Hydraulic ADD-ON ABS system

System description

1st edition

WABCO

Vehicle Control Systems
An American Standard Company

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1. Introduction

This publication dealing with the WABCO hydraulic ADD-ON anti-lock brake system 4S/4M 12 V (HABS), WABCO system part number 400 050 ... 0, is intended for workshop engineers, drivers and companies installing the system in their vehicles.

In addition to operating information, it contains additional technical details and safety instructions. Furthermore, this publication is intended to help the workshop engineer to maintain, repair and diagnose faults in the system.

In this publication, WABCO is also offering some information for companies who install the system in their vehicle, in order to assist them in terms of vehicle design.
More information about the system can be obtained from our Service Hotline, telephone number 0180 223 2337, or on the Internet at www.wabco-auto.com.

2. General operating and safety instructions

2.1 Hydraulic brake system

Brakes are a primary safety component, incorrect work on brakes may result in them failing to operate. Only trained personnel are allowed to perform any maintenance and repair work on the brake system. Take care to maintain absolute cleanliness when working on the brake system. Disconnect the negative battery terminal before starting any work on the electrical system.

The driver of the vehicle is responsible for performing the following work:

- ☞ Checking the brake fluid level
- ☞ Checking the effectiveness of the brake system

Checking the fluid level

The fluid level must always be between the MAX and MIN marks.

A slight reduction in the fluid level takes place in the course of normal driving and is caused by the automatic adjustment of the brake pads (wear).
However, there may be a leak in the brake system if the fluid level drops significantly within a short period of time.

Changing the brake fluid

Brake fluid is hygroscopic, which means it absorbs water. Excessive water content in the brake fluid markedly reduces its boiling point. This can result in brake failure if the wheel brakes are very hot.

As a result, the brake fluid must be changed in accordance with the vehicle manufacturer's instructions.

Warning!

Brake fluid is poisonous!
Consequently, always keep it sealed in its original container and in particular store it out of the reach of children.

Furthermore, bear in mind that brake fluid also attacks the vehicle's paintwork.

Due to the disposal problem, the need for special tools and the technical expertise required, you should only have your brake fluid changed by authorised specialist personnel.

Wear eye protection when changing the brake fluid. If brake fluid comes into contact with any parts of your body during or after the necessary work, immediately wash it off with soap and water.

Seek immediate medical attention if any is swallowed or you get any in your eye.

3. System description

This chapter describes the basic functions of the anti-lock brake system and its tasks, as well as the general structure of the system with its mechanical and electrical features.

3.1 Abbreviations

To aid understanding, it is necessary to present a few basic definitions before explaining the functions of the system.

ADD-ON system
An add-on system can be installed into an existing, conventional dual-circuit service brake system

HABS
Hydraulic anti-lock brake system

ABS
Anti-lock brake system

ECU
Electronic control unit

EBD
Electronic brake force distribution

ETC
Electronic traction control
(traction help)

BWL
Brake warning light

Four-channel modulator
The brake pressure on each individual wheel is controlled by one outlet and one inlet valve each, i.e. there are four outlet and four inlet valves in the modulator.

Drive shaft
This is the axle which carries the torque from the engine to your wheels. It may also be a steering axle, depending on the type of vehicle.

MIC
Modified individual control
(ABS control algorithm)

4S/4M
4 wheels fitted with sensors and 4 wheels with brake pressure control.

12V
Vehicle electrical system voltage
V = 12 volts

3.2 System structure

The vehicle's brake system consists of a hydraulic brake master cylinder with a brake booster as the actuation device and four hydraulic wheel brakes on the front and rear axles.

The WABCO ADD-ON ABS system consists of:

1. A four-channel brake pressure modulator. The brake pressure at each wheel is controlled by an outlet and an inlet valve. If the brake pressure drops during ABS braking, a return pump pumps the brake fluid back into the brake master cylinder (closed system),

2. four speed sensors with impulse wheels which constantly monitor the speed of each wheel,

3. and a central electronic control unit (ECU).

The ECU processes the four speed signals from the wheels and causes the solenoid valves to be actuated. The appropriate solenoid valves are pulsed according to the requirements, in order to maintain, reduce or increase the brake pressure.

Furthermore, the ECU monitors its own functions and checks the electrical components of the system. The ECU automatically switches over to safe mode if a component fails. In such cases, the normal function of the service brake is assured.

An ISO 9141 diagnostic interface forms part of the ECU. This permits messages stored during operation to be downloaded from the ECU's memory chip.

3.3 Basic functions and tasks of the anti-lock brake system

The principal task of the ABS system is to guarantee that the vehicle can still be steered and holds its course during braking.

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.

If the critical locking point of the wheels is reached during braking, the brake pads are pulsed (released and reapplied) within fractions of a second. This permits the wheels to continue to turn and means that the vehicle can still be steered, even during full braking.

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.

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.

Requirements on ABS:

- ABS must work even at very slow speed.
- ABS must adapt to the coefficient of friction of the carriageway without delay.
- It must still be possible to steer the vehicle when cornering.
- ABS must also detect aquaplaning and react accordingly.
- Engine braking must not influence anti-lock brake control.
- If a fault is detected which impairs the ABS function, the underlying brake system must continue to operate correctly.
- A check lamp must clearly signal the ABS failure.

Advantages of ABS:

- Guarantees stable braking characteristics on all road surfaces.
- Means the vehicle can still be steered and, as a rule, shortens the braking distance.
- 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.

