machinery. 1d Single-track vehicles. 1e Trucks with forward loading area.	10	20
1f Trucks with rear loading area.[3]) 1g Semitrailer tractors.[3]) 1h Buses.[3])	30	40
2 Motor vehicles on which the upper edge of the reflector surface is not more than 140 cm above the standing surface.[4])	H/3	H/3)+7
3 Single-axle tractors or special-purpose machinery with permanently dimmed headlamps on which the required light beam center inclination is indicated.[5])	2 N	20
4 Vehicle with homologation in acc. with Directive 76/756/EEC or ECE R48	Reference dimension on vehicle	see above

[1]) The results obtained with the aid of headlamp aiming equipment must correspond to the figures in the table.
[2]) Special attention must be paid to compliance with the manufacturer's instructions.
[3]) Except motor vehicles as defined in 1b.
[4]) H Height of center of headlamp above support surface in cm.
[5]) N Specified figure for inclination of beam center at distance of 5 m.

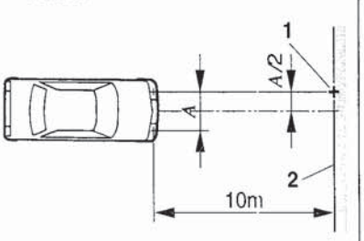
Adjustment information:
The adjustment marks and lines are arranged to accommodate main headlamps at a normal installation height, with the center mark set to height H, corresponding to the middle of the headlamp. The adjustment dimension e = 10 cm represents the vertical distance between the center mark and the boundary line.

On headlamps with e > 10 cm the boundary line is lowered to the required level. Obviously, the center mark will then no longer be level with the center of the headlamp. It can, however, be used to check the position of the high beam (where present).

Test surface for headlamp beam
1 Boundary line, 2 Center mark,
3 Test surface, 4 Break point.
H Height of headlamp center above standing surface in cm.
h Height of test-surface boundary line above standing surface in cm.
e = H – h Setting dimension.



Relative positions of test surface and vehicle's longitudinal axis
1 Center mark
2 Test surface
A Distance between headlamp centers.



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

Table 3. Geometric range of the horizontal component of the low beam's light/dark cutoff line. Headlamp installed at height of 65 cm

Inclination of light/dark cutoff line in % (1 % = 10 cm/10 m)	1 %	1.5 %	2 %	2.5 %	3 %
Reference dimension *e*	10 cm	15 cm	20 cm	25 cm	30 cm
Geometric range in m for the horizontal component of the light/dark cutoff line	65 m	43.3 m	32.5 m	26 m	21.7 m

The left-side (horizontal) section of the light/dark cutoff line must be adjusted to the limit line.
Refer to Table 2 for dimension *e*.
The headlamps must be readjusted following any operations that could affect their height (suspension work, etc.). The procedure is also recommended after bulb replacement.

If the high beam is incorporated in a single unit along with the asymmetrical low beam (Bilux and Duplo bulbs) then it will be aimed automatically when the low beam is adjusted.

Separate individual high-beam units are aimed horizontally and symmetrically using the center of the headlamp and the center mark as references.

Headlamp aiming devices

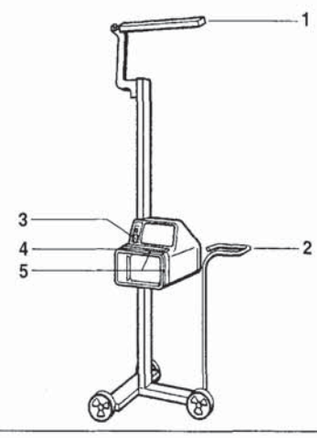
Function

Correct adjustment of motor-vehicle headlamps should ensure the best possible illumination of the roadway by the low beam while at the same time minimizing dazzle for oncoming traffic. For this purpose, the inclination of the headlamp beams with respect to a level base surface, and their direction to the vertical longitudinal center plane of the vehicle, must satisfy the official requirements.

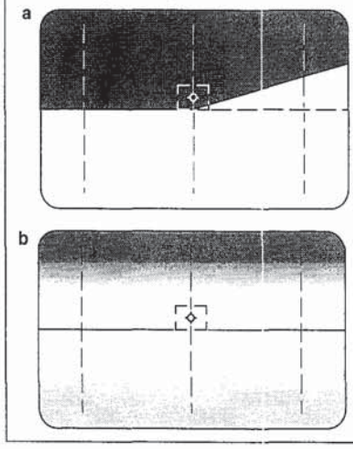
Equipment design

Headlamp aiming devices are portable imaging chambers which comprise a single lens and a collector screen located in the focal plane of the lens and rigidly connected to it. The collector screen has

Headlamp test and adjustment device
1 Orientation mirror, 2 Handle, 3 Photometer, 4 Refraction mirror, 5 Markings for center of lens.



Viewing window in aiming device
a) Boundary line for light/dark cutoff on asymmetrical low beam, b) Center mark for middle of high-beam pattern.



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

markings to facilitate correct headlamp adjustment, and can be viewed by the equipment operator using suitable appendages such as windows and adjustable refraction mirrors.

The prescribed headlamp adjustment, i.e. the inclination relative to the center line of the headlamp in cm at a fixed distance of 10 m, is set by turning a knob to move the collector screen.

The aiming device is aligned with the vehicle axis using a sighting device such as a mirror with an orientation line. It is turned and aligned so that so that the orientation line uniformly touches two external vehicle-reference marks. The imaging chamber can be moved vertically and clamped at the level of the vehicle headlamp.

Headlamp testing

The headlamp can be tested once the equipment has been correctly positioned at the front of the lens. An image of the light distribution pattern as emitted by the headlamp appears on the collector screen. Some test devices are also equipped with photodiodes and a display to allow measurement of luminous intensity.

On headlamps with asymmetrical low-beam patterns the light/dark cutoff line should contact the marked limits; the point of intersection for the horizontal and vertical components must lie on the center mark of the vertical line. Following adjustment of the low beam's light/dark cutoff line in accordance with the regulations, the center of the high beam (assuming that high and low beam are adjusted together) should be within the corner limits indicated around the center mark.

Main headlamps, North American regulations

Regulations and guidelines

Federal Motor Vehicle Safety Standard (FMVSS) No. 108 and SAE Ground Vehicle Lighting Standards Manual (Standards and Recommended Practices).

The regulations governing installation and control circuits for headlamps are comparable to those in Europe. Since 1. 5. 1997, headlamps with light/dark cutoffs have likewise been authorized in the USA.

The main differences were previously in the headlamp systems. Until 1983 the available sealed-beam types in the USA were restricted to the following dimensions:

Dual-headlamp systems:
- 178 mm diameter (round),
- 200 x 142 mm (rectangular).

Quad-headlamp systems:
- 146 mm diameter (round),
- 165 x 100 mm (rectangular).

Since 1983 a supplement to FMVSS 108, has made it possible to use RBH (Replaceable Bulb Headlamps) headlamp inserts of various shapes and sizes.

Headlamps conforming to ECE regulations or EEC directives are not approved for use on dual-track vehicles in the USA, even if they satisfy the American requirements relating to lighting and aimability (visual). They are however approved for use without restriction on motorcycles.

Conditions for aiming

In Europe, headlamps are always adjusted based on visual assessment of the light beam, but the use of mechanical aiming devices has become the most common method of aiming headlamps in the USA. The headlamp units are equipped with three pads on the lens – one for each of the three adjustment planes. A calibrating unit is placed against these pads. The calibration is carried out with spirit levels.

The VHAD (Vehicle Headlamp Aiming Device) method is employed to adjust the headlamps relative to a fixed reference axis defined by the vehicle. This procedure is carried out using a spirit level firmly attached to the headlamp. The three lens pads are no longer required.

Since mid-1997, however, visual (only vertical) aiming authorized as from 1. 5. 1997 has also gained increasing acceptance in the USA. There is no horizontal aiming here.

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

Headlight leveling control (vertical-aim control)

Table 3 indicates the geometrical ranges at various inclination angles for headlamps installed at a height of 65 cm. The inspection tolerance extends to include inclination angles of up to 2.5% (1.5% below standard setting). According to European Union regulations, the basic setting based on dimension *e* is (10...15 cm)/10 m with the weight of one person on the driver's seat. The specifications for this setting are provided by the vehicle manufacturer.

Since 1.1.1998, an automatic or manually-operated headlight leveling control (range adjustment) device has been mandatory in Germany for all vehicles registered for the first time, except in those cases where other equipment (e. g., hydraulic suspension control) ensures that the light beam's inclination will remain within the prescribed tolerances. Although this equipment is not mandatory in other countries, its use is permitted.

Automatic leveling
must be designed to compensate for load variations by lowering or raising the low beam's projection by between 5 cm/10 m (0.5%) and 25 cm/10 m (2.5%).

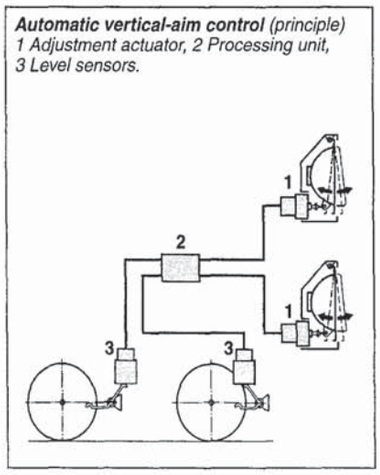
Manual leveling
This device is operated from the driver's seat and must incorporate a detent at the base setting; beam adjustment is also performed at this position. Units with infinitely variable and graduated control, must both feature visible markings in the vicinity of the hand switch which correspond to the vehicle load conditions necessitating vertical-aim adjustment. All design variations employ an adjustment mechanism to provide vertical adjustment of either the headlamp reflector (housing design) or the entire headlamp unit.

Manually operated units employ a switch at the driver's seat to control the setting, while automatic units rely on level sensors on the vehicle axles to monitor suspension compression and relay the corresponding signals to the adjustment actuators.

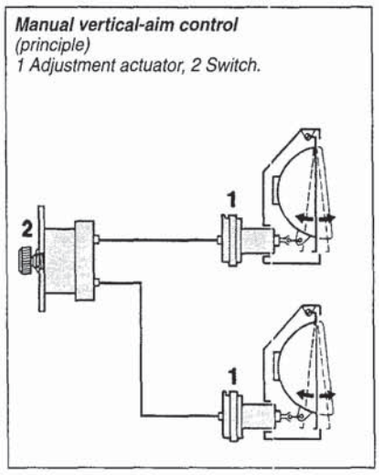
Hydromechanical systems
This type of system operates by transmitting a fluid through the connecting hoses between the manual switch (or level sensor) and the adjustment elements. The degree of adjustment corresponds to the quantity of pumped fluid.

Vacuum systems
The manual switch (or level sensor) in this type of system modulates vacuum from the intake manifold and transmits it to the adjustment actuators to achieve varying degrees of adjustment.

Electrical systems
These employ electric gear motors as ad-



Automatic vertical-aim control *(principle)*
1 Adjustment actuator, 2 Processing unit, 3 Level sensors.



Manual vertical-aim control *(principle)*
1 Adjustment actuator, 2 Switch.

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

justment actuators. These are switched either by the relevant switches in the vehicle or by axle sensors.

Headlamp cleaning systems

Headlamp cleaning systems remove dirt from the lenses of the main headlamps. This ensures unimpaired illumination of the roadway and prevents oncoming traffic from being dazzled. There are two types of cleaning system:

Wipe/wash system
The use of these systems is restricted to glass lenses because plastic lenses, despite having high scratch-resistant coatings, are too sensitive to mechanical cleaning.

High-pressure washer system
High-pressure washer systems (see Fig.) are gaining increasing acceptance as they can be used on both glass and plastic lenses. The cleaning effect is chiefly determined by the cleaning pulse of the water droplets. The decisive factors are:
- the distance between jet nozzle(s) and lens,
- the size, contact angle and contact velocity of the water droplets and
- the amount of water.

As well as fixed nozzle holders on the bumpers, telescopically extending nozzle holders are also used. The telescope significantly improves the cleaning effect because it always assumes an optimal spray position. Furthermore, when not in use, the nozzle holder can be concealed e.g. inside the bumper.

High-pressure washer systems consist of
- water reservoir, pump, hose and non-return valve and
- nozzle holder, which is extended by means of a telescope, with one or more jet nozzles.

