Purpose

Anti-lock brake systems (ABS) - generally also referred to as **anti-lock systems (ALS)** - must prevent the vehicle's wheels from locking as a result of excessively powerful actuation of the service brake, mainly on slippery road surfaces.

As a result, cornering forces on braked wheels should be maintained even during full braking, so as to guarantee that the vehicle or vehicle combination remains stable and can still be steered as far as physically possible. At the same time, the friction contact between tyres and the carriageway should be fully optimised, therefore reducing the braking distance and making the vehicle decelerate more rapidly.

Why ABS?

Despite the advanced development status of commercial vehicle brakes, potential accident situations often occur when braking on slippery road surfaces. During full or even partial braking on a slippery road, it may no longer be possible to transmit all of the brake force onto the road due to the low coefficients of friction between the tyres and the carriageway. The braking force is excessive and the wheels lock up. When the wheels are locked up, they cease to offer any purchase on the road and they transmit almost no cornering forces (steering and tracking forces). This often has dangerous consequences.

- The vehicle cannot be steered
- The vehicle swerves despite countersteering and starts to skid
- The braking distance is significantly increased
- Tractor-trailer combinations or semitrailer trains may show the dreaded breakaway or jackknifing effect.

Influence of the load sensing valve

Today’s load-sensing valves (ALB) are capable of preventing locking of the wheels of an unladen vehicle on a dry road surface and help the driver to get effectively grade the braking process on wet road surfaces, they are unable to prevent locking as such. In addition, they are incapable of counteracting any overreactions on the part of the driver, or any variances in frictional or adhesion coefficients which may apply to different sides of the vehicle, or indeed to its different axles.

Advantages of ABS

Only the Anti-Lock Brake System (ABS)

- guarantees stable braking characteristics on all road surfaces.
- the vehicle can still be steered and the brake distance is shortened
- prevents the creases of vehicle combinations
- reduces tyre wear.

Limits of ABS

Although ABS is an effective safety device, it cannot overcome the limits of driving dynamics. Even a vehicle fitted with ABS will become uncontrollable if driven too fast around a bend.

As a result ABS is not to be seen as a “get out of jail free” card for a non-conformist way of driving or failure to maintain the correct safety distance.

Why ASR

On slippery road surfaces especially for unladen or half laden commercial vehicles the increasing of the engine output (accelerating) can easily lead to the situation that the maximum adhesion on one or all driving wheels is exceeded and that they will spin.

It is not only locking wheels when the brakes are applied which represent a hazard; the same applies to spinning wheels as the vehicle moves off.

Reasons

1. Wheels which spin transfer as little cornering force as locking wheels.
2. In addition, they no longer transfer any propulsive thrust onto the road.

Consequences:

– Vehicles which are incapable of moving forward, or get stuck.

– Vehicles which are no longer steerable and which may jackknife on an uphill gradient, or swerve when negotiating bends.

Advantages of ASR

ASR prevents the spinning of the driving wheels and offers the following advantages:

– Propulsive thrust and cornering forces are maintained.

– Stable driving behaviour is ensured when moving off, accelerating and negotiating bends on slippery roads.

– The driver is warned of slippery roads via a indicator lamp (if fitted).

– Tyre wear is reduced to a minimum, and the motor vehicle’s driving gear is protected

– The danger of accidents is reduced further.

ASR and ABS

ASR represents a worthwhile addition to an ABS-controlled braking system. All it needs is an ECU which has had the ASR function included, and a few additional components for controlling the differential brake and the engine in order to turn the basic ABS into complete ABS/ASR control. ASR is available only in combination with ABS.

Even a differential lock for Off-Road use and ASR do not exclude each other, but form a meaningful addition.

Limits of ASR

The traction fortune of an all-wheel driven using motor vehicle can not be achieved by a motor vehicle with only one driving axle - not even with an optimal ASR.

After extensive studies, the first prototype is presented to the public at the IAA Motor Show in 1969.

1974	WABCO and Mercedes-Benz enter into a co-operation agreement. System development and vehicle testing are accelerated by means of team work.
1975	WABCO begins to develop its own electronics on the basis of linear and integrated signal processing. Co-operation is extended to other manufacturers.
1980	Introduction of fully digitized electronics. Microcomputers represent the core; it is the first time they have been used in commercial vehicles. Final winter testing in Lapland on the Arctic Circle in the presence of experts from many different countries.
1981	Release of the WABCO-ABS-System by Mercedes-Benz and a bit later by other car manufacturers. Series production of its A version (2- and 4-channel systems).
1986	Introduction of WABCO ASR (drive-slip control) with the B-generation electronic control units. Introduction of 6-channel ABS.
1989	Introduction of modular VARIO-C ABS for trailers (with error memory and ISO diagnostics).
1990	Introduction of the ABS/ASR C-generation in the motor vehicle (with error memory, ISO diagnostics and additional optional features).
Since October 1991	EC Directive stipulating ABS as compulsory for heavy-duty commercial vehicles.
1994	Introduction of the VARIO COMPACT SYSTEM (VCS) for trailer vehicles and integration of the speed limiting in vehicles of the C-generation which was now demanded legally.
1996	Introduction of the ABS-D-Generation in vehicles and introduction of the electronically controlled braking system EBS for vehicles.
1998	Introduction of the EBS for trailer vehicles and gradual equipment duty of ABS also for lighter motor vehicles.

Simplified Theoretical Principles ABS

The brake force coefficient (μB)

The brake force coefficient (adhesion) between the wheel and the carriageway determines what braking forces can be transmitted. It is dependent upon the brake slip between the tyre and the road, and among the factors affecting it are:

- The condition of the road and the tyres
- The wheel or axle load
- The speed of the vehicle
- The temperature
- the tyres' slip angle or the utilized cornering force.

The cornering force coefficient (μs)

Maintaining lateral control is an essential requirement for the steerability of a vehicle. The cornering force coefficient reduces much more rapidly than the brake force coefficient does.

The brake slip (λ)

The brake slip is the ratio between the speed of the vehicle and the wheel speed expressed as a percentage. The slip is defined by the following equation:

$$\textbf{brake slip } \lambda = \frac{V_F - V_R}{V_F} \times \textbf{100 \%}$$

V_F = Vehicle's speed
V_W = Wheel circumference speed

Explanation of slip curves (μB and μs)

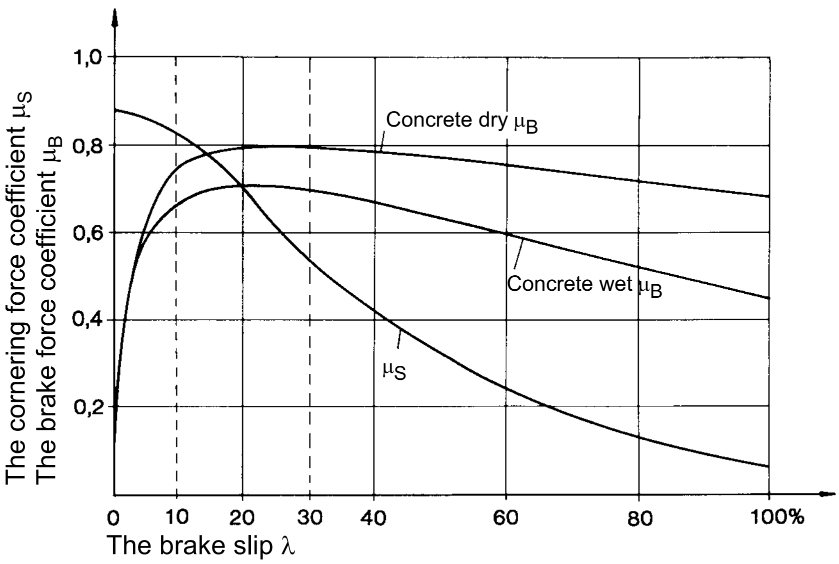


Fig. 26 shows the relationship between the brake force coefficient μB, the cornering force coefficient μs and the brake slip λ for different road conditions.

Providing maximum adhesion has not yet been achieved, it is possible to continue increasing the braking force in the "stable" range by increasing slip. In this case, there are also sufficiently large cornering forces available to keep the vehicle steerable and therefore stable.

If as a consequence of excessive brake forces, the unstable range of the μ–λ-curve (between approx. 30 and 100%) is reached, the wheel is overbraked and will lock (100% slip). The vehicle is then almost completely unsteerable.

To prevent this from happening, the ABS system keeps the adhesion between 10 % and 30 % slip.

Simplified Theoretical Principles ASR

The brake slip (λ_{an})

Similar to the braking process, the propulsive force which can be transferred from the tyre to the road surface depend on the slip between the tyre and the road.

Drive slip is the percentual ratio of wheel speed versus vehicle speed and is defined by the equation:

$$\lambda_{an} = \frac{V_W - V_F}{V_W} \times 100\ (\%)$$

V_W = Wheel circumference speed
V_F = Vehicle's speed

The brake slip (μ_{an})

The brake slip and thus the propulsive force is depending from the same factors as the already mentioned brake force coefficient.

When the wheels spin heavily (μ_{an} = 100%), the adhesion will be reduced way below its maximum. The cornering force coefficient also falls as drive slip increases, and by the time the wheels spin it is negligible.