Despite the above, you should not expect that ABS will reduce the braking distance under all circumstances. The braking distance may even be slightly longer when driving on gravel or new snow on a slippery base (grit/snow wedge) when in any case you should only ever drive slowly and with the utmost care.

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

Operation:

The stationary sensor continuously picks up the rotary motion of the wheel by means of the impulse wheel. The electrical pulses generated in the sensor are sent to the electronic control unit which uses them to calculate the speed of the wheel.

At the same time, the electronic control unit utilises an internal mode to calculate a reference speed which approximates to the indirectly measured vehicle speed.

Using all this information, the electronic control unit continuously calculates the wheel acceleration or deceleration values as well as the amount of brake slip.

The modulator is activated whenever certain slip values are exceeded. This causes the pressure in the brake to be restricted, maintained or even lowered. As a result, the wheel is kept within the optimum slip range.

3.4 An ABS control loop

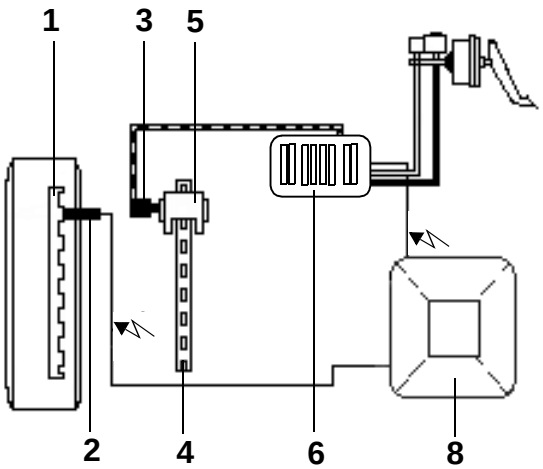


Fig. 1

1 = Impulse wheel

2 = Sensor

3 = Brake cylinder

4 = Brake disc

5 = Brake calliper

6 = HABS modulator

7 = Master cylinder

8 = Electronic control unit

Graphic representation of the ABS control cycle

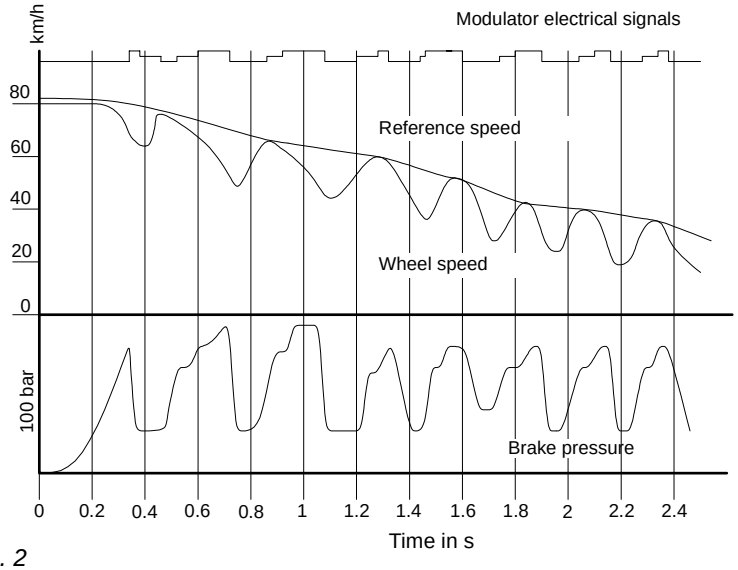


Fig. 2

Example: The recording relates to the control of a wheel. The initial speed of the vehicle is 80 km/h.

The horizontal axis (X-axis) shows the control cycles over time.
The bottom third of the vertical axis (Y-axis) shows the brake pressure while the reference and wheel speeds are shown in the middle third. The pulses of the solenoid valve are shown in the top third.

The control procedure:

The driver presses the brake pedal. 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.

A corresponding trigger signal is sent to the integrated ABS solenoid valve installed in the modulator, which rapidly reduces the pressure in the brake cylinder of this wheel. The wheel begins to accelerate again.

The electronic control unit changes over the solenoid valve settings (modulator), thereby keeping the brake pressure constant until the wheel is once again in the stable slip range.

If more brake force can now be transmitted, the brake pressure on the brake is increased further by pulsing (i.e. alternating between maintaining pressure and increasing pressure). A new control cycle starts if the wheel speed once again drops markedly in relation to the reference speed of the ECU.

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.

3.5 What the driver needs to know

Notes:
In case of faults in the brake system

- The ABS warning light comes on
- The vehicle swerves during acceleration (if ETC is fitted)
- The wheels lock up during braking
- The ETC light comes on and remains lit
- The EBD light comes on and remains lit

always contact an authorised specialist workshop. Because parts of the overall ABS system are not functioning, one or more wheels could lock up when the brakes are applied. Take greater care.
However, the brakes will still function although without ABS.

In case of pulsation (vibration) of the brake pedal

- ABS control is in progress, a slight noise can be heard as the control system operates
- The vehicle has reached an absolute limit zone. Adjust your driving style and speed to match the road conditions.
- To achieve an optimum braking effect, continue to press down the brake pedal as before even when ABS control is in progress and in spite of the pulsation felt at the brake pedal. ”Pumping“ the brake pedal may reduce the braking effect of ABS and therefore increase the braking distance.

The brake pedal

- As soon as a brake circuit fails, the driver will notice that it is necessary to press the brake pedal down much further. If this happens, the pedal should be pressed through its idle stroke rapidly.
- Make sure nothing impairs the free movement of the pedal. Do not place any additional floor mats or the like under the pedal since they might restrict braking in the case just described.