Fog lamps

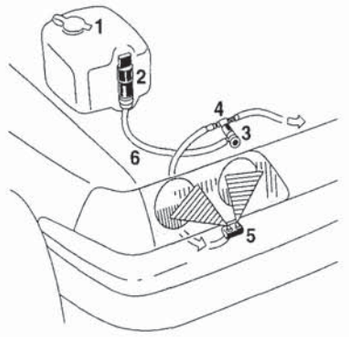
Fog lamps are intended to improve road-surface illumination in fog, snow, heavy rain and dust.

Optical concept

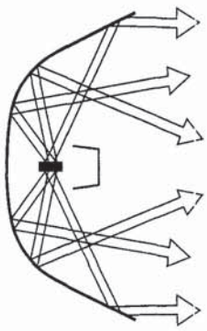
Paraboloid
A parabolic reflector featuring a light source located at the focal point reflects light along a parallel axis (as with the high-beam lamp) and the lens extends this beam to form a horizontal band. A special screen prevents the beam from being projected upward.

Free-form technology
New calculation methods (CAL Computer Aided Lighting) can be used to shape reflectors in such a way that they scatter

High-pressure washer system for headlamps
1 Water reservoir, 2 Pump, 3 Non-return valve, 4 T-connection, 5 Nozzle holder, 6 Hose.



Fog lamp with free-form reflector



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

light directly (i.e. without optical lens profiling) and simultaneously generate (without separate shading) a sharp light/dark cutoff line.

The fact that the lamp features pronounced envelopment of the bulb leads to an extremely high volume of light combined with maximum dispersion width.

PES fog lamps

In fog, this technology minimizes the glare reflected back to the driver. The screen, the image of which is projected onto the road surface by the lens, furnishes maximum contrast at the light/dark cutoff line.

Designs

DIY and dealer-installed fog lamps are designed as individual projection units in their own housings. These are installed either upright on the bumper, or suspended beneath it.

Stylistic and aerodynamic considerations have led to increased use of integrated fog lamps, designed either for installation within body openings or included as a component within a larger light assembly (with adjustable reflectors when the fog lamps are combined with the main headlamps).

Most fog lamps are designed to project a white beam. There is no substantive evidence that yellow lamps provide any physiological benefits. A fog lamp's effectiveness depends upon the size of the illuminated area and the focal length of the reflector. Assuming the same illuminated area and focal length, from the lighting-engineering viewpoint the differences between round and rectangular fog lamps are insignificant.

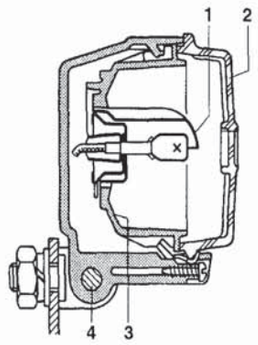
Regulations

Design is governed by ECE R19, installation by EEC 76/756, ECE R48, StVZO (FMVSS/CUR) § 52. Two white- or yellow-light fog lamps are permitted. The control circuit for switching the fog lamps must be independent of that used for high and low beams. The (German) StVZO allows fog-lamp installation in positions more than 400 mm from the widest point of the vehicle's periphery provided that the switching circuit is designed to ensure that they operate only in conjunction with the low beams. The adjustment procedures for fog lamps are basically the same as for headlamps. Adjustment dimensions *e* are provided in Table 2.

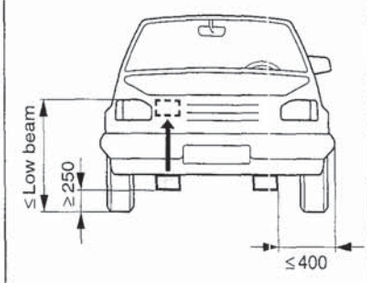
Auxiliary driving lamps

Auxiliary driving lamps enhance the high-beam visibility provided by dual, quad and six-headlamp systems. The basic optical principles are similar to those used for fog lamps. The only difference being the lens, which is specifically designed to furnish an extended beam. Auxiliary driving lamps are often identical to fog lamps in

Fog lamp *(parabolic reflector, upright installation)*
1 Mask, 2 Lens, 3 Reflector, 4 Vertical adjustment shaft.



Fog lamps *(positioning)*



Dimensions in mm

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

shape and size.

Auxiliary driving lamps are mounted and aimed in the same way as standard headlamps, and the underlying lighting concepts are the same. Auxiliary driving lamps are also subject to the cited regulations governing maximum luminous intensity in vehicular lighting systems, according to which the sum of all reference numbers is not to exceed 75. For older lamps without approval number, the number 10 is used for general assessment purposes.

Lights and lamps

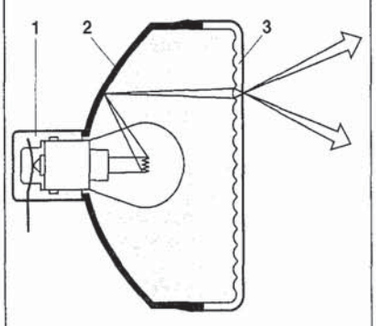
Design specifications are contained in ECE R6, R7 and R38, installation is governed by EEC 76/756, ECE R48 and StVZO § 49a (FMVSS/CUR).

These types of lamp are intended to facilitate recognition of the vehicle and to alert other road users to any intended or current changes in direction or motion. Either of two basic concepts can be employed to satisfy the corresponding technical requirements.

Lamps with reflector optics

A reflector in one of various forms (often parabolic) redirects the light emitted by the bulb to obtain a roughly axial projection angle. A lens with optical dispersion elements then determines the beam pattern.

Lamp with reflector optics *(principle)*
1 Housing, 2 Reflector,
3 Lens with dispersion elements.



Lamps with Fresnel optics

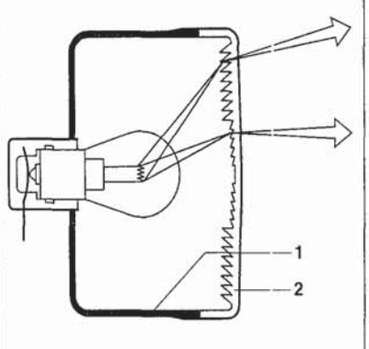
The light is projected directly against the lens, with no refraction at a reflector. A lens utilizing Fresnel technology then directs the beam in the desired direction.

Fresnel optics devices are usually less efficient than reflector-optics lamps.

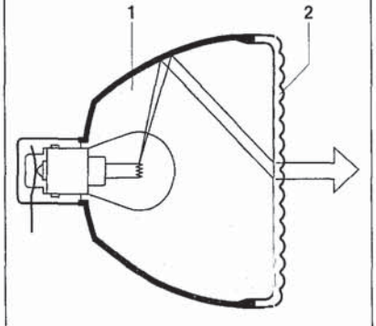
Lamps combining reflector and Fresnel optics

Designs combining both the above principles have been used with success. The GP reflector (rotated parabola) is employed to derive undiminished luminous flux from more compact units featuring

Lamp with Fresnel optics *(principle)*
1 Housing, 2 Lens with Fresnel optics.

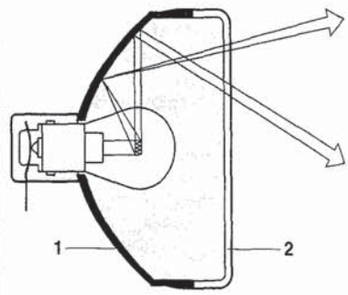


Reflector with rotated parabola
1 GP reflector, 2 Fresnel lens.

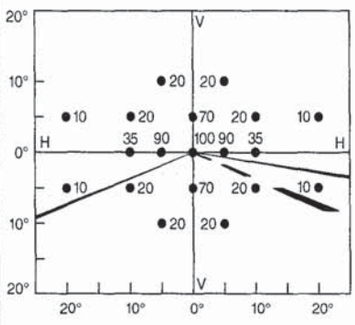


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

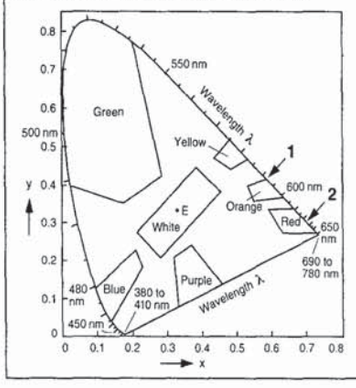
Free-form lamp with clear lens
1 Reflector, 2 Clear lens.



ECE measuring screen "lights and lamps" *(values in %)*



Standardized color scale *(color location)*
1, 2 Ranges for yellow/orange and red.



both shallower reflectors and smaller lenses. These designs employ a specially shaped reflector (rotated parabola) to capture the light beam emanating from the bulb at the largest possible peripheral angle. The Fresnel optics then homogenize the light beam for projection along the desired path. A free-form lamp with Fresnel cap combines excellent luminous efficiency with a variety of stylistic conversion options. The light from the lamp is deflected by the reflector. In the process, the required expansion of light distribution is generated completely or partially by the reflector. The outer lens can thus be designed as a clear lens or supplemented with cylindrical lenses in the horizontal or vertical direction. The Fresnel lens improves the luminous efficiency by deflecting in the desired direction a further part of the light which would not otherwise contribute to the function of the lamp. Both versions are mainly used in the front turn-signal lamps. Which version is actually used depends on the body shape and thus on the available structural space, on the stylistic requirements and on the luminous values required.

Illumination technology, luminous intensities

As projected along the reference axis, minimum and maximum luminous intensities for all lamps must remain within a range calculated to ensure signal recognition without, however, inducing annoying glare for other road users.

Luminous intensity levels to the sides, and above and below the reference axis, may be lower than along the axis itself. This deviation has been quantified on a percentual basis ("unified spatial light distribution").

Color filters

Depending on their application (e.g. stop, turn-signal, fog warning lamps), motor-vehicle lamps must display uniform, distinctive colors in the red or yellow color range. These colors are defined in specific ranges of a standardized color scale (color location). Since white light is composed of various colors, filters can be used to weaken or filter out completely the radiation of undesired spectral regions

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

(colors). The color-filter functions may be performed by either the tinted lenses of the lamp or a colored coating on the glass bulb of the lamp (e.g. yellow lamp in turn-signal lamps with clear lens).

Filter technology can also be used to adapt lamp lenses in such a way that when the lamp is switched off the color is matched to the vehicle's paintwork and nevertheless the existing homologation regulations are complied with when the lamp is on. In the EU region, color locations have been laid down which e.g. correspond to a wavelength of 592 nm for turn-signal lamps that are colored "Yellow/Orange" and to a wavelength of 625 nm for stop and tail lamps that are colored "Red" (see Fig.).

Turn-signal indicators

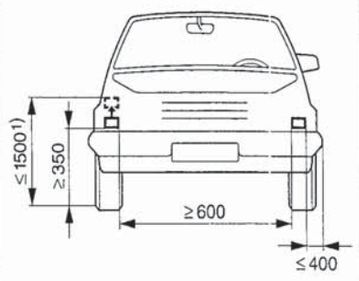
EEC 76/759, ECE R6, StVZO § 54 (FMVSS/CUR).
Group 1 (front-mounted), Group 2 (rear-mounted) and Group 5 (side) turn-signal lamps are required on dual-track vehicles. Group 2 turn-signal lamps are sufficient for motorcycles and mopeds. The instrument cluster indicator lamp may be in any desired color. The flash frequency is defined as 90 ± 30 cycles per minute.

Front turn-signal lamps
Two yellow turn-signal lamps are stipulated. An indicator is required inside the vehicle.

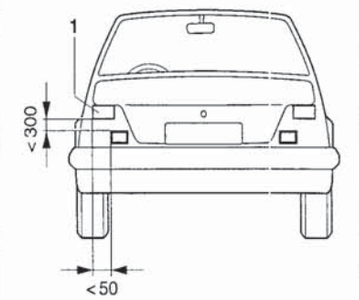
Rear turn-signal lamps
Two yellow turn-signal lamps are stipulated.

Side-mounted turn-signal lamps
Two yellow turn-signal lamps are stipulated.

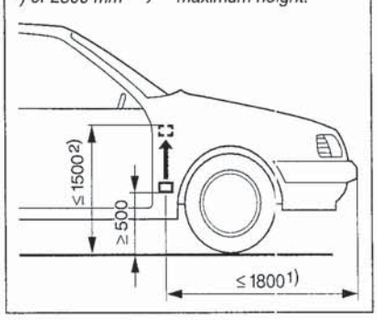
Front turn-signal lamps
(position, dimensions in mm)
[1]) less then 2100 mm if vehicle body type prohibits compliance with regulations on maximum height.



Rear turn-signal lamps
(position, dimensions in mm)
1 Tail lamp. Height and width as for front turn-signal lamps.