ASR Control

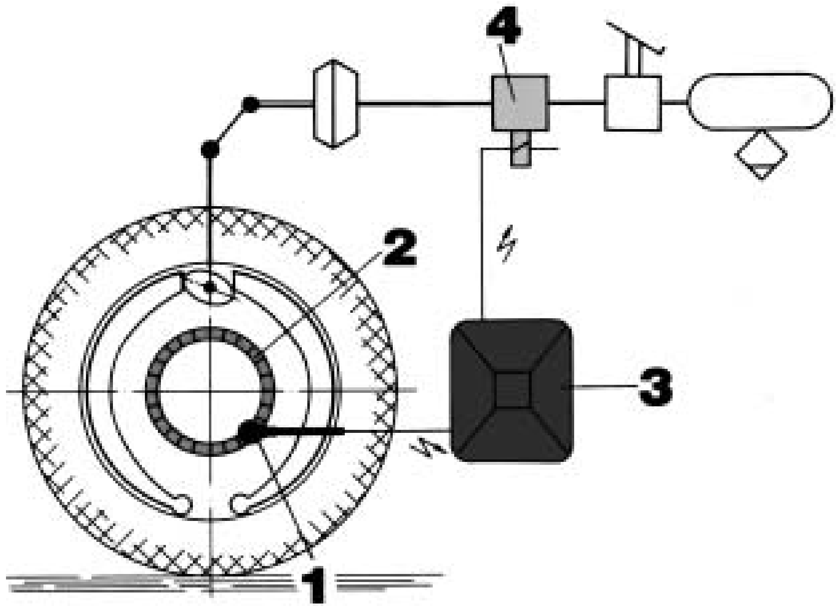
Drive slip regulators influence the acceleration events only if certain threshold values of the wheel slip or the wheel acceleration are exceeded.

Electronically operated solenoid valves brake the wheel in question carefully or reduce the engine’s performance until the stable frictional connection is reached again.

For any further control the wheel is hold, when poosible, in a narrow slip range in the near of the maximum frictional connection.

An ABS control circuit

Structure



1 = sensor, 2 = pole wheel, 3 = electronic control unit, 4 = solenoid valve

Operation

The sensor fixed to the axle, with the assistance of the pole wheel, continuously picks up the rotary movement of the wheel. The electrical pulses generated within the sensor are transmitted to the electronic control unit (ECU) which uses them to compute the wheel speed.

At the same time, the ECU uses a certain mode to determine a reference speed which is close to the vehicle speed which is not actually measured.

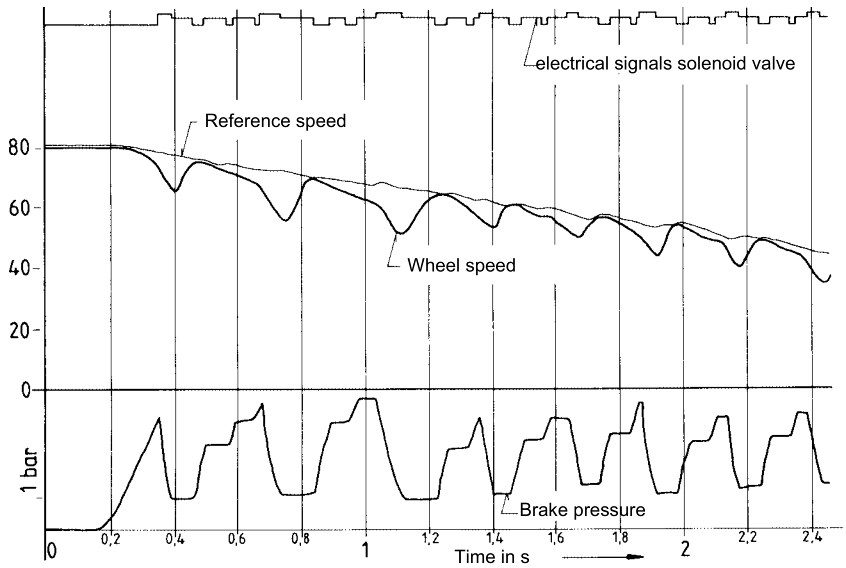
From all of this information, the ECU continuously computes the wheel acceleration (+b) or wheel deceleration (-b) and brake slip values.

When certain slip values are exceeded, the solenoid control value is actuated. This causes the pressure in the brake cylinder to be limited or reduced, thereby keeping the wheel within its optimum slip range.

An ABS Control Cycle

Example

The values recorded refer to the control cycle of **one wheel**. The vehicle's initial speed is 80 k. p. h.



On the absciss the control cycles are recorded as a function of the time. In the area of the ordinate, the braking pressure is shown in the bottom section, and the middle section shows the reference and wheel speeds. The solenoid valve's pulses appear in the top section.

The control procedure

The driver actuates the braking system. The brake pressure increases. The speed of the wheel in question suddenly drops more quickly than the reference speed of the ECU. Although the wheel is still within the stable braking range (i.e. between 10 % and 30 % slip), the electronic control unit already starts the control procedure.

The solenoid valve is actuated and rapidly reduces the pressure in the brake cylinder of that wheel, and the wheel begins to accelerate again.

The electronics cause the solenoid control valve to reverse, keeping the braking pressure at a constant level, until the wheel once again runs within the stable slip range.

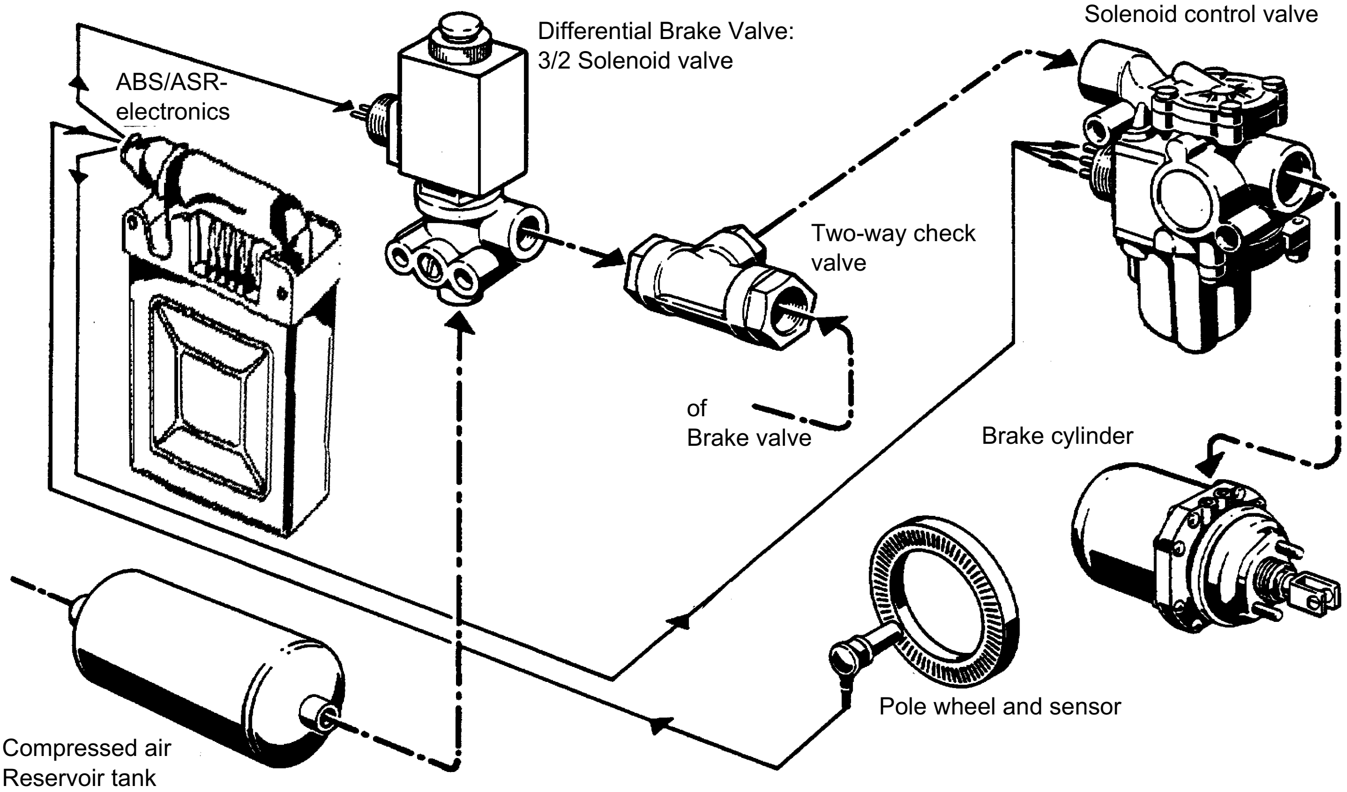
When more brake force can now be transmitted again, the braking pressure is increased by means of pulsing - i. e. alternate holding and increasing of the pressure. If the wheel speed again clearly falls below the reference speed, another control cycle begins.

The procedure repeats itself for as long as the brake pedal continues to be pressed down too much for the condition of the road in question, or until the vehicle comes to a halt. The maximum control frequency (valve pulses) which can be achieved in this case is 3 to 5 cycles per second.

Differential Brake Control

Immediately after the ignition has been switched on and the vehicle moves off, the ECU monitors the rotational behaviour of all wheels above a wheel speed of approx. 2 k. p. h.

The speed and acceleration values of the driving wheels are compared with those of the non-driving wheels.