Driving on unconsolidated ground

- Actuate the brakes carefully when driving on surfaces with a soft, deep covering such as in deep powder snow, sand or gravel. The braking distance may be longer under certain circumstances. Under such conditions, the braking distance may be shorter if the wheels lock up as in a system without anti-lock brakes (due to the wedge of material which forms). However, ABS offers the advantage of ensuring that the vehicle remains stable and can still be steered.

Driving on gradients

- Driving on steep gradients with a low coefficient of friction and braking the vehicle to a halt may result in a situation where the vehicle starts to slide with its wheels locked up. This is because the ECU only gets information about the motion of the vehicle if one or more wheels are turning. In order to initiate ABS control if the vehicle starts sliding from stationary on a steep gradient, you must quickly release the brake and apply it again so that the ECU gets the information that the vehicle is moving.

Road safety does not just depend on a comprehensive range of safety features, but also requires a responsible driving style.

4. Mode of function

This chapter takes a detailed look at the mode of function of WABCO ADD-ON ABS. The individual functions involved are MIC, EBD and ETC.

Mode of function of the ADD-ON ABS system

The WABCO ADD-ON system ensures the vehicle remains stable and can still be steered during braking, and minimises the braking distance under most road conditions.

The ECU continuously registers the speed of all wheels using the speed sensors. The ABS algorithm determines whether any wheel is starting to lock up and this causes the ECU to activate the corresponding solenoid valves in the modulator in order to adjust the brake pressure at the wheel brake. The brake pressure is set so the wheel continues to turn while still transmitting the greatest possible brake force.
As a rule, every wheel is individually controlled depending on the adhesion between its particular tyre and the carriageway. In case a carriageway has varying coefficients of friction, modified individual control (MIR) is performed in order to reduce the yawing moment on the front axle. In this way, an optimum compromise is reached between stability/steering ability and deceleration.

By way of example, a front axle is examined which is braked with its left wheel on dry asphalt and its right wheel on ice (see Fig. 3).

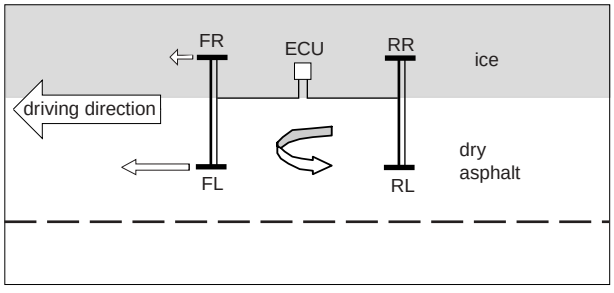


Fig. 3 Vehicle on different road surfaces

4.1 Why modified individual control (MIC)?

Vehicles with a short wheelbase are difficult to control during full braking on carriageways with different coefficients of friction on each side and when cornering if they have straightforward individual control (IC). Since the braking forces which result are different on each side, this produces a yaw moment and these factors make the vehicle hard to control.

Fig. 4 shows by way of example the principle of a control loop with the most important control parameters, the wheel deceleration threshold -b, the wheel acceleration threshold +b and the slip thresholds λ_1 and λ_2.

The wheel undergoes continuous increasing deceleration or braking as the brake pressure increases. At point 1, the braking of the wheel is greater than a value which cannot be physically exceeded by the vehicle braking. The reference speed corresponded to the wheel speed up to this point, but afterwards it deviates and reduces at a slight deceleration compared to a theoretically specified high level of vehicle deceleration

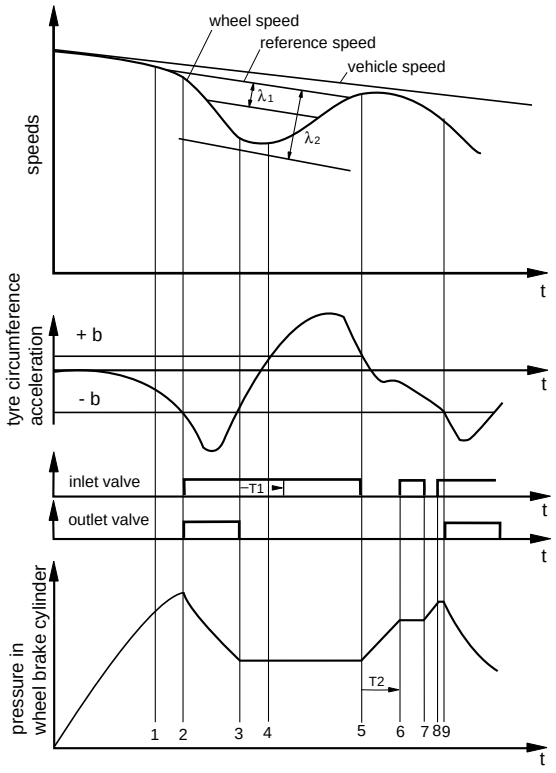


Fig. 4

The threshold value for wheel deceleration -b is exceeded at point 2. The wheel characteristics are now in the unstable range. The wheel has now reached its maximum braking force.

Any further increase in the braking torque does not further increase the braking of the vehicle but exclusively contributes to increasing the wheel deceleration.

For this reason, the brake pressure is rapidly reduced. The braking of the wheel is reduced. This delay time is largely determined by the hysteresis of the wheel brake and by the profile of the $\mu-\lambda$ slip characteristic in the unstable range.

Only once the wheel brake hysteresis has been overcome (continuation of an effect after cessation of its cause) does continuing the pressure reduction actually lead to a reduction in the braking of the wheel.