Side-mounted turn-signal lamps
(position, dimensions in mm)
[1]) or 2500 mm
[2]) or 2300 mm
if vehicle body type prohibits compliance with regulations on maximum height.



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

Hazard-warning and turn-signal devices

Regulations

Both the StVZO (FMVSS/CUR) and EU Directive EEC 76/756 stipulate that the standard lighting will be supplemented by visual signaling devices for indicating turns and for use as hazard-warning flashers on all vehicles with a top speed exceeding 25 km/h.

Flashing signals: Signals with a frequency of 60...120 pulses per minute and a relative illumination period of 30...80 %. Light must be emitted within 1.5 s of initial activation. Should one lamp fail, the remaining lamps must continue to generate visible light.

Turn-signal flashing: Synchronous signal generated by all turn-signal lamps on one side of the vehicle. The lamps are electrically monitored. Malfunctions are indicated.

Hazard-warning flashing: Synchronous flashing of all turn-signal lamps, also operational with the ignition off. An operation indicator is mandatory.

Hazard-warning and turn-signal devices for vehicles without trailer

The electronic hazard-warning and turn-signal flasher includes a pulse generator, designed to switch on the lamps via relay, and a current-controlled monitoring circuit to modify the flashing frequency in response to bulb failure. The turn-signal stalk controls the turn signals, while the hazard flashers are operated using a separate switch.

Hazard-warning and turn-signal devices for vehicles with/without trailers

This type of hazard-warning and turn-signal flasher differs from that employed on vehicles without trailers in the way that turn-signal operation is monitored.

Single-circuit monitoring

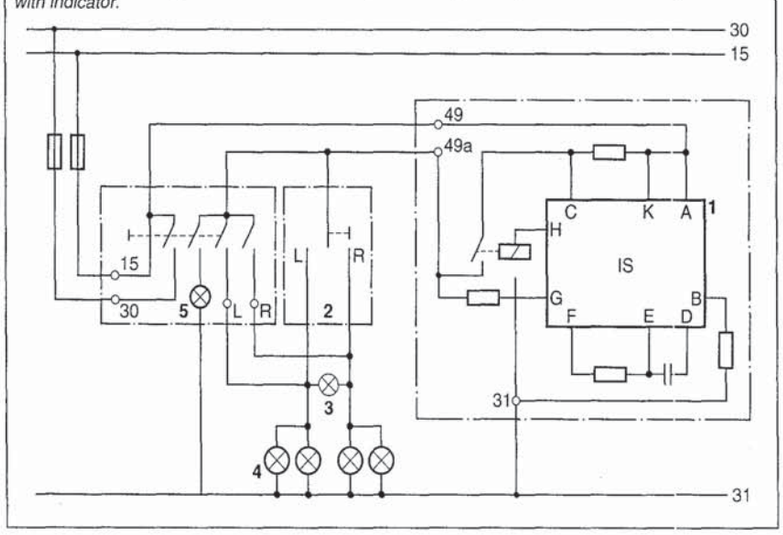
The tractor and trailer share a single monitoring circuit designed to activate the two indicator lamps at the flashing frequency. This type of unit cannot be used to localize lamp malfunctions. The flashing frequency remains constant.

Dual-circuit monitoring

Tractor and trailer are equipped with separate monitoring circuits. Localization of malfunction is by means of the indicator

Hazard-warning and turn-signal flasher for passenger cars

1 Hazard-warning and turn-signal flasher unit with integrated circuit (IS) or pulse generator G and control circuit H, 2 Signal stalk, 3 Indicator lamp, 4 Turn-signal lamps, 5 Hazard-warning switch with indicator.



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

lamp which fails to light up. The flashing frequency remains constant.

Side-marker, clearance and tail lamps

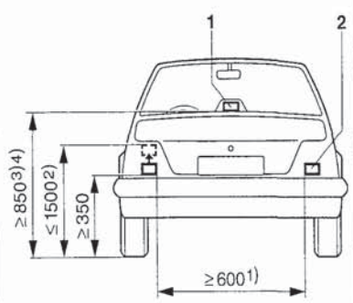
EEC 76/758, ECE R7, StVZO §§ 51 and 53 (FMVSS/CUR). Side-marker lamps (visible from the front) are stipulated on vehicles and trailers with a width exceeding 1600 mm. Tail lamps (at rear) are mandatory equipment on vehicles of all widths. Vehicles wider than 2100 mm (e.g., trucks) must also be equipped with clearance lamps visible from the front and rear.

Side-marker lamps
Two white-light marker lamps are stipulated.

Tail lamps
Two red tail lamps are mandatory equipment.

When the tail and stop lamps are joined in a nested assembly the luminous-intensity ratio for the individual functions must be at least 1:5. Tail lamps are to operate together with the side-marker lamps.

Stop lamps *(positions, dimensions in mm)*
1 Central high-mounted stop lamp (cat. S3),
2 Stop lamps (cat. S1/S2).
[1]) ≥ 400 mm (if width < 1300 mm),
[2]) ≤ 2100 mm (if compliance with max. height regulations not possible) or
[3]) ≤ 150 mm below lower edge of rear window,
[4]) however, the lower edge of the central high-mounted stop lamp must be higher than the upper edge of the (main) stop lamps.



Clearance lamps
Two white-light lamps to be visible from the front, and two red lamps from the rear. Position: As far outward and as high as possible.

Parking lamps

EEC 77/540, ECE R77, StVZO § 51 (FMVSS/CUR).
The vehicle may be equipped with either two parking lamps front and rear or one parking lamp on each side. White light is prescribed at the front and red at the rear. Yellow may also be used at the rear if the parking lamps have been designed as single units with the side turn-signal lamps.

The parking lamps must be designed to operate even when no other vehicle lights (headlamps) are on. The parking-lamp function is usually assumed by the tail and side-marker lamps.

License-plate lamps

EEC 76/760, ECE R4, StVZO § 60 (FMVSS/CUR).
The rear license-plate lamp(s) must be designed to ensure that the rear license plate remains legible up to a distance of at least 25 m by night. Approved are:

The minimum luminance at all points on the surface of the license plate is 2.5 cd/m². The luminance gradient of 2x B_{min}/cm should not be exceeded between any of the test points distributed across the surface of the test plate. B_{min} is defined as the smallest luminance measured at the test point.

Stop lamps

EEC 76/58, ECE R7, StVZO § 53 (FMVSS/CUR).
For each passenger car, two category S1 or S2 stop lamps and one category S3 stop lamp are prescribed as mandatory.

When a nested design with the stop and tail lamps is used, the luminous-intensity ratio between individual functions must be at least 5:1.

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

The category S3 stop lamp (central high-mounted stop lamp) must not be incorporated in a nested design with another lamp.

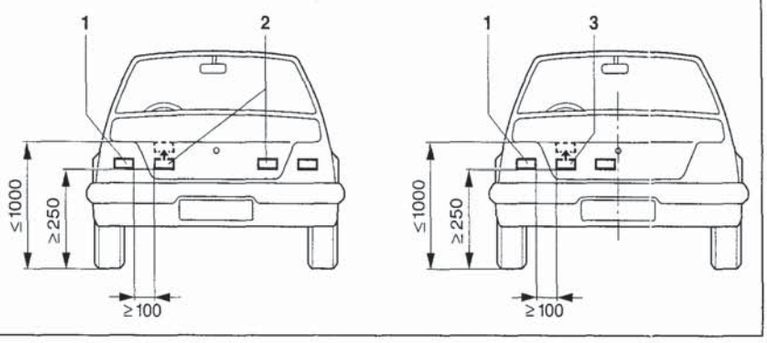
Fog warning lamps (rear fog lamps)

EEC 77/538, ECE R38, StVZO § 53d (FMVSS/CUR).
The European Union nations have mandated that one or two red-light fog warning lamps (rear fog lamps) will be installed on all new vehicles.

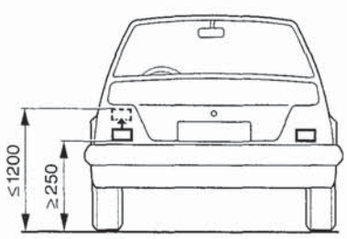
They must be distanced at least 100 mm from the stop lamp.

The visible illuminated area along the reference axis is not to exceed 140 cm². The electrical switching must be designed to ensure that the fog warning lamp operates only in conjunction with the low beam, high beam and/or front fog lamp. It must also be possible to switch off the fog warning lamps independently of the front fog lamps.

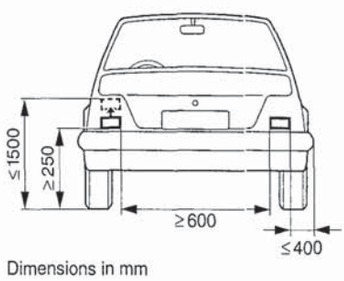
Fog warning lamps (rear fog lamps)
(position, dimensions in mm)
1 Stop lamp,
2 Fog warning lamps (2 units),
3 Fog warning lamp (1 unit).
Position for 1 unit shown for right-hand traffic.



Backup (reversing) lamps
(position, dimensions in mm)
Qty: 1 or 2.



Daytime running lamps
(position, dimensions in mm)



Dimensions in mm

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

Prescribed indicator lamp: Yellow (green also approved on vehicles initially registered prior to January 1981).

Backup (reversing) lamps

EEC 77/539, ECE R23, StVZO § 52 (FMVSS/CUR).
One or a maximum of two white-light lamps are approved.

The switching circuit must be designed to ensure that the backup lamps operate only with reverse gear engaged and the ignition on.

Daytime running lamps

ECE R87.
ECE R87 authorizes the installation of daytime running lamps in Europe. Their use or the use of low-beam headlamps to generate daytime running light is prescribed as mandatory in Denmark, Norway, Finland and Sweden. "Low beam on" during daytime hours is required by law in out-of-town areas in Poland and Hungary.

Other lighting devices

Identification lamps StVZO § 52 (FMVSS/CUR), ECE R65.
Identification lamps must be visible through 360 degrees from the vehicle, and should be perceived as flashing when viewed from any particular location. The flashing frequency *f* lies between 2 and 5 Hz. Blue identification lamps are intended for installation on official vehicles. Yellow identification lamps are designed to warn of dangers or dangerous transport.

Table 4. Specified minimum flash intensities for identification lamps

Measurement range		Flash intensity cd blue	yellow
Parallel to road surface		> 20	> 40
Within light beam Angle to road surface	± 4°	> 10	
	± 8°		> 30

Spot lamps
Spot lamps generate a narrow beam of light of high luminous intensity, making it possible to illuminate a small area from a substantial distance.

Floodlamps
On a moving vehicle, floodlamps may be switched on only when the vehicle's motion represents an integral part of the operation being performed, for instance, when tractors are used in agriculture and forestry, on self-propelled machinery, on rescue vehicles, etc.

Motor-vehicle bulbs

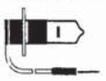
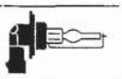
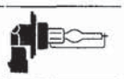
Bulbs for automotive lighting in accordance with ECE R37 are available in 6 V, 12 V and 24 V versions (see table on following pages). To help avoid mix-ups, different bulb types are identified by different base configurations. Bulbs of differing operating voltages are labeled with this voltage in order to avoid mix-ups in the case of identical configurations. The bulb type suitable in each case must be indicated on the equipment.

The luminous efficiency (lumens per watt) represents the bulb's photometric performance level relative to its power input. The luminous efficiency of vacuum bulbs is 10...18 lm/W. The higher luminous efficiency of halogen bulbs of roughly 22...26 lm/W is primarly a result of the increased filament temperature. D2S and D2R gaseous-discharge bulbs (Litronic) provide a luminous efficiency level in the order of 85 lm/W for substantial improvements in low-beam performance.

Replaceable bulbs must be homologated in accordance with ECE R37. Other light sources which do not conform to this regulation (LED, neon, light bulbs) can only be installed as a fixed component part of a lamp. In the event of repair work, the entire unit must be replaced.