Function

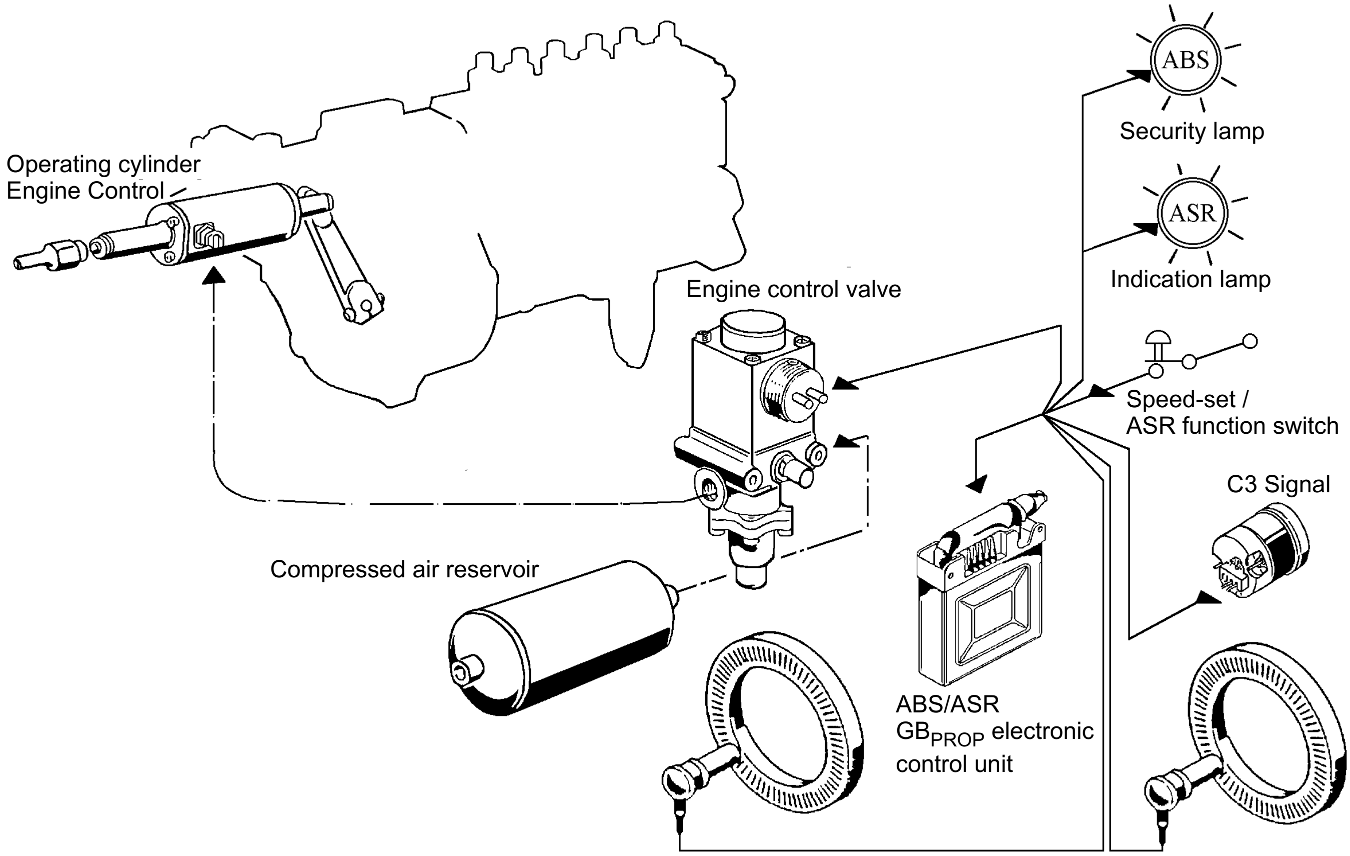
When a certain difference in speed or slip threshold is exceeded ASR control sets in.

As soon as a driving wheel exceeds the slip threshold as it accelerates, the ECU will actuate the respective differential brake valve and thus control the braking pressure in the applicable brake cylinder of the service brake.

The engine’s driving torque can now rest on this braked wheel, causing the driving force on the other wheel to rise as it would if the differential lock had been applied.

Engine Control

As soon it is not just one wheel which spins but both driving wheels have exceeded the slip threshold, differential brake control is terminated, and the engine's power is reduced. The Differential Brake Control is today only used to synchronise the wheels. At a speed over 50 km/h only the engine control is used.



Function

To achieve this, the ECU actuates the engine control valve which rapidly at first and then more slowly moves the adjusting lever of the fuel-injection pump via the ASR operating cylinder (by means of a special characteristic of the pressure curve) towards the idle position, even if the driver continues to depress the accelerator.

As soon as the engine's braking effect has brought the slip rate of the wheels back to within the slip threshold, the engine control valve, at first rapidly and then more slowly, reduces the pressure in the operating cylinder. This causes the engine's performance to rise again up to the level selected by the pressure which the driver applies to the accelerator, or until another control cycle begins.

Please note

This function can also be used as integrated speed limiting **(GB_{Prop})** and complies with all legal requirements for speed limiting.

Alternating Between Differential and Engine Control

In roads in winter, the coefficients of friction tend to vary. As a consequence, engine and differential brake control alternate.

On a plain road surface the control is mainly done by reduction of the engine revs and the differential brake control restricts itself to synchronise the driving wheels.

On side wise different rubbing values mainly the differential brake control is used and pressurizes only the cylinder of the spinning wheel. The driving torque is therefore transfered to the other wheel.

To avoid overheating of the wheel brake the differential brake threshold value is raised linear from approx. 35 km/h. The slip is now more and more controled by the control of the engine revs. Over 50 km/h no diff-control is started anymore.

ASR Engine Control in vehicles with E-gas

Electronic engine controls are often used in articulated buses but also on other motor vehicles. The mechanical linkage between the accelerator pedal and the fuel-injection pump is then dispensible apart from a short link between the electrical operating motor and the pump adjusting lever.

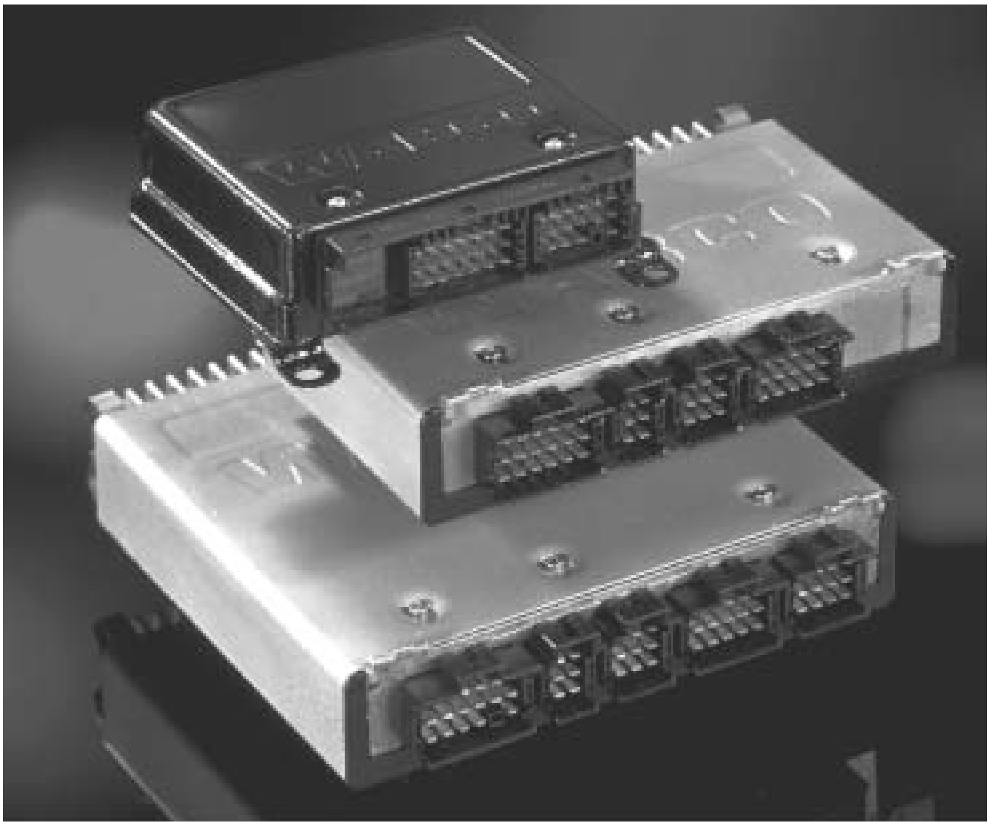
The mechanical linkage is replaced by an electrical set point transmitter on the accelerator pedal (potentiometer) and an operating motor located close to the fuel-injection pump.

The output of the ABS/ASR ECU which would normally actuate the engine control valve now energizes an electrical relay and thus affects the E-gas ECU via a certain input.