The wheel deceleration drops below the threshold value -b at point 3, and the brake pressure is kept constant for a defined time T1.

Normally, the wheel acceleration exceeds the acceleration threshold +b within this defined time (point 4). The brake pressure is kept constant for as long as this threshold continues to be exceeded. If the +b signal is not reached within the time T1 (for example on a low-friction surface), the brake pressure is further reduced by means of the slip signal λ_1. The higher slip threshold λ_2 is not attained during this control phase.

The value drops below the threshold value +b at point 5; the wheel is now in the stable range of the $\mu-\lambda$ slip characteristic.

The brake pressure is applied with a steep gradient for the time T2 in order to overcome the brake hysteresis. Time T2 is defined for the first control cycle and then recalculated for every subsequent control cycle. Following the first steep-gradient application phase, the pressure is then increased by "pulsing" (alternating between pressure holding and pressure application).

This logical principle as shown in this example is by no means a set process. Instead, it adapts to the dynamic behaviour of the wheel in response to varying coefficients of friction, i.e. it uses an intelligent system control. All threshold values are based on several different parameters such as the vehicle's speed, the braking of the vehicle, etc.

4.2 How the anti-lock brake system operates

When the wheel brakes of the vehicle are applied, ABS makes optimum use of the surface friction for braking. It ensures that the wheels continue to turn so the vehicle remains manoeuvrable. This is guaranteed by the anti-lock brake system control components. These components evaluate the rotation speed of the wheel and adjust the braking procedure to match the road conditions. Depending on the requirements, the brake pressure is reduced, increased or kept constant using solenoid valves. This is so the wheels continue to turn and optimum braking is assured. The values are controlled by the ECU in accordance with the ABS algorithm.

Every wheel has two solenoid valves, and inlet valve and an outlet valve. If the inlet valve is closed, the pressure in the wheel brake cylinder and in the line is maintained. The pressure is reduced if the outlet valve is opened whilst the inlet valve is closed. The pressure is increased if the inlet valve is opened whilst the outlet valve is closed (providing the brake pedal remains fully depressed).

During ABS control, the solenoid valves are pulsed, which allows the brake pressure of the hydraulic fluid to be set in finely spaced stages.

4.3 Purpose of electronic brake force distribution (EBD)

The EBD module is intended to guarantee the necessary locking sequence (front axle before rear axle) like a pressure reduction valve; it replaces the pressure reduction valve on the rear axle.

The optimised brake force distribution during partial braking manoeuvres (long before ABS control intervention is required) increases utilisation of adhesion on the rear axle with less force being required at the pedal.

How EBD operates

When the vehicle's brakes are applied, EBD guarantees the specified locking sequence is achieved (front axle before rear axle), so that the vehicle will remain stable and can be steered during partial braking manoeuvres. This is guaranteed by the ABS control components which evaluate the wheel speed and set the brake pressure at the rear axle.

Every wheel needs a solenoid valve in order to function correctly. If the inlet valve is closed, the pressure in the brake cylinder and in the line is maintained. The pressure is increased if the inlet valve is opened whilst the outlet valve is closed (providing the brake pedal remains actuated).

4.4 Purpose of electronic traction control (ETC)

In a speed range from zero to 50 km/h, electronic traction control ETC guarantees the maximum possible traction and constant vehicle stability with minimum steering intervention. If braking takes effect on a wheel which is spinning, the corresponding torque is transferred via the axle differential to the wheel with the higher coefficient of friction. The limits of traction control are represented by the maximum engine or braking torque and the available adhesion between the tyres and the carriageway.

How the ETC system functions

The ETC system uses largely the same components as the ABS, i.e. wheel speed sensors, an ECU and a modulator with integrated ABS solenoid valves for each wheel. Using the ABS wheel speed signals, the algorithm in the ECU calculates the speed difference between the wheels on one axle. As a result, it can determine when a wheel is slipping excessively. The electronic control unit actuates the return pump and the ABS solenoid valves of the modulator in order to direct hydraulic power to the brake. The brake pressure is then adapted by the corresponding ABS solenoid valves of the modulator. The pressure at the spinning wheel is increased until the speed of both wheels is once again synchronised.
This means a torque is transmitted to the wheel which is not spinning. ETC is switched off as soon as the electronic control unit detects a fault in the vehicle wiring harness or in the system components.

4.5 Anti-lock brake system warning light

The purpose of the ABS warning light is to display a malfunction of the electronic or electrical ABS components or of the entire system. A self-test of the ECU and the connected electrical circuits is performed when the ignition is switched on.

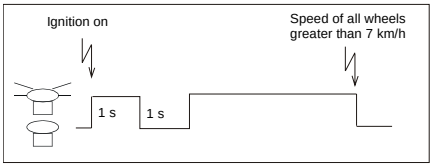


Fig. 5 ABS warning light function (following initial start)

Function of the ABS warning light

The light comes on when the ignition is switched on. It then goes out for about 2 s and comes back on until all wheels with sensors have exceeded a road speed of 7 km/h for the first time. This provides an optical indicator that the system self-test has been performed successfully. If the 1 s light off phase does not take place, this means a fault has been detected first and stored in the non-volatile memory. If a fault is currently present, the light remains continuously lit even when the vehicle is driving.

4.6 ETC light

The ETC function is available between 0 and 50 km/h, as soon as the ignition is switched on and the ECU has completed its self-test. A yellow display light indicates when the ETC function is operating.

If a fault occurs, both the ETC display light and the ABS warning light come on.