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

Table 5. Specifications for motor-vehicle bulbs (2-wheeled vehicles not included)

Application	Category	Voltage rating V	Power rating W	Luminous flux Lumen	IEC Base type	Illustration
High beam/ Low beam	R2	6 12 24	45/40[1]) 45/40 55/50	600 min/ 400-550[1])	P 45 t-41	
Fog lamp, High, low beam in 4-HL systems	H1	6 12 24	55 55 70	1350[2]) 1550 1900	P14.5 e	
Fog lamp, High beam	H3	6 12 24	55 55 70	1050[2]) 1450 1750	PK 22s	
High beam/ Low beam	H4	12 24	60/55 75/70	1650/ 1000[1]), [2]) 1900/1200	P 43 t – 38	
High beam, Low beam in 4-HL systems, Fog lamp	H7	12	55	1500[2])	PX 26 d	
Fog lamp	H10	12	55	1250(?)	PY20d	
Low beam in 4-HL systems	HB4	12	55	1100	P 22 d	
High beam/ Low beam	HIR2	12	55	1875	PX22d	
High beam in 4-HL systems	HB3	12	60	1900	P 20 d	
High beam/ Low beam	HIR1	12	65	2500	PX20d	
Stop, flasher, rear fog, reversing lamp	P 21 W PY 21 W[6])	6 12 24	21	460[3])	BA 15 s	
Stop lamp	P 21/5 W PY 21 W[7])	6 12 24	21/5[4]) 21/5 21/5	440/35[3]), [4]) 440/35 440/40[3])	BAY 15d	
Side-marker lamp, tail lamp	R 5 W	6 12 24	5	50[3])	BA 15 s	

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

Table 5. Continued

Application	Category	Voltage rating V	Power rating W	Luminous flux Lumen	IEC Base type	Illustration
Tail lamp	R 10 W	6 12 24	10	125[3]	BA 15 s	
Stop, flasher, rear fog, reversing lamp	P 27 W	12	27	475[3]	W2.5x16d	
Stop lamp/ tail lamp	P 27/7 W	12	27/7	475/36[3]	W2.5x16q	
License-plate lamp, tail lamp	C 5 W	6 12 24	5	45[3]	SV 8.5	
Reversing lamp	C 21 W	12	21	460[3]	SV 8.5	
Side-marker lamp	T 4 W	6 12 24	4	35[3]	BA 9 s	
Side-marker lamp, License-plate lamp	W 5 W	6 12 24	5	50[3]	W 2.1 x 9.5 d	
Side-marker lamp, License-plate lamp	W 3 W	6 12 24	3	22[3]	W 2.1 x 9.5 d	
Low beam in 4-HL systems	D1S	85 12[5]	35	3200 approx. 40[5]	PK 32 d-2	
Low beam in 4-HL systems	D2S	85 12[5]	35	3200 approx. 40[5]	P 32 d-2	
Low beam in 4-HL systems	D2R	85 12[5]	35	2800 approx. 40[5]	P 32 d-3	

[1]) High/low beam. [2]) Specifications at test voltage of 6.3; 13.2 or 28.0 V.
[3]) Specifications at test voltage of 6.75; 13.5 or 28.0 V
[4]) Main/secondary filament. [5]) With ballast unit. [6]) Yellow-light version.

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

Acoustic signaling devices

Regulations

The internationally applicable ECE Regulation No. 28 specifies that the acoustic signals produced by motor vehicles will maintain a uniform sound quality with no perceptible frequency fluctuations during operation. The use of sirens, bells and the like is not permitted, as well as the playing of melodies by means of sound generators operating in a given sequence.

Installation

Elastic couplings must be used to decouple electric horns from the vehicle's body, as the horn would otherwise induce sympathetic oscillations in the adjacent bodywork. The resulting feedback would diminish both volume and tone quality. Both electric and electropneumatic horns are sensitive to resistance in their control circuits. When horns are installed in pairs, they should be triggered by relays.

Horns

Standard horns

The mass of the armature together with the flexible diaphragm forms an oscillating system within the horn. When voltage is applied to the contacts controlling the solenoid coil, the armature impacts against the magnetic core at the horn's fundamental frequency. A fixed tone disk, directly attached to the armature, responds to these intense periodic impacts by radiating harmonic waves. Legal regulations stipulate that the maximum sound energy must lie within a band of 1.8...3.55 kHz. This frequency explains the horn's relatively piercing note. This sound, which is essentially emitted along the horn's axis and out toward the front, can be heard above the background noise in traffic, even over longer distances.

The horn's size is one of the factors which determine the fundamental frequency and volume.

Supertone horns

As well as increased diameters, supertone horns have a higher electrical power input. Their warning signals can therefore still be heard under extreme conditions (truck driver's cab with high noise levels).

Fanfare horns

The electropneumatic fanfare horn employs the same basic actuating system as its standard counterpart, the salient difference being that the armature is allowed to vibrate freely in front of the coil with no impact occurring. The oscillating diaphragm induces vibration of an air column within a tube. The resonant frequency of the diaphragm and the air column are tuned to one another and they determine the pitch of the signal. The tube is in the shape of a funnel, with a wide opening to enhance the efficiency of sound propagation. The funnel tube is generally coiled to minimize the unit's size.

The presence of upper harmonics in the lower range of the frequency spectrum endows the fanfare horn with a rich, melodious sound. The tone is less penetrating than that of a standard horn due to the more consistent distribution of sound energy over a wide spectrum.

Selecting the correct horn

The warning produced by the impact horn is more conspicuous; it thus represents the better choice for vehicles which are frequently used for long hauls on roads with a large amount of truck traffic. Alternatively, the fanfare horn is superior for urban driving, as pedestrians often find the standard horn excessively loud and unpleasant. Both sets of requirements can be fulfilled by installing the two horn types together in a single system with a selection switch for urban or rural traffic. Standard and fanfare horns both operate at standardized frequencies. High and low tones can be combined to produce a harmonious dual-tone sound.

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

Theft-deterrent systems

Regulations

Theft-deterrent systems (car alarms) installed in motor vehicles must conform to the regulations defined in Paragraph 38 b of the StVZO Road Licensing Regulations (FMVSS/CUR) as well as ECE Directive R18. A primed alarm system responds to attempts at unauthorized vehicle entry by emitting warning signals.

Approved warning signals

- Intermittent audible signals of max. 30 s in length emitted by either the vehicle's own horn or an auxiliary unit.
- Flashing signals of max. 5 min in length using the hazard warning flashers (StVZO), or 30 s flashing of the low beams (ECE).

If the vehicle is repeatedly tampered with, the system may only produce a further acoustic alarm once the previous alarm has expired. The driver or authorized person must be able to deprime the alarm immediately. It must be impossible for alarm units to become active when the engine is running. The alarm is not to be triggered by vehicle movements (such as tremors etc.) not caused by attempted unauthorized entry.

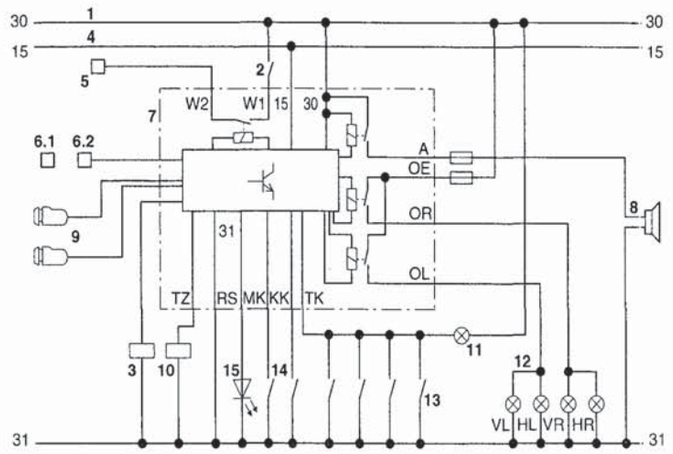
Automotive alarm systems

Basic system

The schematic diagram below is of an actual unit available on the market. The central ECU evaluates the signals at its input terminals, activates the system and switches on the warning signals (horn and visual signals) via its outputs.

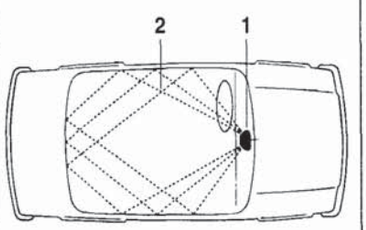
The system is primed and deprimed with an infrared or radio remote-control unit which uses individual codes. This secures the vehicle against unauthorized

Theft-deterrent system (car alarm)
1 Battery, 2 Driving switch, 3 Radio, 4 Ignition, 5 Starting motor, 6 Remote control system (6.1 Transmitter, 6.2 Receiver), 7 Alarm system ECU, 8 Alarm horn, 9 Ultrasonic passenger-compartment protection, 10 Tilt alarm, 11 Interior lighting, 12 Direction indicator, 13 Door contact switch, 14 Contact switches for hood and trunk, 15 Status display.



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

Ultrasonic protection for passenger compartment
1 Ultrasonic detector, 2 Ultrasonic field.



use. The ignition must be off (i.e. engine off) before the system can be primed.

The input terminals TK, MK, KK serve as connections for the door and hood switches. Opening one of these will immediately trigger the alarm. This will also occur when the radio-monitoring loop is open-circuited or the ignition is turned on with the alarm primed. Output Z activates the external ancillaries which trigger the alarm via input TZ.

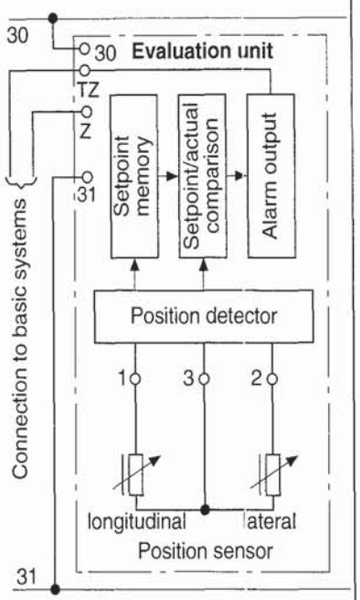
All of the mutually independent inputs are able to trigger consecutive alarms. The starter-motor disable facility prevents unauthorized starting of the engine.

An LED at output RS blinks when the unit is primed and in doing so signals the unit's operating status (primed/deprimed).

Ultrasonic passenger-compartment protection
Such installations generate an ultrasonic field inside the vehicle. An ultrasonic detector registers motion or pressure variations that cause the field to fluctuate. Such variations occur, for instance, when a hand reaches into the vehicle or when a window is broken). The electronic evaluation unit responds with an immediate alarm. The response threshold can be adjusted to optimize the system's protective efficiency.

The following principles are applied for the evaluation of the ultrasonic field: The amplitude method, the pulse-echo method, or a method based on the Doppler effect.

Electronic wheel and tow-away protection



Optional extras

Electronic wheel and tow-away protection
This unit consists of a position sensor and evaluation electronics. Upon priming the alarm unit the inclination or tilt angle at which the vehicle has been parked (on a level surface or on a hill) is stored as the zero reference angle. An alarm is triggered when either the rate of variation in the angle or the angle itself exceeds the programmed limits. Normal changes in the vehicle's position (for instance due to air loss in the tires, deliberate rocking of the vehicle, or settling in soft ground) are recognized as such by the electronics, and do not trigger an alarm.

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

Vehicle immobilizers

In addition to the ignition and steering-wheel lock, electronic vehicle immobilizers are employed to protect the vehicle against unauthorized use.

After switching off the ignition, and at the latest when locking the doors after leaving the vehicle, the vehicle immobilizer is automatically activated and puts one or more of those major units out of action which are essential to vehicle operation. Systems incorporating interrupter circuits use a relay to immobilize the units. Normally, the following three major circuits are interrupted:

- Starter motor,
- Fuel supply,
- Ignition or diesel fuel-injection pump.

In the case of units featuring coded access, one or more units are blocked or switched into circuit again by entering a code.

The following systems are used for deactivating the immobilizer:

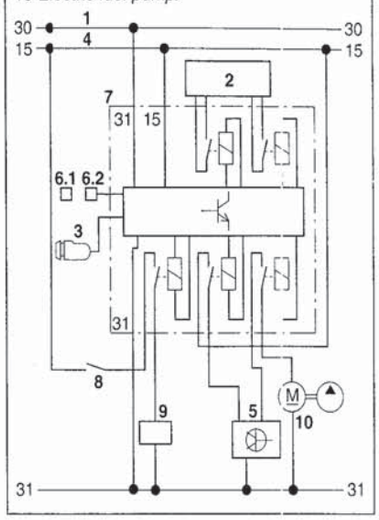
Radio/infrared system
By means of a hand-held transmitter, a coded signal is sent to the immobilizer. The fact that the central-locking system can also be operated with this system represents a further increase in operative comfort for the driver.

Transponder systems
The key is fitted with a transponder which from a short distance transmits a coded signal to a receiver coil (wound around the ignition lock for instance). The system deactivates the immobilizer as soon as the transponder enters the coil's receive area.