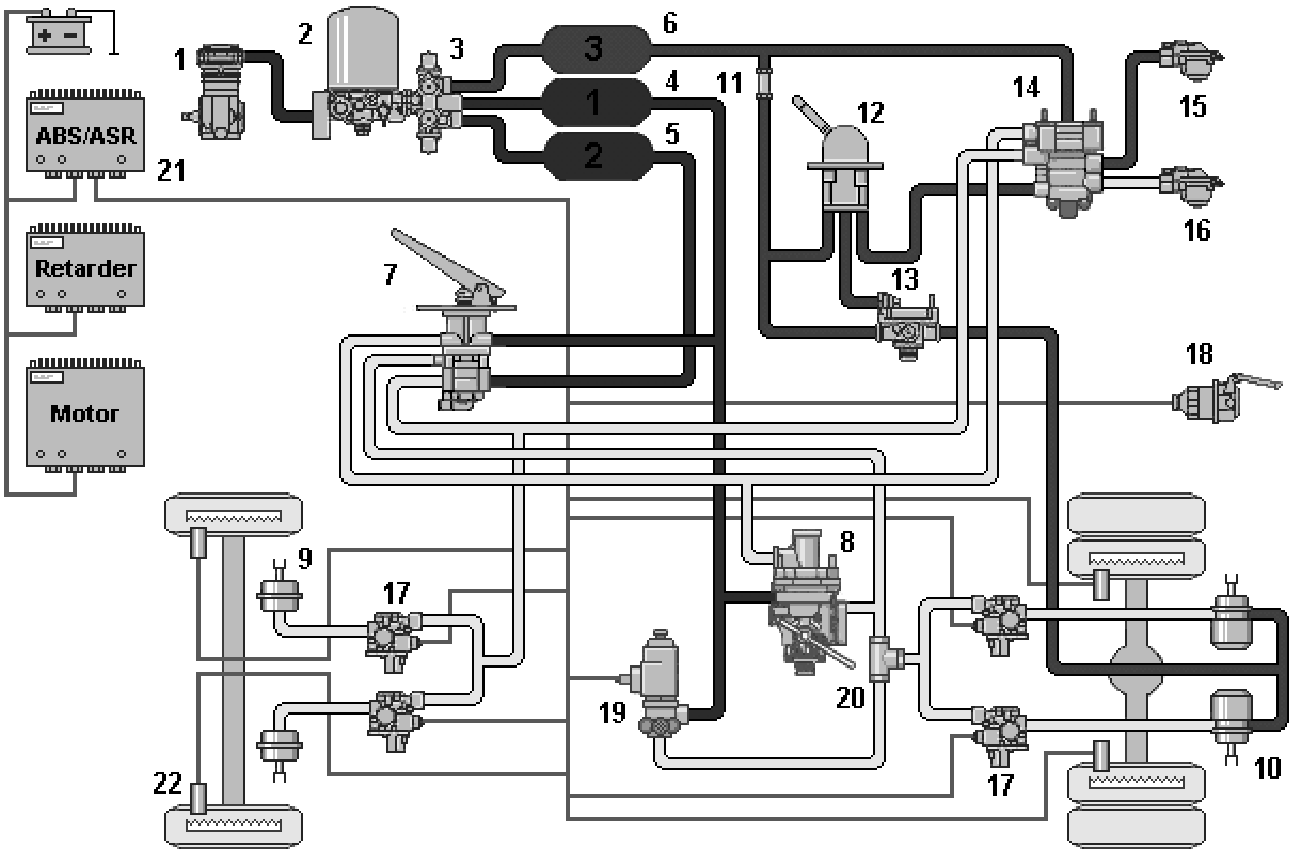
Traction mode and ASR off-road switch

In deep snow or in similar conditions the tensile force can be increased by actuating the “ASR off-road” button which is optional avaiable. If this screw is actuated, the ECU changes the conditions (slip thresholds) for the ASR Control to permit higher slip conditions.

To inform the driver about the reduced stability, the ASR lamp is blinking in regular cycles when the button is actuated.

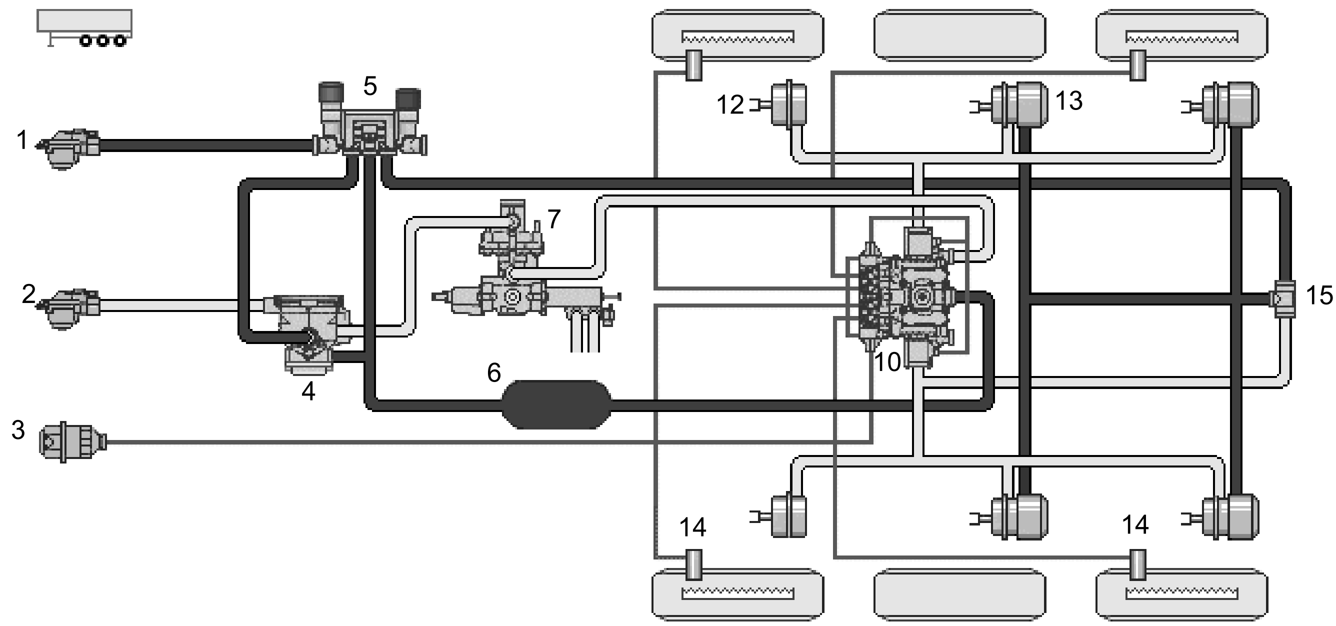


Construction of an EC Air Braking System in trucks with ABS / ASR

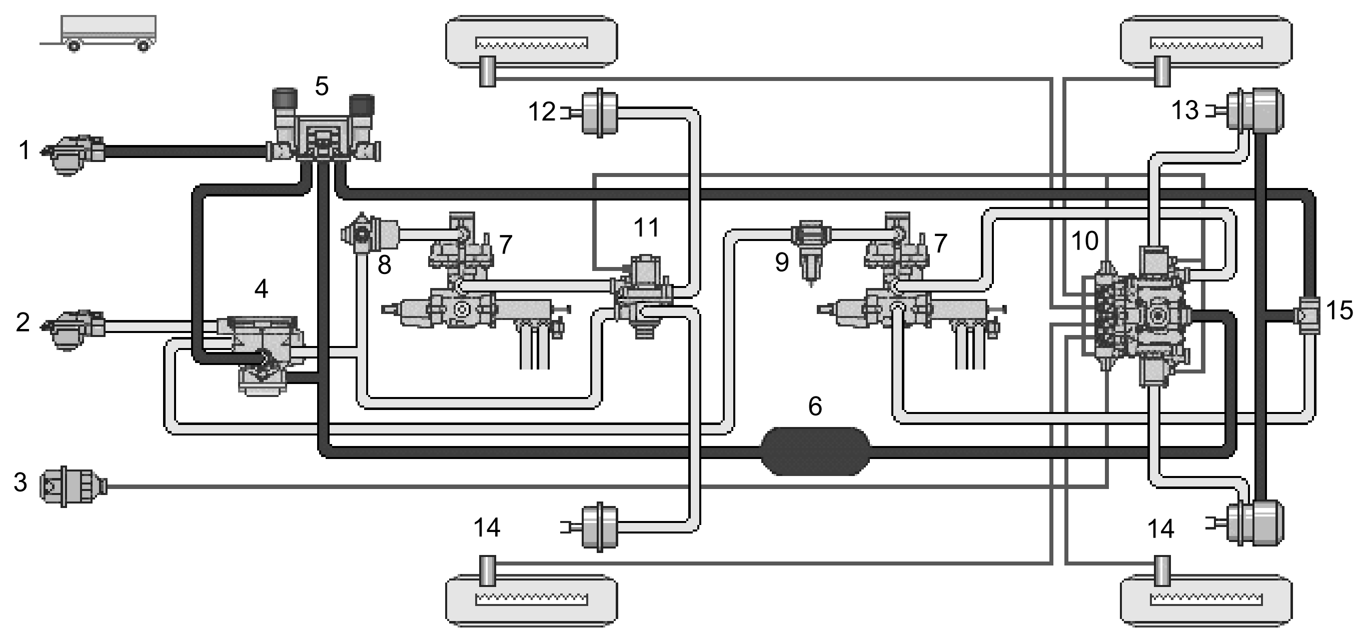


1	Compressor	12	Hand brake valve
2	Air dryer with unloader	13	Relay valve
3	Four-circuit protection valve	14	trailer control valve
4	Circuit 1	15	coupling head “supply”
5	Circuit 2	16	coupling head “brake”
6	Circuit 3	17	ABS solenoid control valve
7	Foot brake valve	18	ABS plug connection
8	Load sensing valve	19	ASR solenoid valve
9	Brake chamber VA	20	two-way valve
10	Tristop cylinder HA	21	ABS/ASR-ECU (D-version)
11	Check valve	22	ABS sensors

Construction of an EC Air Braking System in trucks with ABS / ASR



1 Coupling head “supply”
2 Coupling Head “Brake”
3 ABS plug connection
4 Trailer emergency valve
5 Dual release valve for BBA and FBA
6 Air reservoir
7 Load sensing valve
8 Adapter Valve
9 pressure limiting valve
10 VCS-ABS electronic with ABS Boxer relay valve
11 ABS relay valve steering valve
12 brake chamber
13 Tristop cylinders
14 ABS sensors
15 two-way valve



Electronic Control Unit 446 003/004 ... 0 on the vehicle

Purpose

The electronic control unit (or “ECU“ for short) computes vehicle and wheel speeds, and wheel decelerations and accelerations, from the sensor signals. If necessary it activates solenoid valves to avoid locking of the vehicle's wheels.