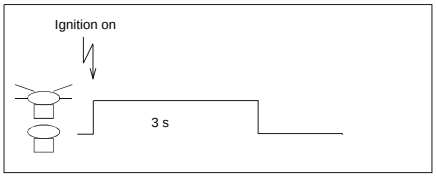


Fig. 6 ETC and brake warning light function

4.7 Mode of operation without electronic traction control

At this point, drawings are used to describe the three phases of pressure buildup, pressure holding and depressurisation. First of all, the procedures are explained with the help of a modulator without ETC.
Fig. 7 shows:

- Four inlet valves (solenoid control valves) (1)
- Four outlet valves (solenoid control valves) (2)
- Expander chamber (3)
- Pump system with pressure and suction valves (4)
- Electric motor (6)
- Four brakes (7)
- Brake pedal with brake booster master cylinder (5)

in rest position.

4.7.1 Pressure buildup:

If the driver now actuates the brake, a pressure is built up (displacement of volume) which is channelled directly to the brakes by the medium of the brake fluid flowing through the open inlet valves. The vehicle is decelerated (no ABS control). When the brake pedal is released, the pressure at the brakes is reduced through the inlet valves which remain open. The brake fluid flows through the system via the master cylinder and back into the tank.

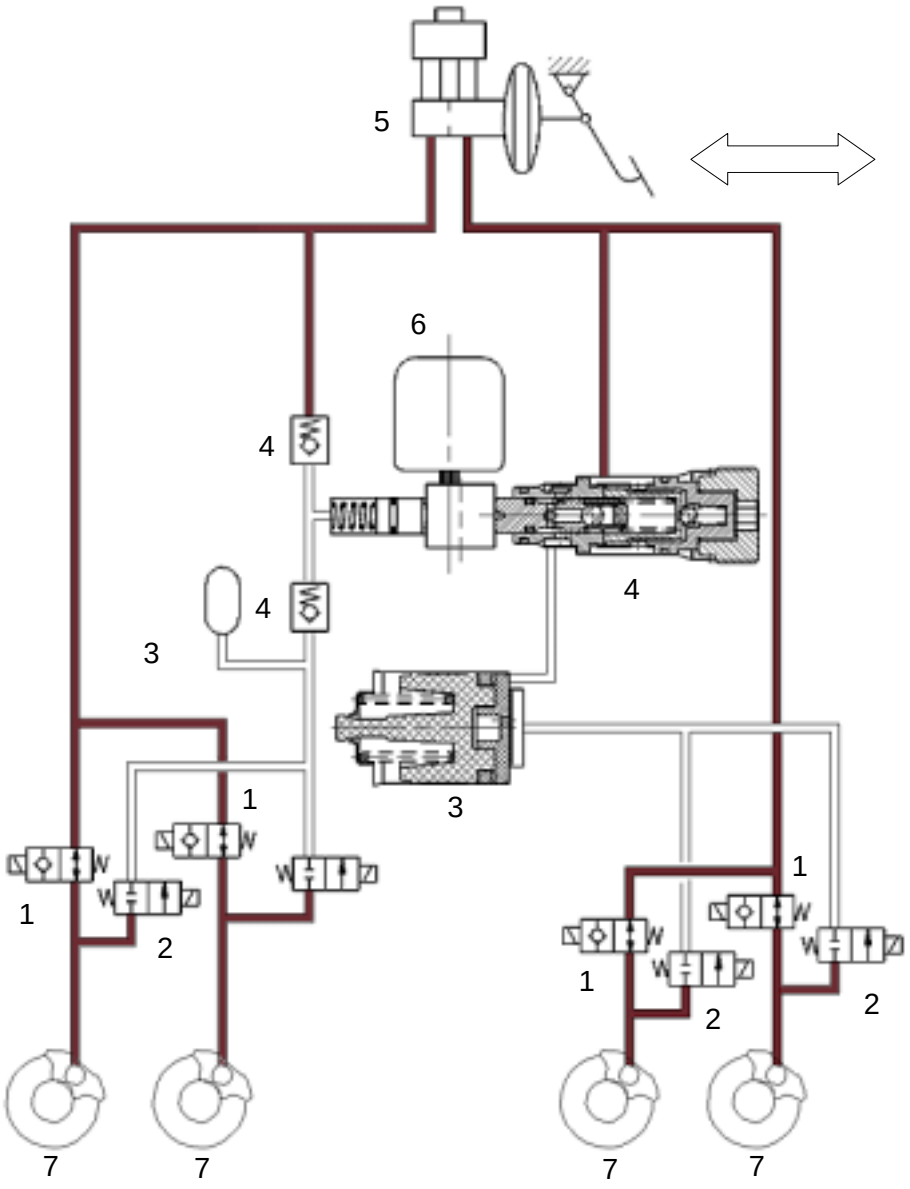


Fig. 7

4.7.2 Pressure holding:

If the ECU now detects via the speed sensors that one or more wheels (in the example in Fig. 8, the rear left wheel) are starting to lock up during a deceleration procedure, the corresponding inlet valves are activated and closed in order to prevent any further pressure buildup (the wheel remains in the stable range). The outlet valves remain closed for the moment. The driver continues to press down on the brake.