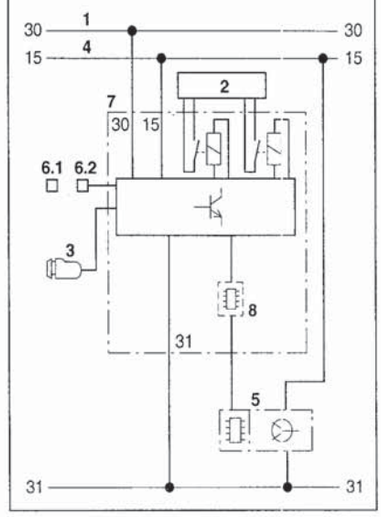
Electronic key
The immobilizer is deactivated when conductive coupling takes place between the electronic key and the immobilizer system.

Code keypad
The secret code number to deactivate the system is entered using a keypad.

System with interrupter circuits
1 Battery, 2 Central locking system, 3 Display unit, 4 Ignition, 5 Engine ECU, 6 Remote-control system (6.1 Transmitter, 6.2 Receiver), 7 Immobilizer ECU, 8 Starting switch, 9 Starting motor, 10 Electric fuel pump.



System with coded access
1 Battery, 2 Central locking system, 3 Display unit, 4 Ignition, 5 Engine ECU, 6 Remote-control system (6.1 Transmitter, 6.2 Receiver), 7 Immobilizer ECU, 8 Code unit.



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

Windshield and rear-window cleaning

Systems for cleaning the vehicle's windshield, headlamps, and rear window are needed in order to comply with legal stipulations for good visibility at all times. Such systems can be subdivided as follows:
- Windshield wiper systems,
- Rear-window wiper systems,
- Headlamp wiper systems
- Headlamp washer systems
- Combination wiper-washer (wipe/wash) systems.

Windshield wiper systems

The following are the most important windshield-cleaning systems, using the passenger car as an example. These systems are based on the legally prescribed areas of vision (Europe, USA and Australia). The wiped areas may be changed by additional controls acting on the wiper blades (parallelogram, general four-bar mechanism).

The windshield wiper system must meet the following requirements:
- Removal of water and snow,
- Removal of dirt (mineral, organic or biological),
- Operation at high temperature (+ 80 °C) and low temperature (– 30 °C),
- Corrosion resistance against acids, alkalis, salts (240 h), ozone (72 h),
- Service life: passenger cars $1.5 \cdot 10^6$ wipe cycles, commercial vehicles $3 \cdot 10^6$ wipe cycles,
- Stall test.

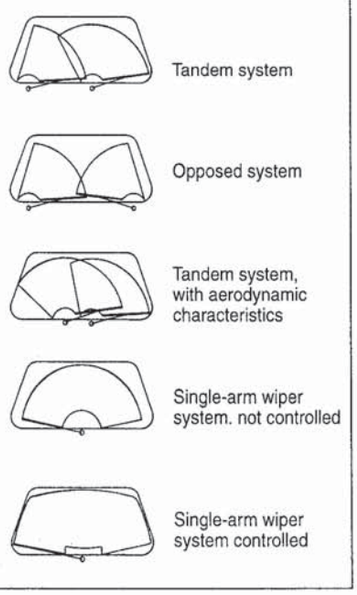
Mechanical wiper mechanism

Series- or parallel-coupled four-bar mechanisms are used, with transversely jointed linkage or additional controlled four-bar linkages also being used for large wipe angles or difficult mechanical transmission configurations.

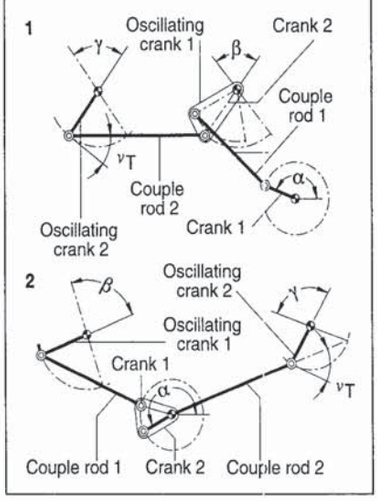
Optimization of the mechanism is important. Smooth operation can be achieved by matching the maximum values of angular acceleration and/or the force-transmission angles near to the wiper reversal points.

The trend is no longer to allow the crank to rotate fully but to allow it to complete

Windshield cleaning systems



Principle of the mechanical wiper mechanism
1 Series-coupled, 2 Parallel-coupled, α Crank angle. β, γ Wipe angle, ν_T Tangential force-transmission angle



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

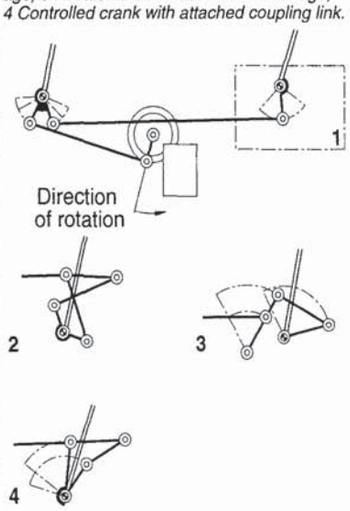
only (barely) a half rotation. This significantly reduces the space needed by the linkage for movement. For this purpose, the drive motor is electronically controlled and its direction of rotation reversed in line with the wiping motion.

It is thus also possible with only minor additional expenditure to achieve an "extended parking position", "protection against snow overload" and, despite varying operating conditions, a relatively constant wiped area.

If problems are experienced in locating the linkage, the above-mentioned technology permits a large linkage to be replaced by 2 significantly smaller units, each with its own (smaller) drive motor.

A second step towards optimization of the wiper mechanism involves the working position of the wiper-blade lip relative to the surface of the windshield or rear-window. By positioning the wiper bearings at the proper angle to the windshield, and by applying additional torsion to the wiper arms, the position of the wiper blades is defined so that at their reversal points they are inclined laterally towards the wiped-area bisector, thus assisting the wiper-blade elements to swivel into their new working position when reversal takes place.

***Tandem wiper system** (series-coupled)*
Right-hand part of wiper mechanism designed as:
1 Oscillating crank, 2 Transversely jointed linkage, 3 Additional controlled four-bar linkage, 4 Controlled crank with attached coupling link.



Wiper blades

Wiper blades are used in lengths of 260...1000 mm. Their dimensions for mounting (e. g., slide-in or hook mounting) are standardized. Minimum-wear operation is achieved by eliminating play in their mountings and joints. The tops of the center brackets are perforated to prevent blade lift-off at high speeds. In special cases aerodynamic deflectors are integrated in the wiper arms or blades to press the blades against the windshield.

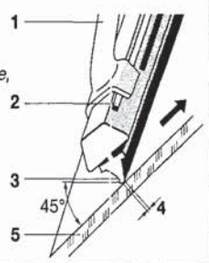
Rubber wiper-blade elements

The most important component of a wiper system is the rubber element. It is loaded by the claws of the bracket system, and supported by spring strips. Its double microedge is pressed against the windshield, and at its point of contact has a width of only 0.01...0.015 mm. When moving across the windshield, the wiper-blade element must overcome coefficients of dry friction of 0.8...2.5 (depending upon air humidity), and coefficients of wet friction of 0.6...0.1 (depending upon frictional velocity). The correct combination of wiper-element profile and rubber properties must be chosen so that the wiper lip can wipe the complete wiped area of the windshield surface at an angle of approx. 45°.

Rear-window cleaning systems

These systems perform similar to windshield-cleaning systems. However, service life is limited to $0.5 \cdot 10^6$ wipe cycles.

Rubber wiper-blade element in working position
1 Claw bracket,
2 Spring strip,
3 Lip,
4 Double microedge,
5 Windshield.



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

In right-hand traffic vehicles, the wiped area is preferred with parking position on the right-hand side (as viewed in the direction of travel). The 180° system is used when rear-window dimensions permit.

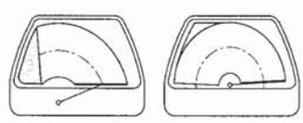
Headlamp cleaning systems

Two systems have been adopted for cleaning headlamps: the wipe/wash system and the wash-only system (P. 773). For the wipe/wash system a wiper arm is driven directly by a motor with a step-down gear unit; the water required to clean the headlamps is taken from the windshield-washer reservoir.

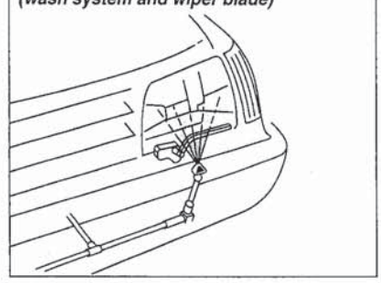
The advantages of the headlamp-wash system lie in its simplicity and often in its easier adaptation to the vehicle styling concept. It is important that the nozzles are positioned correctly so that water jets properly cover the headlamps at all driving speeds.

The law requires that a dirty headlamp whose luminosity has been reduced to 20% must regain 80% luminosity within a period of 8 seconds. The system must be able to complete at least 50 cycles on one charge of cleaning fluid.

Rear-window wiped areas
The shaded areas (here, LHD vehicle) represent impaired visibility with regard to vehicles which are overtaking.



Location of headlamp cleaning nozzle (wash system and wiper blade)



Wiper motors

Permanent-magnet DC motors are used as wiper motors. For normal use in windshield-wiper systems, they incorporate a worm-gear unit, but when used in rear-window and headlamp cleaning systems, they often incorporate an additional gear unit for translating rotary motion into oscillating motion (four-bar linkage, rack-and-pinion mechanism or crank-wheel mechanism).

The output of wiper motors for windshield and window cleaning systems is rated differently from that of common electric drives. Legal regulations and application requirements usually specify that the operating speed of the first wipe frequency be n_{B1} = 45 min^{-1} and for the second wipe frequency n_{B2} = 65 min^{-1}. Taking the maximum friction between rubber element and window, this results in a torque for each wiper arm which the wiper motor must produce at a minimum speed of n_A = 5 min^{-1}. The starting torque M_{An} in Nm for operation of one wiper arm is calculated as follows:

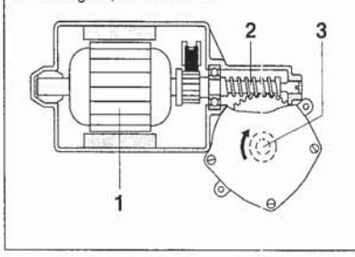
$$M_{An} = F_{WFN} \cdot \mu_{max} \cdot f_S \cdot f_T \cdot L_A \cdot (\omega_{H\,max}/\omega_{Mot}) \cdot (1/\eta_{Getr.}) \cdot (R_{Aw}/R_{Ak})$$

F_{WFN} Downward nominal load of wiper arm in N (arm movement on windshield or rear window, approx. 15 N per m wiper-blade length),

μ_{max} Max. coefficient of dry friction of rubber element (2.5 at φ = 93% relative air humidity),

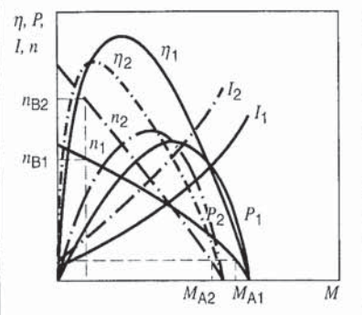
f_S Multiplier to account for joint fric-

Wiper motor with worm gear
1 Permanent-magnet DC motor, 2 Worm gear, 3 Shaft end.

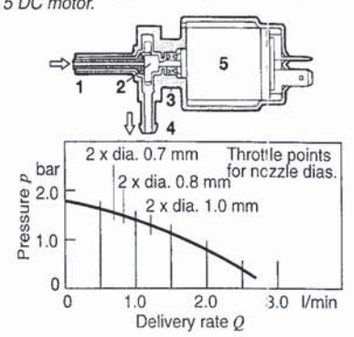


PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Characteristic curve of a wiper motor
n Speed, I Current, P Power output, η Efficiency, M Torque. The subscripts refer to wiper speeds 1 and 2.



Electric washing-system pump with characteristic curve
1 Inlet connection with inlet fitting, 2 Impeller, 3 Pump housing, 4 Delivery connection, 5 DC motor.



tion of wiper arm (usually 1.15),

f_T Tolerance factor to account for wiper-arm load tolerance (usually 1.12),

L_A Wiper-arm length in m,

ω_{Hmax} Max. angular velocity of the wiper arm,

ω_{Mot} Mean angular velocity of the wiper-motor crank,

$\omega_{H\,max}/\omega_{Mot} \approx 0.15 \cdot (0.01 \cdot \omega_W)^2 + \sin(\omega_W/2)$

ω_W = Wiper angle β or γ

η_{Getr} Efficiency of gear unit, usually assumed to be 0.8; must be measured separately when using special mechanism components (e.g. transversely jointed linkage, additional controlled four-bar linkage, multiple O-ring seals),

R_{Aw} Electrical resistance of armature winding heated by nominal operation,

R_{Ak} Electrical resistance of cold armature winding.