Operation

The 4- and 6-channel ECUs have two circuits, Each circuit monitoring two (the 6-channel ECU monitoring three) diagonal vehicle wheels. They can be divided into four functional groups:

Electronic of the A/B generation

– Input circuit
– Master circuit
– Safety circuit
– Valve control

In the **input circuit**, the signals generated by the speed sensors are filtered and converted into digital information.

Electronic of the C generation

The **master circuit** consists of a microcomputer. With the assistance of a complex programme, the control signals are computed and logically operated, and the control signals output for actuating the valves.

Each circuit has its own **safety circuit** which essentially consists of the safety computer and which monitors the whole of the ABS, i. e. the sensors, solenoid control valves, ECU and wiring, both before the vehicle moves off and while it is in motion.

Electronic of the D generation

It alerts the driver to any errors by actuating a failure lamp (SILA), switching of control for one wheel or both diagonal wheels, or in certain cases the whole of the ABS. Whenever this is the case, the braking system continues to be fully operational, with only the anti-lock and drive-slip control systems being deactivated.

C- and D-type ECUs permanently store any errors perceived for the purpose of diagnosis. The error memory can be read out or deleted via the diagnostic connection (to ISO standard), or by exciting a flash-code.

D-Basic-Electronic

The **valve actuations** contain power transistors which are driven by the signals received from the master circuit, and which release the current for actuating the control valves.

Design types

The ECUs are available with **4 channels (446 004 0.. 0)** and **6 channels (446 003 0.. 0)** 0)The ECUs are available for on-board voltages of 24 or 12 volts. For combined braked vehicles (Air Over Hydraulic or AOH units) with only one hydraulic cylinder on the steering axle special 4S/3M ECUs are offered, that means that the front axle is controled by only one solenoid valve.

The non-steered axle(s) is/are controlled individually (IC). Modified individual control (MIC) is used for the steered axle. Despite that on vehicles with 4S/3M ECUs the modified axle control (MAR, see Trailer ABS) is installed on the steering axle.

The previous **A- and B-generations** used ECUs **both on the motor vehicle and in the ABS for the trailer**. With the **C-generation ABS**, we distinguish because of the special functions implemented (e. g. ASR, GB_{Prop}), between **motor vehicle ECUs and trailer ECUs (VARIO-C).**

Compatibility

The ECUs of the B and 4-Channel-C-generation (35-pin plug) are downwards compatible.

For the 6-channel-C-generation the use of a 54-pin electronic plug was required. For diagnostic purposes adapter plugs of 35 to 54-pin plug connections do exist.

The ECUs of the D-generation are not downwards compatible, because the cable harness and the plug concept (modular design) have changed.

Installation

The ECU is installed in the protected environment of the driver's cab. For trailers, the ECU is located in a special protective housing which is mounted on the vehicle frame.

Testing

The electronic control unit and the connected solenoid valves, sensors and the cabling are checked by the integrated safety circuit and any faults are displayed.

Any additional inspection of the electronic control unit itself is only possible on a special test rig in the manufacturing plant.

Please note

Always switch off the ignition before removing and installing the electronic control unit, i.e. to disconnect or connect the ECU plug!

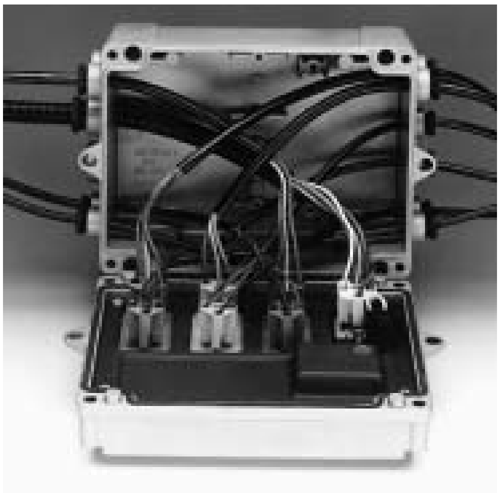
VARIO-C Control Unit for Trailer ABS 446 105 ... 0

Structure

The electronic control unit for VARIO-C for trailers is based on the same electronics technology as the C-type ECU for motor vehicles although it has been designed specifically for operation on the trailer.

This means that it can be mounted on the vehicle frame, that it is designed as a modular system with up to 6 sensors and 3 solenoid valves (6S/3M), and that it recognizes up to two lifting axles.

Operation



The VARIO-C ECU is based on a single circuit and, as described previously for other ECUs, is subdivided into four circuits:

– Input circuit
– Master circuit
– Safety circuit
– Valve control

It processes the signals from **three functional groups with two sensors each and a solenoid valve** whose presence is perceived automatically. Any errors detected are stored permanently for the purpose of diagnosis. The error memory can be read out and deleted by exciting a flash-code, or by using the ISO diagnostic connection.

Design types

The ECUs are available for on-board voltages of 24 or 12 volts.

In addition to a **standard ECU** for the respective voltage which can be used for implementing any system from 2S/1M to 6S/3M, there is one lean variant each specifically for semitrailers; these can, however, be used only to control 4S/2M or smaller systems.

A special ECU **(VARIO-C plus)** can be optionally operated with ABS solenoid relay valves or the ABS solenoid control valves (or even a mixture for different axles).

Testing

The same applies as mentioned for the motor vehicle ECUs.

VARIO Compact ABS (VCS) for Trailer 446 108 ... or 400 500 ... 0

Structure

The ECU of the VARIO-COMPACT-ABS is a further development of the approved VARIO-C ABS and builds on its proven system.

VCS is an ABS system for trailers, ready for installation. It meets all the statuatory requirements defined for category A.

Design types

400 500 … 0

According to the specific requirements defined by the vehicle manufacturers, VCS II is available as a **compact unit** or in **modular design** (i. e., ECU and valves can be installed separately).

Plugs on the outside and new cable hardware connections and makes the necessity of opening the ECU for installation or diagnosis unnecessarily.

446 108 … 0

The range of models reaches from the 2S/2M system designed for semitrailers to the 4S/3M system which is used for drawbar trailers or for a semitrailer equipped with steering axle.

Operation

The VARIO-C ECU is based on a single circuit and is with one, two or three control channels, as described previously for other ECUs, subdivided into four circuits:

– Input circuit
– Master circuit
– Safety circuit
– Valve control

Any errors detected are stored permanently for the purpose of diagnosis. The error memory can be read out and deleted by exciting a flash-code, or by using the ISO diagnostic connection.

Testing

For testing the same notes are valid as by already before described ECUs.

Bar sensor 441 032 ... 0 and pole wheel

Purpose

The rod sensor and the pole wheel pick up the rotary motion of the wheel. The pole wheels for intermediate and heavy-duty commercial vehicles have 100 teeth; for wheels with a smaller rolling circumference, pole wheels with 80 teeth may also be used. Because of the diagonal reference speed being generated in the ECU, the ratio of the number of teeth and the wheel circumference on the front and rear wheels must be identical to a few percent.

Operation

The bar sensor operates inductively and mainly consists of a permanent magnet with a round pole pin and a coil. The rotation of the impulse wheel connected to the wheel hub produces a change in the magnetic flux picked up by the sensor coil, thereby generating an alternating voltage. The frequency of this voltage is proportional to the wheel speed.

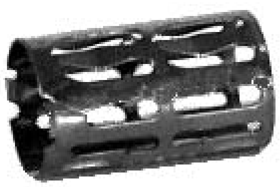
Design types

The rod sensor has been developed specifically for use in commercial vehicles. Good temperature stability and resistance to vibration ensure that it operates reliably even under extreme conditions.

The output voltage of newer WABCO sensors has been increased for the same wheel speed by modifying the internal design of the sensor. This ensures ABS and ASR reliability even at very low wheel speeds even if the air gaps have widened. These sensors are marked with a **K** or **S** or **S+** on the sensor head. They are compatible with the system and be used in exchanged with old sensors.

With the introduction of the VARIO-B wiring system, WABCO has included two sensor types with a sprayed-on coupling socket which, in combination with special sensor extension cables of various lengths, facilitate the installation in trailers.

Sensor installation



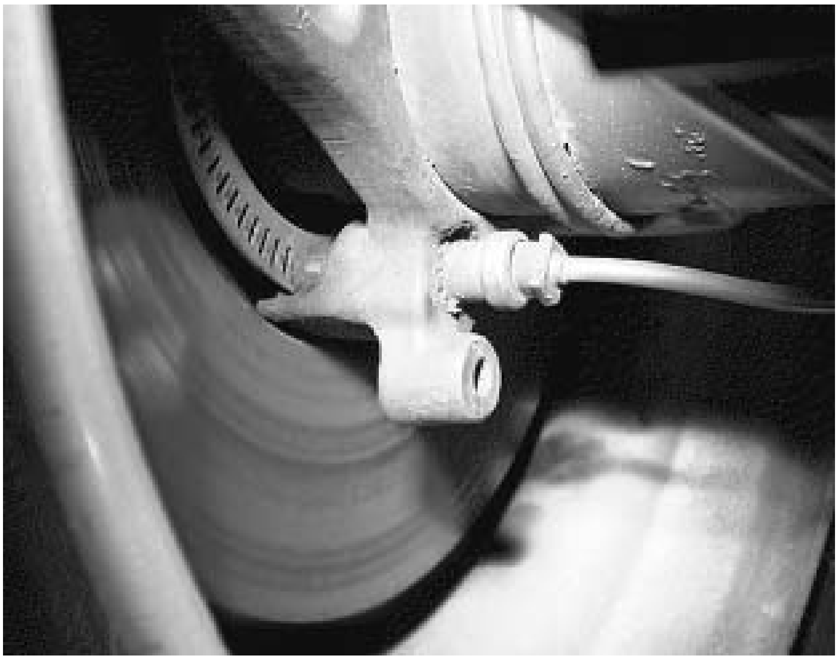
The speed sensor is mounted using **clamping bush 899 760 510 4** (CuBe) or **899 759 815 4** (CrNi) and mounting grease in a hole in the axle stub or in a special sensor holder. It is held in a sliding arrangement.