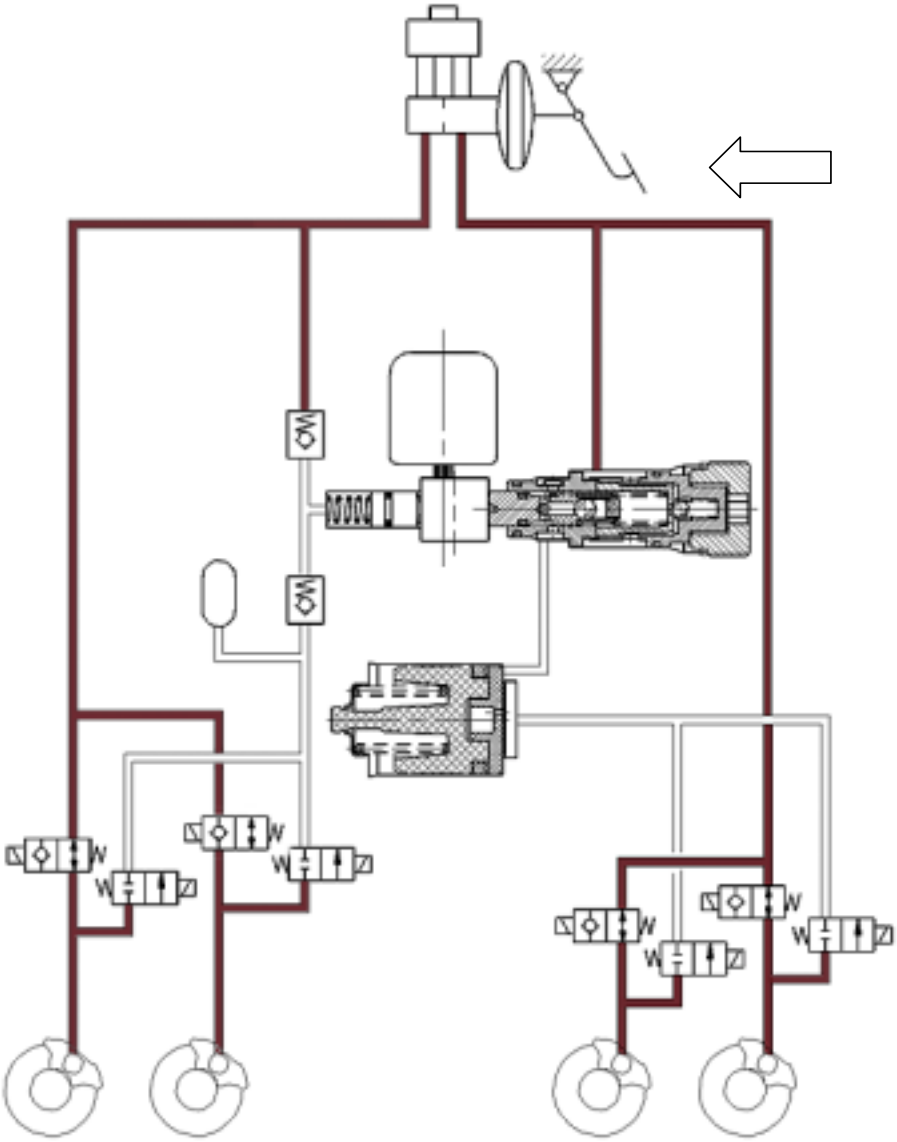


Fig. 8

4.7.3 Depressurisation:

As the wheel deceleration continues to increase with the pressure held constant, the outlet valve is activated and opened (in this figure, it is the wheel at the rear left). This means the brake fluid flows through the valves into the expander chamber and is pumped by the pump system though the suction and pressure valve back into the circuit against the force applied by the driver at the pedal.

If the driver continues to press down the brake pedal, the outlet valve is closed and the pressure at the wheel in question is built up again by pulsing of the inlet valve. This entire procedure from pressure buildup to depressurisation starts all over again if anti-lock brake system control is still necessary.