(R_{Aw}/R_{Ak}) usually 1.25

The motor's short-circuit strength is another important factor in its design. This is defined as the length of time during which the stalled motor must withstand the full test voltage without short-circuiting its windings (usually specified as t_K = 15 min).

Together, the frictional load and the gear ratio result in an operating torque on wet glass which is 0...20 % of the tightening torque. In the case of very large wiper systems operating on nearly vertical windshields (e.g. on buses), the torque of the wiper arm resulting from its own weight must also be taken into consideration (separately calculated allowance).

In the case of drive motors with pendular mechanisms (rear window and headlamp cleaning systems), the required torque is determined at the oscillating shaft.

It is calculated as:

$$M_H = F_{WFN} \cdot \mu_{max} \cdot f_S \cdot f_T \cdot L_A \cdot (R_{Aw}/R_{Ak})$$

Washing systems

To ensure good visibility in the wiped areas, it is imperative that the wiper system is backed by a washing system. Electrical centrifugal pumps of simple design are used (characteristic pump curve) to pump the water through 2 to 4 nozzles and onto the windshield in a narrow spray pattern. The water, to which a cleaning additive is added, is contained in a reservoir of 1.5...2 l capacity. If the same water is used also to clean the headlamps, a larger volume of up to 7 l is necessary. A separate reservoir can be provided for the rear-window cleaning system. The washing system is often coupled to the corresponding wiper system by means of an electronic control so that water is sprayed onto the window or windshield while a pushbutton is pressed, with the wiper system continuing to operate for several additional cycles after the pushbutton is released.

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

Automotive windshield and window glass

Silica glass is used for automotive windshields and windows. Approximate composition:
72 % SiO_2 as vitrifier
14 % Na_2O as flux
10 % CaO } as stabilizer
4 % MgO }

Windows are made of flat glass which is poured using the float-glass process. Fusion occurs at a temperature of 1550 °C; the melt then passes through a refining zone of 1500 °C to 1100 °C before being poured onto the so-called float bath (liquid tin) and cooled to a temperature of 600 °C. It is at this stage that the two plane-parallel surfaces of exceptionally high quality are produced (tin-bath surface below, fire-finished surface above). After passing through a cooling zone, the glass is then cut to pieces of 6.10 m × 3.35 m.

The glass can now be further processed in one of two ways:
- as single-pane toughened safety glass (TSG)
  or
- as laminated safety glass (LSG), which is primarily used for windshields.

TSG windows differ from LSG windows in that they exhibit higher mechanical and thermal strength as well as different breakage and shattering behavior. TSG panes pass through a toughening process which greatly prestresses the surface of the glass. In case of breakage, these windows break into many small dull-edged pieces.

The LSG window, on the other hand, exhibits a normal shattering pattern. When an LSG window is cracked, it is

Material properties and physical data of automotive glass (finished windshields and windows)

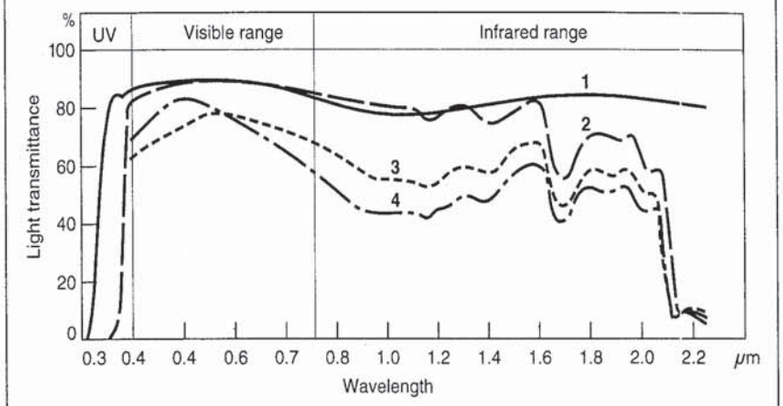
Property	Dimension	TSG	LSG
Density	kg/m³	2500	2500
Surface hardness	Mohs	5...6	5...6
Compressive strength	MN/m²	700...900	700...900
Modulus of elasticity	MN/m²	68 000	70 000
Bending strength			
before prestressing	MN/m²	30[2])	30[1])
after prestressing	MN/m²	50[2])	
Impact-ball strength (DIN 52 306)	Nm	> 7	> 90[1])
(at room temperature)		(227 g ball)	(2.26 kg ball)
Arrow-drop strength			> 18[1])
DIN 52 307 (at room temperature)			
Specific heat	kJ/kgK	0.75...0.84	0.75...0.84
Coefficient of thermal conductivity	W/mK	0.70...0.87	0.70...0.87
Coefficient of thermal expansion	m/mK	$9.0 \cdot 10^{-6}$	$9.0 \cdot 10^{-6}$
Dielectric constant		7...8	7...8
Light transmittance (DIN 52 306), clear	%	≈ 90	≈ 90[1])
Index of refraction		1.52	1.52[1])
Deviation angle of wedging	Angle	< 1.0 flat	≤ 1.0 flat[1])
	minute	< 1.5 bent	≤ 1.5 bent[1])
Dioptric faults (DIN 52 305)	Dptr.	< 0.03	≤ 0.03[1])
Temperature resistance	°C	200	90[1]) (max. 30')
Resistance to temperature shocks	K	200	

[1]) Properties of finished laminated safety glass (LSG). In calculating the permissible bending stress, the coupling effect of the PVB film is to be disregarded.

[2]) Calculated values; these values already contain the necessary safety margins.

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

Light transmittance of automotive windshield and glass
1 Float glass and TSG windows, thickness: 4 mm,
Tinted LSG windows of different colors, total thickness: 5.5 mm,
2 Clear, 3 Bronze-colored, 4 Green



easier to see through than a TSG window. Laminated glass is made of two panes of glass bonded to each other by means of an intermediate film of plastic (polyvinyl butyral).

The formation of many small, blunt fragments of glass which are held in position by the plastic film reduces the danger of injury. In the case of the Sekuriflex window (a refinement of the LSG window), an additional plastic film with excellent optical and mechanical properties (e.g., abrasive and scratch resistance) is applied to the inside surface of the window.

Green or bronze-colored windows are used for heat absorption because they block the transmission of infrared light more strongly than light of shorter wave lengths. On the other hand, light transmission in the visual spectrum is reduced from 90% to 80%.

Optical properties

The optical properties of TSG and LSG windows are roughly the same, because the optical properties of the PVB film are very closely aligned to those of glass.

Heatable safety glass

In the case of heatable safety glass (TSG), heating conductors are applied to the window (not yet prestressed) using the silk screen process, and are sintered in place during the prestressing process. Subsequent galvanization increases the strength of the heating conductors, tempers them and protects them against environmental influences. Window areas treated in this way can be kept free of mist by heating, and even of ice if the heating power is high enough.

Heated window areas must never be cleaned using caustic or scouring cleansers (e.g. chlorine, ammonia, sand or acids).

In the case of LSG windows, very thin, nearly invisible heating wires are applied in wavy lines to the plastic adhesive film. They are connected in series and/or parallel in order to achieve the intended electrical resistance. The thin wires provide even better heating coverage. The heating power of passenger-car rear window heating systems is approximately 3...5 W/dm^2.

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

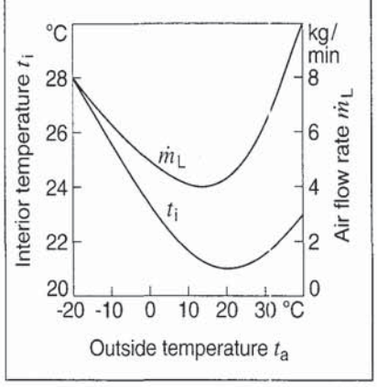
Passenger-compartment heating, ventilation and air conditioning (HVAC)

Function

The vehicle's climate-control system provides for the following:

- a comfortable climate for all passengers,
- an environment calculated to minimize driver stress and fatigue,
- more recent units use filters to remove particulate matter (pollen, dust) and even odors from the air,
- good visibility through all windows, and windshield.

Comfortable interior temperature and air flow rate as a function of outside temperature



In many countries the performance of the heater unit is governed by legal requirements, with emphasis on the defroster's ability to maintain clear windows and windshields (such as EEC Directive 78/317 within the European Community, and MVSS 103 in the USA).

Systems deriving heat from the engine

On vehicles with liquid-cooled engines, the engine heat (by-product of the combustion process) contained in the coolant is used to warm the passenger compartment. With air-cooled engines, engine heat is taken from the exhaust or, in some cases, from the engine's lubrication circuit. The heater core consists of tubes and fins, and has the same basic design as the engine radiator. Coolant flows through the core's tubes while air flows through its fins. Two design concepts are available for regulating the heater's thermal output.

Coolant-side heater control

In these systems, the entire air flow is usually directed through the heater core while a valve controls the heating output by regulating the flow of coolant through the unit. Extreme precision is required from the valves, which must be capable of providing consistent, stable settings for accurate control at the minimal flow rates necessary for maintaining low heat levels (important between seasons). A disadvantage lies in the fact that the heating output varies according to the coolant's pressure and temperature, meaning that heater performance is affected by engine speed and load.

Air-side heater control

In this type of system the flow of coolant through the heater core is unrestricted. The heat is regulated by dividing the air flow before it reaches the core: A portion of the air flows through the core, while the rest is directed around it. The two currents are subsequently reunited in the plenum chamber. An air flap can be used to regulate the distribution of the two currents, thereby determining the amount of heat taken from the coolant. This type of control arrangement is less sensitive to fluctuations in engine load, and air-temperature adjustments take effect immediately. Water and/or air-side blocks prevent undesirable residual warmth from emerging from the hot core when the heater is not in operation.

One disadvantage of the air-side control layout lies in the larger installation volume required for housing the bypass duct and the plenum chamber.

The air-ventilation current is provided by a constant-speed or adjustable-speed electric blower, whereby aerodynamic

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

pressure can also become a significant factor as vehicle speed increases. The minimum hourly air-flow rate should be 30 m^3 per person (figure for reference purposes only). Factors such as passenger-compartment temperature, outside temperature, air flow and (to a certain degree) heat radiation, all affect the process of achieving a comfortable climate (see illustration). Because the precise data on these variables vary substantially from one vehicle to the next, actual figures must be derived empirically.

As motor vehicles have relatively small passenger compartments, drafts and sunlight entering through windshield and windows confront the heating, ventilation and air-conditioning (HVAC) systems with extreme challenges. In order to enhance passenger comfort, an attempt should be made to maintain the temperature in the footwell 4...8 °C above that of the air around the upper body.

Electronic heater control

Variations in outside-air temperature and vehicle speed cause fluctuations in the temperature of the passenger compartment. On standard systems, the heater controls must be constantly readjusted by hand in order to maintain an agreeable temperature. Electronic heater control dispenses with this requirement by maintaining the interior temperature at the desired level automatically.

On heater units featuring water-side regulation, sensors monitor the temperatures of the vehicle's interior and of the emerging air; the control unit processes this information and compares it with the preselected temperature. Meanwhile, a solenoid valve installed in the cooling circuit opens and closes at a given frequency in response to the signals which it receives from the control unit. The adjustments in open/close ratio in the cycle periods regulate the flow rate from the closed position up to the maximum. A servo-actuated adjustment flap is usually employed to provide infinitely-variable temperature regulation in air-side systems (pneumatic linear adjusters are also occasionally used). Sophisticated systems allowing separate adjustment for the left and right sides of the vehicle are also available.

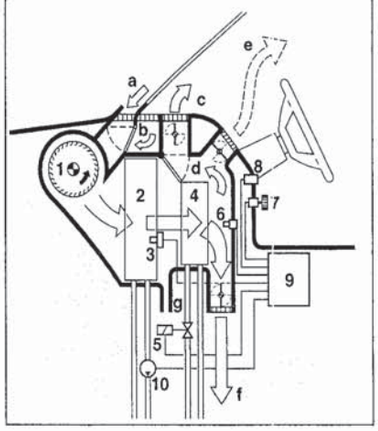
Air conditioners

The heater unit alone is not capable of providing a comfortable environment at all times. When the outside temperature climbs beyond 20 °C, the air must be cooled to achieve the required interior temperatures. Here, compressor-driven refrigeration units with R 134a refrigerant are in use (until 1992, R12 refrigerant).