On the front axle the sensor is manually pushed all the way until stop into the clamping bush. At the rear axle or at the trailer axles, the sensor has to be pushed until stop into the clamping bush at the demounted wheel hub and by putting on the wheel hub pressed out that far, that the sensor fits in the toothed wheel.

Please note

There is no need to set a minimum air gap for the sensor since it sets its position automatically during the first couple of wheel rotations as a result of the wheel bearing play and the impulse wheel wobble.

Example for the Installation of a sensor on a trailer axle

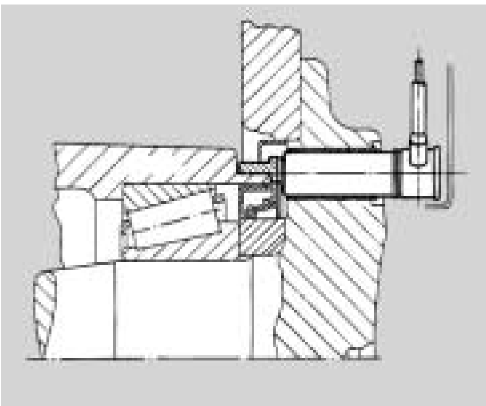


Lubricant

In applications which are exposed to greater contamination, we recommend using a clamping bush and sensor with a thermally stable grease which is also resistant to splashing water. This is in order to guard against corrosion of the hole in the axle stub and the penetration of dirt.

We recommend:	**"Klueber Staburags NBU 30 PTM"**
1 kg can	Order no. 830 502 063 4
8 g tube	Order no. 830 502 068 4

Maintenance



As well as regularly checking the wheel bearing play, you should push the sensor back in **by hand** as far as the stop when working on the wheel brake.

In order to adjust the speed sensor (if the air gap is too large) never use force or an unsuitable tool such as pointed or sharp objects. Doing so may otherwise lead to damage to the sensor cap!

When replacing a sensor, it is advisable to replace the clamping bush at the same time.

Testing

Resistance of the sensor coil, proper setting for the air gap and the sensor/wheel allocation can be tested using the ABS Tester or the Diagnostic Controller.

ABS Solenoid Valves 472 195 ...0

Purpose

During a braking process, the solenoid control valves adjust the brake cylinder pressure as a function of the control signals received from the ECU. On the powered axle they are also used for ASR differential brake control.

They permit the following ABS functions:

– Pressure build-up

– pressure hold

– Pressure release

Design types

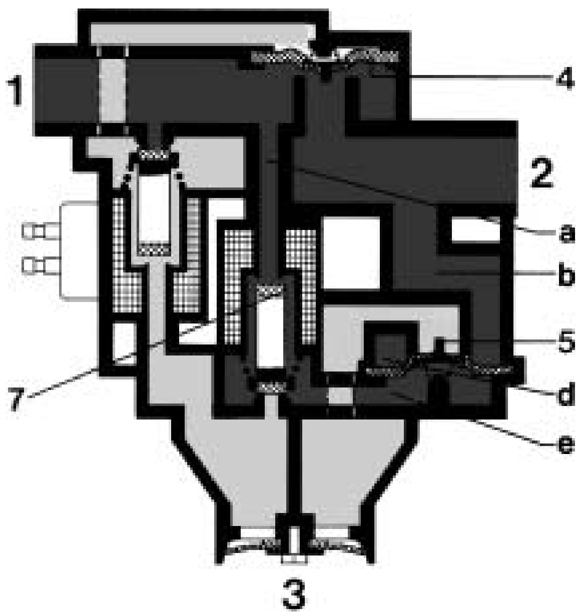
Solenoid control valves are available for on-board voltages of 24 and 12 volts.

The various types vary in terms of different connecting threads (metric screw-threads, inch-based threads, stepped hole for Voss plug-in connections) and in the way the connecting plug is fastened (Kostal screw-in plug, bayonet locking or snap fastener). For special-purpose vehicles, a water-crossing variant is also available.

Operation

The valve consists of a double solenoid and two diaphragm sections. The very rapid solenoid valves merely release the pressure from the pilot control chambers of the diaphragms. These then control the brake cylinder pressures via corresponding cross-sections.

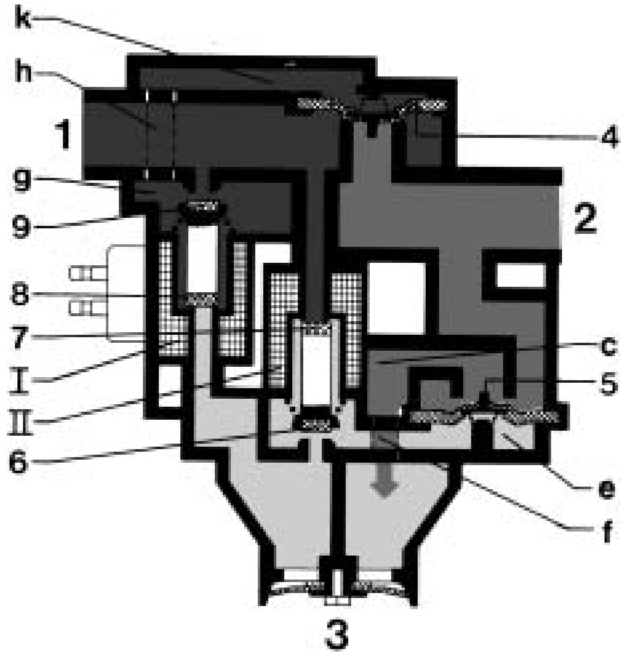
a. Pressure build-up



Neither of the solenoids (I and II) have been energized (neutral position).

The input pressure from port **(1)** immediately opens the inlet diaphragm (4). This causes chamber (b) to be pressurized, and the compressed air flows via port **(2)** to the brake cylinder and into annular duct (d) above the outlet diaphragm (5). At the same time, compressed air flows through duct (a), via the open valve into chamber (e) beneath the outlet diaphragm (5). Unless actuated, the solenoid will not reverse. Any increase in pressure in port **(1)** is passed on through port **(2)**. The same applies vice-versa whenever the pressure is reduced.

b. Pressure Reduction

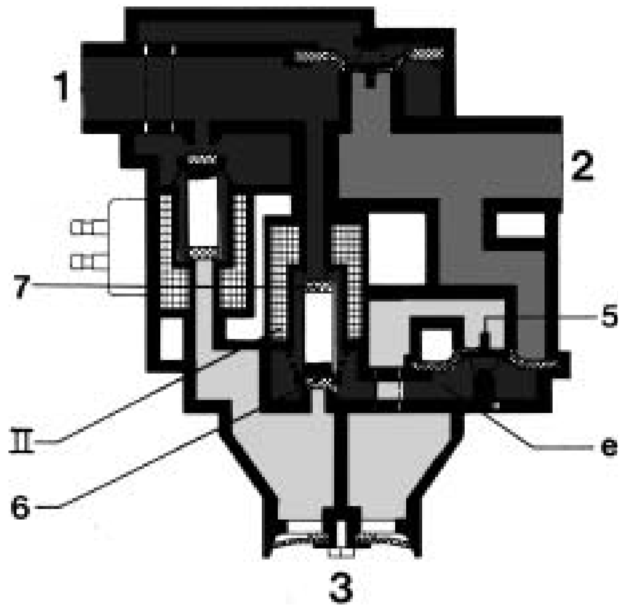


Both solenoids (**I** and **II**) are energized. Solenoid **I** (inlet valve) closes valve (8) and opens valve (9). The compressed air from port **(1)** thus flows through chamber (g), duct (h) and into chamber (k) where it closes the inlet diaphragm (4).

Solenoid **II** (outlet valve) closes valve (7) and opens valve (6). This causes the pressure in chamber (e) to be reduced via vent (3). The outlet diaphragm (5) opens.

The braking pressure at port **(2)** escapes to atmosphere through chamber (c), duct (f) and vent **(3)** until the solenoid valve reverses.

c. Pressure hold



Only solenoid **I** (inlet valve) is energized. Since solenoid **II** (outlet valve) is switched off, valve (6) is closed and valve (7) opened. This allows the pressure from port **(1)** to flow into chamber (e), closing the outlet diaphragm (5). The solenoid control valve is thus in the “pressure hold“ position.

Maintenance

No maintenance is required beyond the checks required by law.

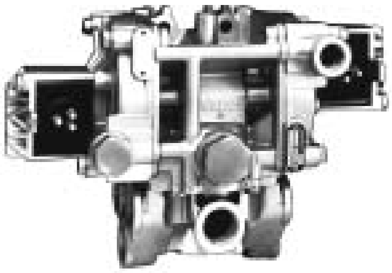
Testing

Resistance of the solenoid coils, proper functioning of inlet and outlet solenoids and proper wheel allocation can be tested with the ABS Tester or the Diagnostic Controller.