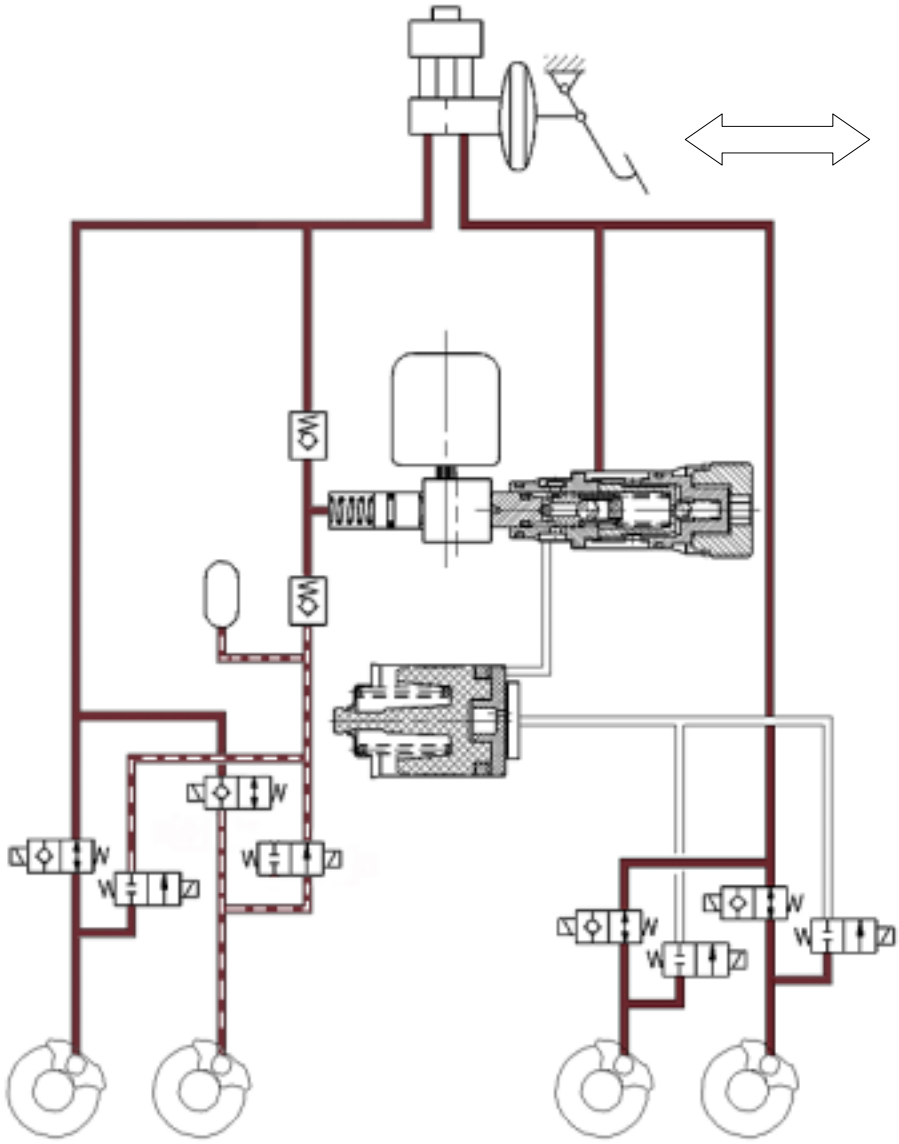


Fig. 9 Front axle Rear axle

4.8 Mode of operation during electronic traction control

Secondly, the procedures are explained with the help of a modulator with ETC.
Fig. 10 shows the brake pedal with master cylinder and brake booster (1), the ETC valve with switch (2), the filling piston (3), the pump system (4), the suction and pressure valves (5), the dampers (6), the system valves (7), the expander chambers (8), the inlet valves (9) and the outlet valves (10) in their initial positions.

4.8.1 Pressure buildup / pressure holding / depressurisation

If the driver presses down the brake, a pressure is built up (displacement of volume) as in the case of the system without ETC. This pressure is channelled directly to the brakes using the medium of the brake fluid flowing through the ETC valve and the vehicle is decelerated. During ABS control, the principle of the system without ETC takes effect. When the brake pedal is released, the pressure at the brakes is reduced through the inlet valves which remain open.