The engine-driven compressor compresses the vaporous refrigerant, which heats up in the process and is then directed to the condenser where it cools and liquefies. The energy supplied in the compressor and the heat absorbed in the evaporator are dissipated to the environment here.

An expansion valve sprays the cooled liquid into the evaporator where the evaporation process extracts the required evaporation heat from the incoming stream of fresh air, thereby cooling the air.

Air conditioner with electronic water-side control (schematic)
1 Blower, 2 Evaporator, 3 Evaporator temperature sensor, 4 Heater core, 5 Solenoid valve, 6 Air exit-temperature sensor, 7 Setpoint control, 8 Interior sensor (ventilated), 9 Control unit, 10 Compressor; a) Fresh air, b) Recirculated air, c) Defrost, d) AC bypass, e) Ventilation, f) Footwell, g) Condensation drain.



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

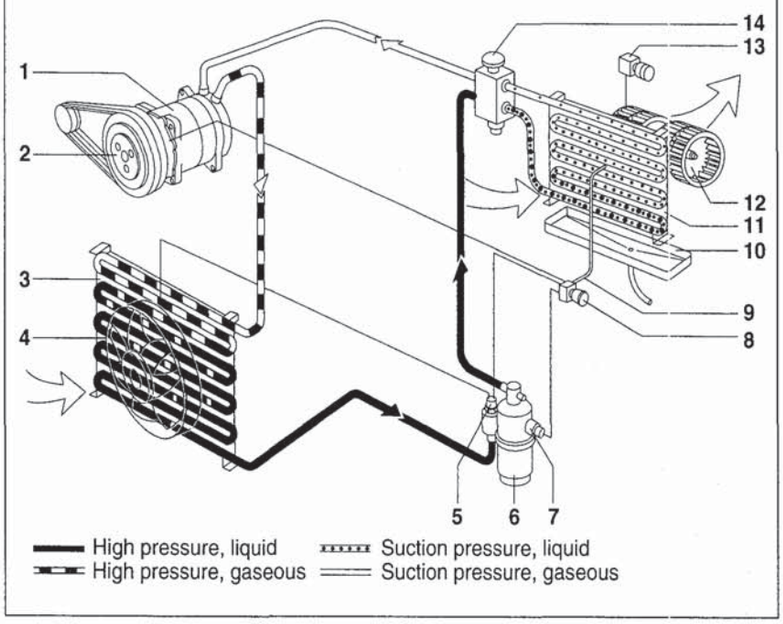
Moisture is extracted from the cooled air as condensation, and the air's humidity is reduced to the desired level. Evaporators and condensers are generally designed as tube-and-fin heat exchangers. The evaporator is located before the heater core in the fresh-air stream and cools the air to approx. 3...5 °C. The dehumidified air is reheated in the heater core to the desired temperature.

Automatic climate control

Automatic climate control is particularly useful for vehicles in which both air conditioner and heater are installed, because the constant monitoring and adjustment required to maintain a temperate climate presents the occupants with a complicated task. This rule applies to bus drivers in particular, as they are exposed only to the conditions at the front of the vehicle. An automatic climate control system incorporating a preselection feature can automatically maintain the correct temperature, air flow and air distribution in the passenger compartment. These parameters are mutually interdependent, and changes to one will affect the others. At the center of the system is a temperature-control circuit for interior temperature. The control unit continuously monitors both the preselected temperature and all essential variables which affect the system, using this information to calculate a setpoint t_i. The setpoint is compared with the actual temperature, and the control unit uses the difference between the two as the basis for determining the required heating, refrigeration, and air-flow rate. Another function controls the position of the air-distribution flaps with reference to the program which the occupants have selected. Meanwhile, all control circuits continue to respond to manual inputs.

Coolant circuit of an air-conditioning system

1 Compressor, 2 Electric clutch (for compressor on/off function), 3 Condenser, 4 Auxiliary fan, 5 High-pressure switch, 6 Fluid reservoir with desiccant insert, 7 Low-pressure switch, 8 Temperature switch or on/off control (for compressor on/off function), 9 Temperature sensor, 10 Condensate drip pan, 11 Evaporator, 12 Evaporator fan, 13 Fan switch, 14 Expansion valve.



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

The setpoint temperature determined by the control unit is achieved by means of water or air-side adjustments (as described in "Electronic heater control").

Infinitely-variable or graduated blower control is used to adjust the air flow to the specified level. There is generally no setpoint processing involved in this operation. This type of arrangement is inadequate for dealing with the increases in flow rate caused by aerodynamic pressure at high speeds. Here, a special control function can compensate by responding to increasing vehicle speeds, initially by reducing the blower speed to zero, and then, should the flow continue to rise, by using a restriction flap to throttle the stream of incoming air.

Control of air distribution to the three levels – defroster, upper compartment and footwell – is effected manually, with preselection, or with a fully-automatic program. Especially popular are units featuring program control buttons in which each button provides a specific air-distribution pattern for the three levels.

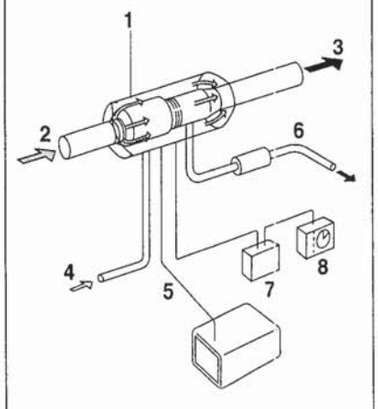
The defroster represents a special case. In order to clear the windows as rapidly as possible, the temperature control must revert to maximum heat and maximum blower speed while directing the air flow through the upper defroster outlets. On systems with program switches and fully-automatic units, this operating mode is selected with a single button; at temperatures above 0 °C the refrigeration unit is also activated to extract humidity from the air. To prevent the still unheated air giving rise to drafts, the blower is switched off electronically after cold starts in winter, except when "DEF" and cooling are in operation.

The variations described above are used in both passenger cars and trucks. Buses require more complicated layouts. The passenger compartment can be divided into several control zones, in which the temperature is controlled by electronically regulating the speed of the zone's individual water pump.

Auxiliary heater installations

The fuel for units which produce heat without the aid of the engine is supplied either by the standard vehicle tank, or, on large vehicles, by a separate tank. An electric pump supplies the fuel to an injector, which sprays a fuel mist into the combustion chamber; the mist mixes with the air and burns. The hot exhaust gases are then directed to a heat exchanger. The heat exchanger can function in one of two ways, either warming the interior air directly, or by transferring heat to the engine's coolant circuit. In the latter case, circulation is maintained by a separate electric pump, making it possible to use the standard heating unit to warm the passenger compartment. This type of auxiliary heating for the engine coolant also improves cold-start response in the winter.

Auxiliary air heater (independent of engine)
1 Air heater with blower for combustion and heating air, combustion chamber and heat exchanger, 2 Hot-air intake, 3 Air outlet to vehicle interior, 4 Combustion-air intake, 5 Fuel supply, 6 Exhaust system, 7 Electronic control unit, 8 Thermostat and timer for preselecting switch-on time.



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

Instrumentation

Drivers have to process a permanently increasing stream of information originating from their own and other vehicles, from roads and from telecommunications equipment. All this information must be conveyed to drivers in the information and communications areas of their vehicles with suitable display and indicating equipment and in compliance with ergonomic requirements. In future, it will increasingly become the norm for cellular phones, navigation systems and ranging systems to join radios and vehicle monitoring systems as standard features in motor vehicles.

Information and communications areas

In any vehicle, there are four information and communications areas, which must satisfy different requirements in terms of their display features:
- the instrument cluster,
- the windshield,
- the center console and
- the vehicle rear compartment.

The display features of these areas are determined by the available range of information and the necessary, useful or desirable information for the occupants concerned.

Dynamic information and monitoring information (e.g. fuel level) to which the driver should respond is indicated in the instrument cluster (i.e. as near as possible to the primary field of vision).

A head-up display (HUD), which reflects the information in the windshield, is especially suited to engaging the driver's attention (e.g. in the case of warnings from a ranging warning radar (ACC) or route directions). The display is supplemented acoustically by voice output.

Status information or dialog prompts are mainly displayed in the vicinity of the operator unit in the center console.

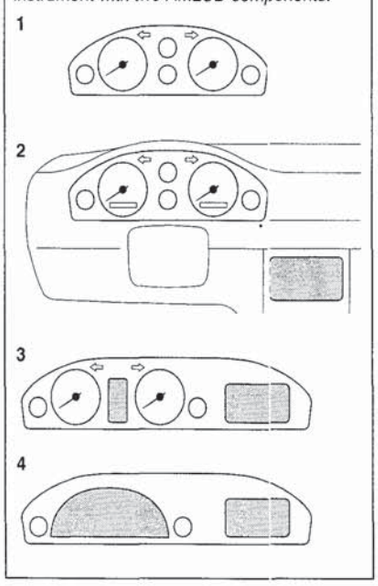
Information of an entertainment nature is featured in the vehicle rear compartment, away from the primary field of vision. This is also the ideal location for the mobile office. The backrest of the front passenger seat is a suitable installation location for the monitor and operator terminal of a laptop computer.

Driver information systems

The driver information area in the vehicle cockpit and the display technologies used have gone through the following stages of development:

Individual and combined instruments
Conventional individual instruments for the optical output of information were initially superseded by more cost-effective instrument clusters (combination of several information units in a single housing) with good illumination and antireflection qualities. The passage of time, with the continual increase in information, saw the creation in the existing space available of the modern instrument cluster with several needle instruments and numerous tell-tale lamps (Fig., no. 1).

Driver information area *(development)*
1 Needle instrument, 2 Needle instrument with TN LCD and separate AMLCD in center console, 3 Needle instrument with (D)STN and integrated AMLCD, 4 Programmable instrument with two AMLCD components.



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

Digital displays

Digital instruments

The first digital instruments used on a large, worldwide scale featuring vacuum fluorescent displays (VFDs) and later liquid-crystal displays (LCDs) can now mainly be found in Japan and the USA in luxury-class cars. These instruments found little favor in Europe and have now virtually disappeared from use. Here the trend towards needle instruments has continued uninterrupted but with a radical technical change in the way in which they are activated (Fig., no. 2).

Central display and operator unit in center console

The introduction of navigation and driver information systems (PP. 796/798) has seen the incorporation of a display monitor and a keypad in the center console. Such systems combine all the additional information from functional units and information components (e.g. cellular phone, car radio/CD, controls for heating/air conditioning (HVAC) and – important for Japan – the "TV" function) in a central display and operator unit. The components are interconnected in a network and are capable of interactive communication.

Positioning this terminal, which is of universal use to driver and passenger, in the center console is effective and necessary from both ergonomic and technical standpoints. The optical information appears in a graphics display. The demands placed by TV reproduction and the navigation system on the image/map display determine the resolution and color reproduction.

Graphics modules

Fitting vehicles with a driver's airbag and power steering as standard has resulted in a reduction in the view through the top half of the steering wheel. At the same time, the amount of information that has to be displayed in the installation space available has increased. This creates the need for additional display modules with graphics capabilities whose display areas are able to show any information flexibly and in prioritized form.

This tendency results in instrumentation featuring a classical needle instrument but supplemented by a graphics display. Even the central display monitor is located at the height of the instrument cluster. What is important to all optical displays is that they can be easily read inside the driver's primary field of vision or in its immediate vicinity without the driver having to divert his eyes from the road for long periods. This is the case for instance when the displays are positioned in the lower area of the center console (Fig., no. 3).

The graphics modules in the instrument cluster permit mainly the display of driver- and vehicle-related functions such as e.g. service intervals, check functions covering the vehicle's operating state and also vehicle diagnostics as needed for the workshop. They can also show route-direction information from the navigation system (no digitized map excerpts, only route-direction symbols such as arrows as turn-off instructions or intersection symbols). It is to be expected that the initially monochrome modules will be succeeded in a second stage by color displays whose reading speed and reliability are increased by color reproduction.

For the central display monitor with an integrated information system, the tendency is now to switch from a 4:3 aspect ratio to a wider format with a 16:9 aspect ratio (cinema-film format), which enables additional route-direction symbols to be displayed as well as the map. More recent developments see the display being split into two separate screens: one screen is only read by the driver and displays driver-related information while the other screen can only be seen by the passenger and shows e.g. a cinema film.