ABS Solenoid Relay Valve 472 195 02. 0 resp. 472 195 04. 0

Purpose

472 195 02. 0



472 195 04. 0

472 195 02. 0 472 195 04. 0

The ABS relay valve is used in trailer ABS VARIO-C. Its purpose is to control the brake cylinder pressure for ABS control.

It permits the three ABS functions:

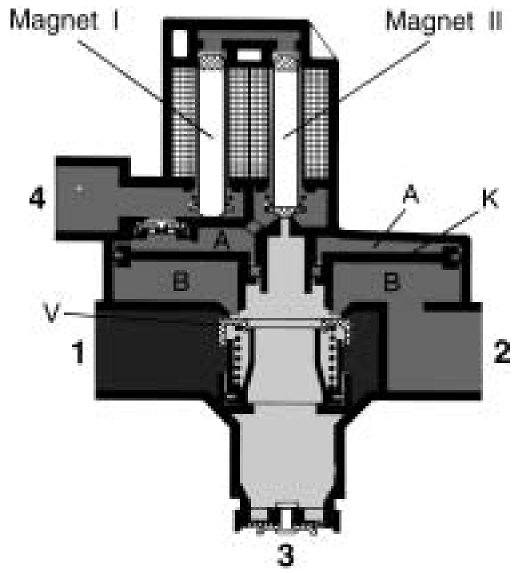
- Pressure build-up
- pressure hold
- Pressure release

When not actuated (solenoids not energized), the valve operates like a relay valve and rapidly increases or decreases the pressure in the brake cylinders.

Design types

The ABS solenoid relay valve is available for on-board voltages of 24 volts (475 195 020 0) or 12 volts (472 195 021 0). In addition to that there is the **flat twin valve** available (472 195 04 . 0). In this valve two ABS relay valves with common connections for control and supply pressure are put together to one compact valve.

Operation



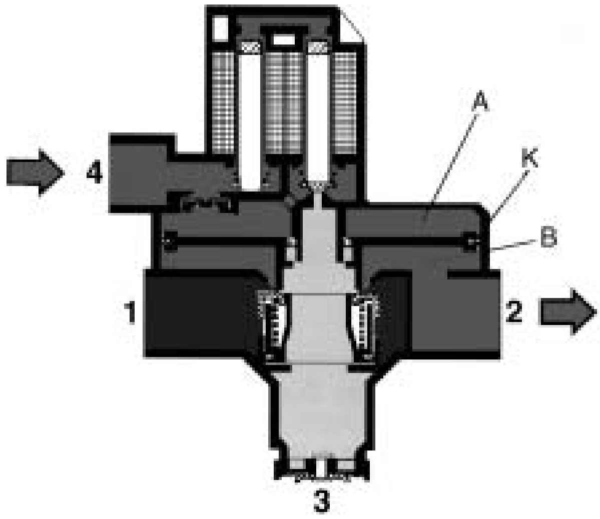
The input pressure from port **4** (e. g. 1 bar) passes solenoids **I** and **II**, which are in a neutral position, and flows into the upper piston chamber A, pushing piston K downwards. The piston rests on valve V, closing the outlet and opening the inlet. The air supply at port **(1)** flows via chamber B and port **(2)** to the downstreamed brake cylinders.

At the same time, pressure builds up in chamber B, acting on the underside of piston K. Since the piston's upper and under sides have similar surfaces, the inlet is closed by valve V as soon as the pressure in chamber B is identical to the input pressure in chamber A. A final position has been reached.

When the pilot pressure at port **(4)** falls, piston K is pushed upwards by the pressure in chamber B. The outlet opens and the pressure at port **(2)** is reduced similarly via vent **(3)**.

Functions of the ABS

a. Pressure build-up



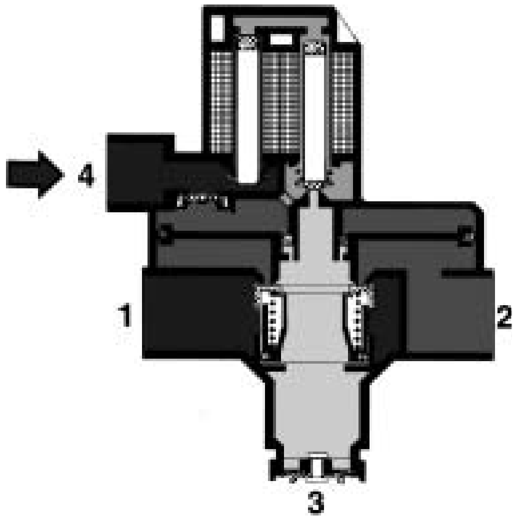
The solenoids are not energized.

Pilot pressure acts on **(4)**.

There is a visible gap between the annular piston and the sealing surface.

Air flows from **(1)** to **(2)**.

b. Pressure hold



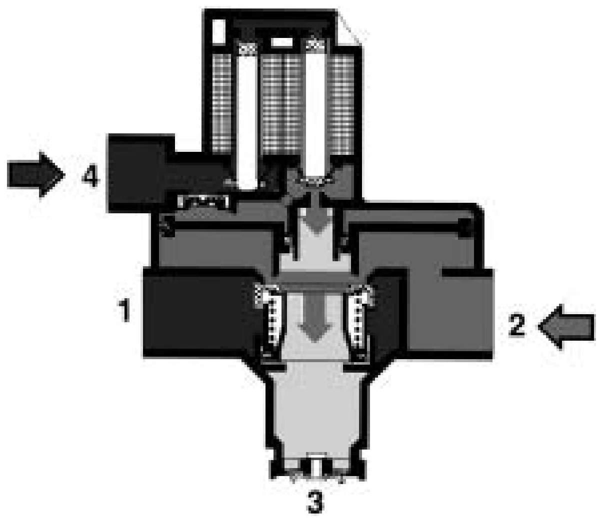
Solenoid I has been excited. The armature has retracted. Thus the air passage from **(4)** to chamber A is interrupted (in spite of the increasing pilot pressure).

The pressures in chambers A and B are similar.

The annular piston rests on the seats.

Air can neither flow from **(1)** to **(2)**, nor can it exit through **(2)**.

c. Pressure Reduction



The solenoid has been excited, the anchor has attracted. The solenoid is in its neutral position again.

1. Pilot pressure closed against chamber A.
2. The raised seal at the foot of solenoid **II** allows the air from chamber A to escape to atmosphere through the inner opening of the annular piston.

This causes piston K to be raised, and the gap which is now visible at the annular piston allows the air to escape from B, port **(2)** and the connected brake cylinder.

Instructions for Setting and Testing

As before described on the ABS solenoid valve.

Additional Components for ASR

Differential Brake Valve 472 1.. … 0

These are fitted upstream from the solenoid control valves. When actuated by the ECU, they control the reservoir pressure for the solenoid control valves independently from the brake valve.

While in the ASR B and C-generation for every driving wheel an own differential brake valve has been required, in the D-generation just only one valve is installed. If a differential brake control is necessary it controls the supply pressure towards the ABS solenoid valves of both driving wheels. The ABS valve of the wheel which should not be braked is The wheel is then switched in the jamming position (keep pressure).

Diagnostic cable 472 250 ... 0

The propotional valve is preconnected for the operating cylinder and controls because of the pressure flowing through it the positon of the regulator lever on the injection pump.

The output pressure is directly related to the - from the ABS/ASR electronic (checked by means of pulse stretching modulation (PWM)) output solenoid current for the proportional valve.

The low hysteresis offers a wide range of control cylinder pressures, which allow both very fast and virtually stationary altering movements of the regulator lever possible. Because of that the appliance can also be used for speed limiting (SL_{prop}).

Two-way valve 434 208 ... 0

These are fitted between the differential brake valves and the solenoid control valves. The two-way valves allow alternate actuation of its downstreamed solenoid control valve, both for the service brake and for **ASR control**.

The following delicate supply and evacuation of air of the downstream brake in case of an **ABS or ASR control process** is taken over by the respective ABS solenoid valve.

While in the ASR B and C-generation for every driving wheel an own differential brake valve has been required, in the D-generation just only one valve is installed. If a differential brake control is necessary it controls the supply pressure towards the ABS solenoid valves of both driving wheels. The ABS valve of the wheel which should not be braked is The wheel is then switched in the jamming position by the ECU (keep pressure).

Two-way valve 534 017 ... 0

In order to permit alternate pressurizing of the operating cylinder, another two-way valve with smaller cross-sections must be fitted between the engine cut-off valve and the engine control valve.

Often the design 534 017 ... 0 is used.

Operating Cylinder for mechanical engine control 421 44. ... 0

The operating cylinder is located within the control linkage between the accelerator pedal and the fuel-injection pump. Its type and dimensions depend on the kind of engine and fuel-injection pump used.

When actuated by the engine control valve, the operating cylinder moves the fuel-injection pump towards its idle position.

Idle stop cylinder 421 444 ... 0

On single-lever fuel-injection pumps, an additional idle stop cylinder prevents that the engine is being switched off during an ASR control process or a an speed limiting.

For switching off the engine the operating cylinders and the idle stop cylinder have to be actuated at the same time.

This is dispensible on twin-lever pumps since switching off is achieved by a second lever not affected by **ASR**.

ABS Control of the Engine Brake or of a Retarder

ABS for motor vehicles has also been designed for controlling the engine brake or a retarder. This is achieved by means of an all-or-nothing circuit. Through a signal from the ECU, a relay actuates a solenoid valve which blocks the air supply for the engine brake cylinder and exhausts the cylinder.