Individual module with computer monitor

By roughly 2003, the remaining mechanical measuring instruments will have disappeared and the entire area of the instrument cluster will have been replaced by a freely addressable graphics monitor (provided the price of LCD computer monitors develops economically). Such a unit module would offer an array of information display options. It is conceivable to have an individually selectable form of display which is geared to the specific needs of individual user groups (e.g. frequent, older or sports car users) (Fig., no. 4).

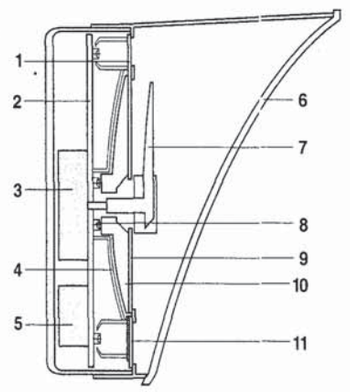
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,557,540

Instrument clusters

Design

Microcontroller technology and the ongoing networking of motor vehicles have in the meantime transformed instrument clusters from precision-mechanical instruments to electronically dominated devices. A typical instrument cluster (LED-illuminated, with TN-type conductive-rubber-contacted segment LCDs, see Fig.) is a very flat component (electronics, flat stepping motors) and virtually all the components (mainly SMT) are directly contacted on a printed-circuit board.

***Instrument cluster** (design)*
1 Tell-tale lamp, 2 Printed-circuit board, 3 Stepping motor, 4 Reflector, 5 Plug, 6 View cover, 7 Needle, 8 LED, 9 Dial face, 10 Optical waveguide, 11 LCD.



Operating concept

While the basic functions are the same in most instrument clusters (see typical block diagram), the partitioning of the function blocks into (partly application-specific) microcontrollers, ASICs and standard peripherals sometimes differs significantly (product range, display scope, display types).

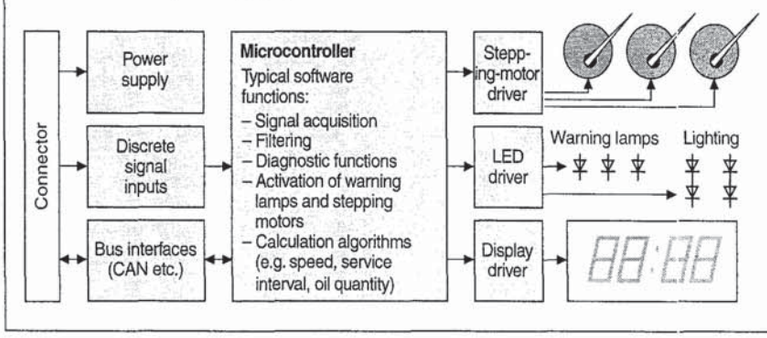
Electronic instrument clusters indicate measured variables with high accuracy thanks to stepping-motor technology, and also take over "intelligent" functions such as engine-speed-dependent oil-pressure warning, prioritized fault indication in matrix displays, or service-interval indicator. Even online diagnostic functions are standard and take up a significant part of the program memory.

Because instrument clusters are standard features on all vehicle types and all the bus systems merge here anyway, the former are becoming increasingly established as gateways, i.e. bridges between the different bus systems in the motor vehicle (e.g. engine CAN, body CAN and diagnostic bus).

Measuring instruments

In Europe, manufacturers still tend towards the classical instrument with mechanical needle and dial face. Here, initially the compact, electronically triggered moving-magnet quotient measuring instrument replaced the bulky eddy-current speedometer. Geared stepping motors with very low

***Instrument cluster** (block diagram)*



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

overall depth and still higher precision are currently used. Thanks to a compact magnetic circuit and (mostly) 2-stage gearing with a power output of only approx. 100 mW, these motors permit swift and highly accurate needle positioning.

Lighting

Instrument clusters were originally lit by frontlighting technology in the form of electric bulbs. Backlighting technology has in the meantime gained acceptance on account of its attractive appearance. Bulbs have been replaced by long-lasting light-emitting diodes (LEDs, see P. 143). LEDs are also suitable for warning lamps and for the backlighting of scales, displays and (via plastic optical waveguides) needles (refer to table headed "Overview of lighting sources").

Highly efficient InAlGaP-technology LEDs are meanwhile available in the colors yellow, orange and red. The newer InGaN technology is currently producing significant efficiency improvements in the colors green, blue and white. Here the color white is obtained through the combination of a blue LED chip with an orange-emitting luminescent material (yttrium-aluminum granulate).

However, new technologies are also being used for special configurations:

- CCFLs (Cold Cathode Fluorescent Lamps): mainly for "black screen" instruments, which appear black when they are deactivated. The combination of a tinted view cover (e.g. 25% transmission) with these very bright lamps (high luminance, high voltage) produces a brilliant appearance with outstanding contrast. Since color LCDs have very low transmission (typically approx. 6%) it is imperative that CCFLs are used to backlight them in order to obtain good contrast even in daylight.
- EL (electroluminescent) film: AC is applied to this flat film in order for it to light up. It features very uniform light distribution, and has only recently become suitable for automotive applications. It offers extensive freedom of design for color combinations and/or for superimposing dial areas on display surfaces.

Overview of lighting sources

Lighting source	Possible colors	Typical data[1]	Technically suitable for	Conventional ICs	Black-screen instrum.	Service life[2] in h	Activation
Bulb	White (every color possible with filter)	2 lm/W 65 mA 14 V	Dial face Needle Display	+ o +	– – o	$B_3 \approx 4{,}500$	No special activation required
SMD LED luminescent diode	Red, orange, yellow (InAlGaP)	8 lm/W 25 mA 2 V	Dial face Needle Display	o + +	– + –	$B_3 \gg 10{,}000$	Series resistors or control required
	Blue, green (InGaN), white (with converter)	2...5 lm/W 20 mA 3.6 V	Dial face Needle Display	o o o	– o –	$B_3 > 10{,}000$	
EL film electroluminescent	Blue, violet, yellow, green, orange, white	2 lm/W 100 V AC 400 Hz	Dial face Needle Display	+ – –	– – –	approx. 10,000	High voltage required
CCFL cold-cathode lamp	White (every color possible depending on luminescent material)	25 lm/W 2 kV AC 50...100 kHz	Dial face Needle Display	+ – +	+ o +	$B_3 \approx 10{,}000$	High voltage required

[1]) Efficiency in lm/W (lumen per watt), current in mA, voltage in V or kV, activation frequency in kHz.
[2]) B_3 Point with 3% failure probability. Suitability: + preferred, o conditional, – no application.

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

Display types

TN LCD

With its high status of development, TN-LCD technology ("Twisted Nematic Liquid-Crystal Display", see P. 143) is the most commonly used form of display. The term stems from the twisted arrangement of the elongated liquid-crystal molecules between the locating glass plates with transparent electrodes. A layer of this type forms a "light valve", which blocks or passes polarized light depending on whether voltage is applied to it or not. It can be used in the temperature range of –40 °C...+85 °C. The switching times are relatively long at low temperatures on account of the high viscosity of the liquid-crystal material.

TN LCDs can be operated in positive contrast (dark characters on a light background) or negative contrast (light characters on a dark background). Positive-contrast cells are suitable for front- and backlighting while negative-contrast cells can only be read with satisfactory reading contrast when strongly lit from the rear. TN technology is suitable not only for smaller display modules but also for larger display areas in modular or even full-size LCD instrument clusters.

Graphics displays for instrument clusters

Dot-matrix displays with graphics capabilities are needed to display infinitely variable information. They are activated by line scanning and therefore require multiplex characteristics. Under the conditions prevailing in a motor vehicle, conventional TN LCDs can today produce multiplex rates of up to 1:4 with good contrast and up to 1:8 with moderate contrast. Other LCD display technologies are needed to achieve higher multiplex rates. STN and DSTN technologies are now being used for modules with moderate resolution. DSTN technology can be implemented to provide monochrome or color displays.

STN LCD and DSTN LCD

The molecule structure of an STN (Super Twisted Nematic) display is more heavily twisted inside the cell than in a conventional TN display. STN LCDs permit only monochrome displays; usually in blue-yellow contrast. Neutral color can be obtained by applying "retarder film", but this is not effective throughout the entire temperature range encountered in the vehicle.

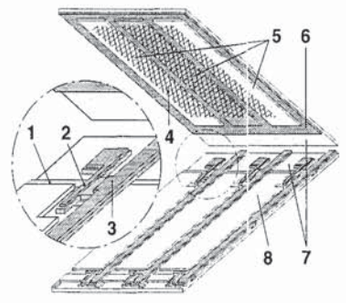
DSTN LCDs (Double-layer STN) feature considerably improved characteristics, which permit neutral black-and-white reproduction over wide temperature ranges with negative and positive contrast. Color is created by backlighting with colored LEDs. Multicolor reproduction is created by incorporating red, green and blue thin-film color filters on one of the two glass substrates. Under automotive conditions, shades of gray are only possible to a very limited extent, the result of which is that the range of colors is limited to black, white, the primary colors red, green and blue and their secondary colors yellow, cyan and magenta.

AMLCD

The task of the visually sophisticated and rapidly changing display of complex information in the area of the instrument cluster and the center console with high-resolution liquid-crystal monitors with video capabilities can only effectively be performed by an AMLCD (Active-Matrix Liquid-Crystal Display).

The best developed and mostly widely used are the TFT LCDs (Thin-Film Transistor LCDs) addressed with thin-film

Thin-film transistor LCD (TFT LCD)
1 Row circuit, 2 Thin-film transistor,
3 Column circuit, 4 Front-plane electrode,
5 Color layers, 6 Black matrix,
7 Glass substrate, 8 Pixel electrode.



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

transistors. Display monitors with diagonals of 4″...7″ in the center-console area and an extended temperature range (–25 °C...+85 °C) are available for motor vehicles. Formats of 10″...14″ with a still wider temperature range (–40 °C... +95 °C) are planned for programmable instrument clusters.

TFT LCDs consist of the "active" glass substrate and the opposing plate with the color-filter structures. The active substrate accommodates the pixel electrodes made from tin-indium oxide, the metallic row and column circuits and the semiconductor structures. At each intersecting point of the row and column circuits, there is a field-effect transistor which is etched in several masking steps from a previously applied sequence of layers. A capacitor is likewise generated at each pixel.

The opposite glass plate accommodates the color filters and a "black-matrix" structure, which improves the contrast of the display. These structures are applied to the glass in a sequence of photolithographic processes. A continuous counter-electrode is applied on top of them for all the pixels. The color filters are applied either in the form of continuous strips (good reproduction of graphics information) or as mosaic filters (especially suitable for video pictures).

Head-up display (HUD)

Conventional instrument clusters have a viewing distance of 0.8...1.2 m. In order to read information in the area of the instrument cluster, the driver must adjust his vision from infinity (observing the road ahead) to the short viewing distance for the instrument. This process of adjustment usually takes 0.3...0.5 s. Older drivers find this process strenuous and in some cases, depending on their constitution, even impossible. HUD, a technology involving projection, can eliminate this problem. Its optical system generates a virtual image at such a viewing distance that the human eye can remain adjusted to infinity. This distance begins at approx. 2 m, and the driver can read the information with very little distraction, and without having to divert his eyes from the road to the instrument cluster.

Design

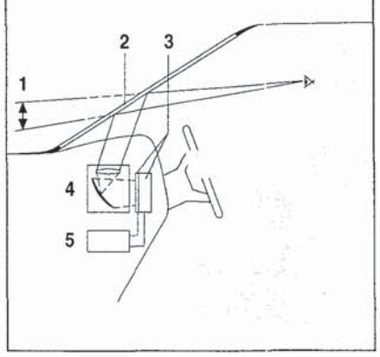
The HUD features an activated display for generating the image, a lighting facility, an optical imaging system and a "combiner", with which the image is reflected into the driver's eyes. The untreated windshield can also take the place of the combiner. Active displays (light emitters) such as CRTs or VFDs and passive displays (light modulators) are used for HUD. PDLC or DSTN displays are suitable but they do need very bright lighting because they absorb approx. 70 % of the transmitted light on account of the required polarizers.

Indication of HUD information

The virtual image should not cover the road ahead so that the driver is not distracted from the traffic or road conditions. It is therefore displayed in a region with a low road or traffic-information content.

In order to prevent the driver from being overwhelmed with stimuli in his primary field of vision, the HUD should not be overloaded with information, and is therefore not a substitute for the conventional instrument cluster. It is however particularly well-suited to displaying safety-related information such as warnings, safety distance and route directions.

Head-up display HUD *(principle)*
1 Virtual image, 2 Reflection in windshield, 3 LCD and lighting (or CRT, VFD), 4 Optical system, 5 Electronics.



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