With retarders, the control process is similar; the all-or-nothing signal actuates the electrical retarder control via a relay.

If the engine brake or the retarder are operated on their own, and if one rear wheel or both rear wheels on the axle with sensors show excessive slip, the engine brake or retarder is switched off until the tendency to lock no longer applies. It is then automatically switched on again until a tendency to lock is perceived once more, or until the driver switches it off.

If the engine brake and the service braking system are actuated simultaneously, the pressures of the service brake and the engine brake are controlled whenever a tendency to lock is perceived.

Differential lock circuit in lorries with All-Wheel Drive Using ABS

If the driver actuates the (“longitudinal”) differential lock for the transfer gear between front and rear axles, the longitudinal lock is usually opened automatically when ABS control commences, and kept open until the end of the braking process.

ABS Reversal for Off-Road Use (A and B Types)

Normal ABS function is designed for normal road conditions. In order to achieve the shortest possible stopping distance also for heavy off-road applications in the construction and military sectors, lorries for such applications nowadays allow the A and B versions of ABS to be switched off at speeds below 15 k. p. h.

For this purpose, the driver needs to actuate an “off-road ABS” switch and the ABS failure lamp flashes as soon as the system is deactivated at speeds below 15 km/h and the wheels might lock.

Off-Road ABS C Type

Optionally the C version offers a special “off-road ABS logic” which provides the normal ABS function within the upper speed range but which allows greater wheel slip at speeds below 40 km/h and which allows the wheels to lock at speeds below 15 km/h.

This permits higher deceleration values to be achieved in off-road operation by allowing the wheels to “dig in” temporarily whilst maintaining a certain degree of stability and steerability.

The ABS failure lamp will flash to let the driver know that “off-road ABS” is active. For newer vehicles the legislator requires a shifting down on the “road logic” automatically after switching the ignition off and on.

Safety Circuit, Detecting Faulty Components and Measures to be taken

The Safety circuit

When the ignition is switched on or the engine is started, the safety circuit briefly energizes the solenoid valves and also checks the other essential ABS and electronic components.

If all ABS components operate without any faults and if sufficiently high alternating voltages are then produced when starting of all sensors the warning lamp - which was switched with the ignition - goes out at a speed of approx. **7 km/h**. In newer vehicles it goes out already after **approx. 2 seconds** after the ignition is switched on if the appliance was recognises with any problems and if there was no current fault on the latest drive.

Monitoring Process whilst the Vehicle is in Motion

Not only are the control signals and the solenoid actuations continuously passively monitored for plausibility, essential components such as solenoids, sensors and wiring are subject to cyclical monitoring processes whilst the vehicle is in motion (with or without application of the brakes).

In addition, the components within the ECU continuously monitor each other.

System Reactions at Faults

If within the ABS system an electrical fault appears, the driver is alerted through the failure lamp (SILA).

The safety circuit will switch off or alter the control process in such a way that any undue impairment of braking safety is avoided and at least normal braking performance is maintained.

Depending on the system layout used, the dual-circuit 4- or 6-channel systems and the single-circuit VARIO-C (6S/3M to 2S/1M) trailer systems may, in terms of the remaining ABS function, react differently to individual defects in components.

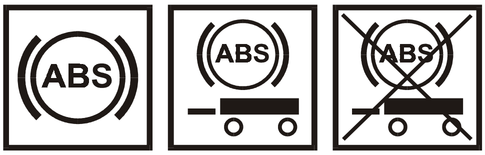
Any error will cause the SILA to come on, at least for as long as the defect persists. Intermittent contact will cause the SILA to stay on until the ignition is switched off, and it will come on again only if the defect occurs again when the ignition is subsequently turned on.

C-generation ECUs also store the error in the non-volatile error memory.

Mechanical Defects

Any mechanical defects on the control valves, especially those which can cause leakages and thus a loss in pressure, are not perceived by the ABS safety circuit. They can only be detected - like similar defects in other components of the braking system - by the driver, or when the vehicle is being serviced (special brake test or intermediate inspection).

ABS/ASR Control Lamps



Example

The motor vehicle usually has three control lamps for indicating functions and monitoring the ABS system: two failure lamps (SILA), and one indicator lamp.

- ABS Warning Lamp for Motor Vehicles
- ABS Warning Lamp for Trailers
- ABS Information Lamp for the information of the driver (no duty equipment)

If the ABS is installed in the vehicle in general an ASR lamp is added.

The Warning Lamps (SILA)

a. SILA (red) for the Motor Vehicle:
This comes on when the ignition has been switched on. It goes off as soon as the vehicle has exceeded a speed of approx. 7 k. p. h. and the ABS safety circuit has perceived no errors.

b. SILA (red) for the Trailer:
This comes on when the ignition has been switched on provided a trailer which uses ABS has been attached and the ABS connector plugged in. Like the SILA for the motor vehicle, it goes off as soon as the vehicle has reached a speed in excess of 7 km/h, provided no error has been detected.

Both warning lamps stay off even when the vehicle stops in traffic (e. g. at a red traffic light).

When the ABS failure lamps have gone off, the anti-lock braking system is operational. However, ABS control will not commence until one or several wheels show a tendency to lock when the brakes are applied.

Important Note

The driver must make sure that the failure lamp(s) has (have) gone off when he has set the vehicle in motion! If a SILA does not go off at speeds in excess of 7 k. p. h., or if it comes on while the vehicle is moving, the respective ABS system is defective.

Warning!

Drive at a shining warning lamp carefully! The braking behaviour of the vehicle can change

To remedy this defect, the vehicle must be taken to an authorized workshop as soon as possible.

The Indicator Lamp (yellow)

The indicator lamp shows the driver whether a trailer with or without ABS has been attached. It will stay on once the ignition has been switched on if the motor vehicle is pulling a trailer that has no ABS, or if the ABS connection for trailer ABS has not been plugged in.

The indicator lamp will **not** come on if the trailer has ABS or when the motor vehicle is being driven without a trailer.

The indicator lamp is no duty equipment!

ASR Lamp

With ASR equipped vehicles have in general one further control lamp: the **ASR Lamp** This informs the driver about the stepping in of the **ASR** and he is warned of a slippery road.

For testing the lamp the ASR lamp shines shortly **approx. for 1 second** after switching on the ignition.

During the drive the **ASR lamp is shining**

– if there is an ASR regulation (slippery road warning for the driver)

– at integrated speed limiting GB_{Prop} if the “2nd limit speed” dialed by the driver by activity of the ASR/speed set switch is reached.

– If the ECU has detected ASR/GB_{Prop} faults (e. g. Interruption of the electronical cables to the prop. valve.)

The **ASR lamp is blinking** steadily if the ASR button or by integrated GBProp the ASR/speed set switch stands in position “ASR off-road” for slip threshold rise.

Furthermore the version of a flashing code can be carried out **via the ASR lamp** at towing vehicles with C or D version of the ABS unit for **diagnosis purposes** if a pushbutton key obstructed to this is pressed.

When is a further-reaching check of the ABS necessary?

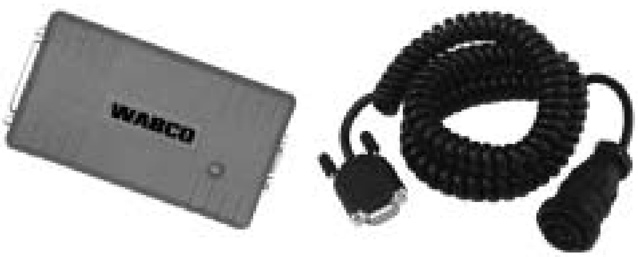
The ABS must be examined whenever the failure lamp (SILA) comes on while the vehicle is moving, or if it does not go off after it has moved off.

ISO Diagnosis using the Diagnostic Controller

The electronic control units of the C-generation for motor vehicles and those of the VARIO-C generation for trailers have an integrated error memory and a diagnostic interface to **ISO Standard 9141**.

WABCO has developed the **Diagnostic Controller** which uses this interface to read out, display in plain writing, and eventually delete any errors stored, their nature, and their frequency. The Diagnostic Controller cannot be used only for WABCO ABS but also for other WABCO system ECUs. The respective test programme is made available in the form of individual **programme cards**. They include a guide through the testing procedure without necessitating any additional test instructions.

ISO Diagnosis via PC and the Diagnostic Controller



In addition to the familiar Diagnostic Controller WABCO offers also **diagnosis via the PC**. For ABS C- and D-generation in the vehicle and for VCS-ABS in the trailer and further electronical WABCO-systems we offer corresponding **Diagnostic Software**.

In connection with the Diagnostic Interface from WABCO the software offers an extensive and convenient diagnosis.

ISO Diagnosis wth the Compact-Tester

With the reasonably priced Compact-Tester for the ABS of the towing vehicle (C- and D-generation) or the trailer ABS (VARIO C and VCS) can be selected and deleted himself in a simple way of the fault lofts.

Depending on the system special functions (e g System baptism, test, selections of the kilometer point integrated in the VCS etc.) are possible.

WABCO -Flash-Code

A limited but still useful and low-cost way to diagnose any defects is the flash-code implemented in C-type ECUs.

By connecting a special diagnostic line (L-line) to earth, a flash-code can be excited. For C-ABS/ASR for motor vehicles, the ASR display lamp is used to display the code; for VARIO-C trailer ABS, it is the failure lamp (SILA). Going by a flash-code list, it is possible to ascertain whether the system is defective, and if so, what type of defect has been perceived.