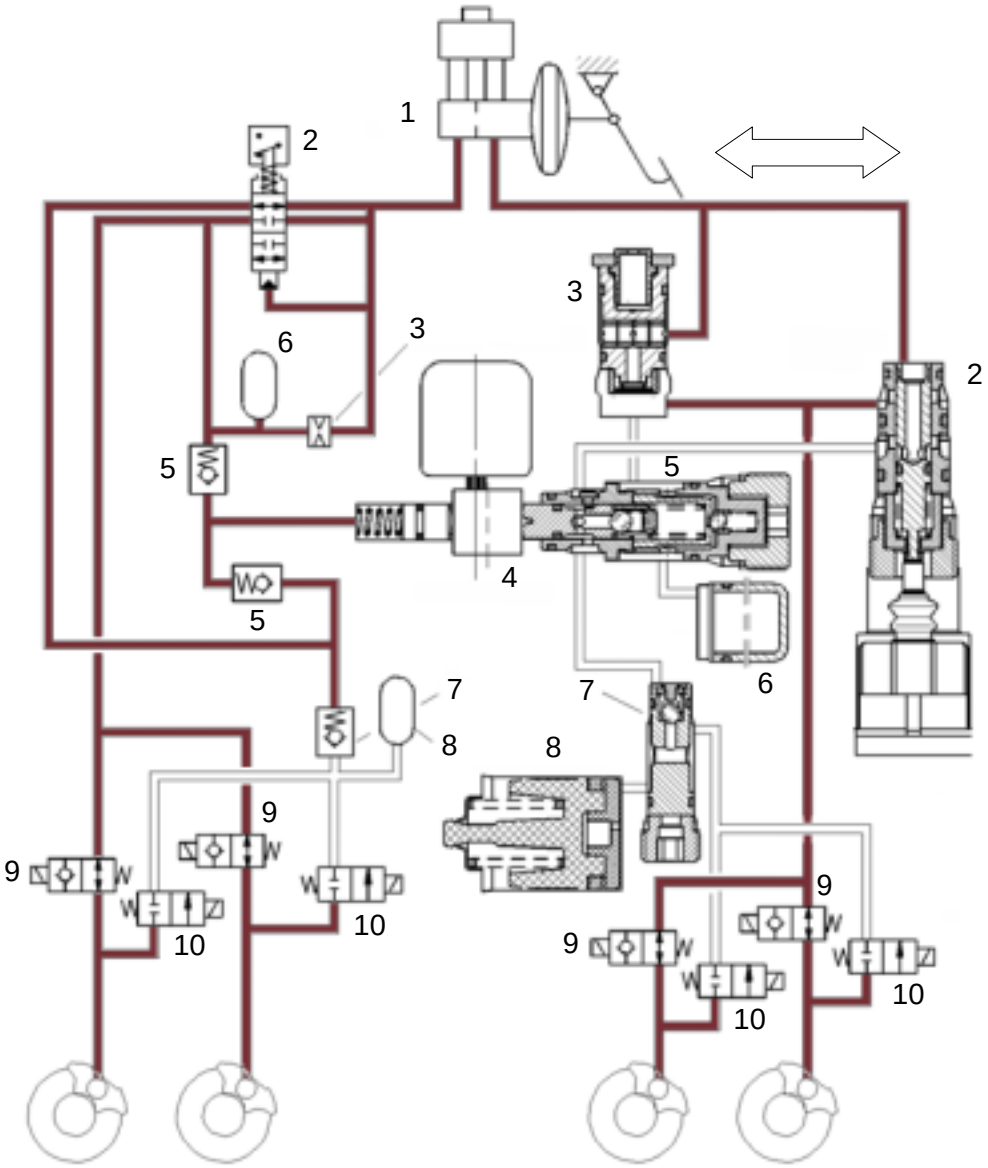


Fig. 10

4.8.2 Control with electronic traction control

Information is supplied to the ECU from the bar sensors. ETC control takes effect if the ECU detects from this information that there are different wheel speeds in the system when moving off. In this drawing, the rear right wheel is subject to ETC control. This involves the motor of the pump system starting and the three inlet valves of the wheels which are not spinning are closed. Brake fluid is drawn from the tank through the master cylinder by the suction valve of the pump system. This brake fluid is pressurised in the pump system using an orifice in the filler piston.

From there, the pressure is directed through the only open inlet valve to the spinning wheel and causes this to be braked. Pulsing of the inlet valve similar to the situation during ABS control causes this procedure to be carried out until all wheels once again share the same speed. If this is the case, the motor of the pump system is switched off by the ECU. The pressure is dissipated through the orifice, through leakage and through the opened outlet valves. If the driver presses the brake during ETC control, ETC is immediately switched off and the closed inlet valves are opened.

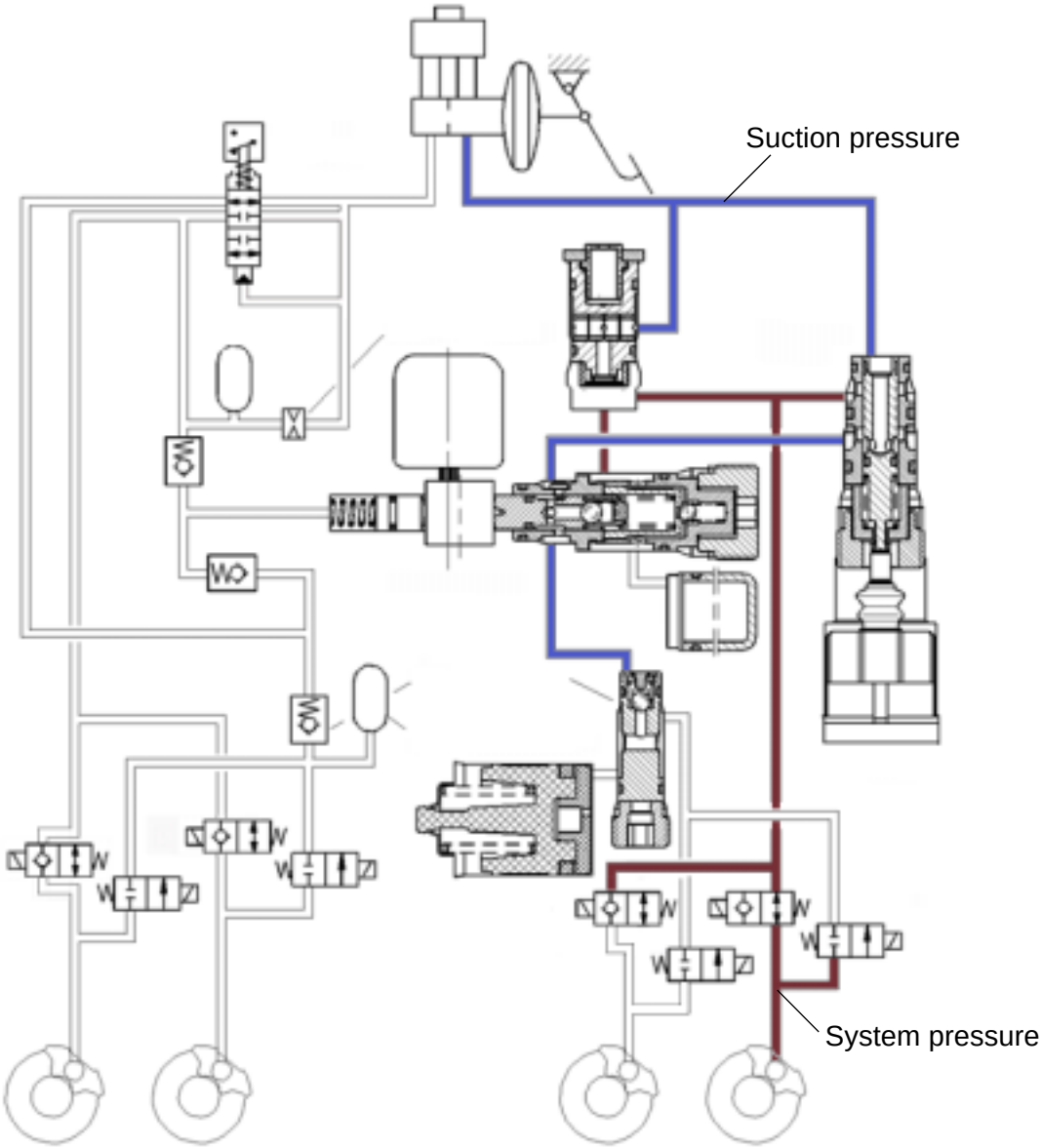


Fig. 11

5. Components

In this chapter, the drawing below is used to explain the individual components of the WABCO ADD-ON ABS system. Furthermore, the description focuses on the aspects of inspection, installation position and cabling.

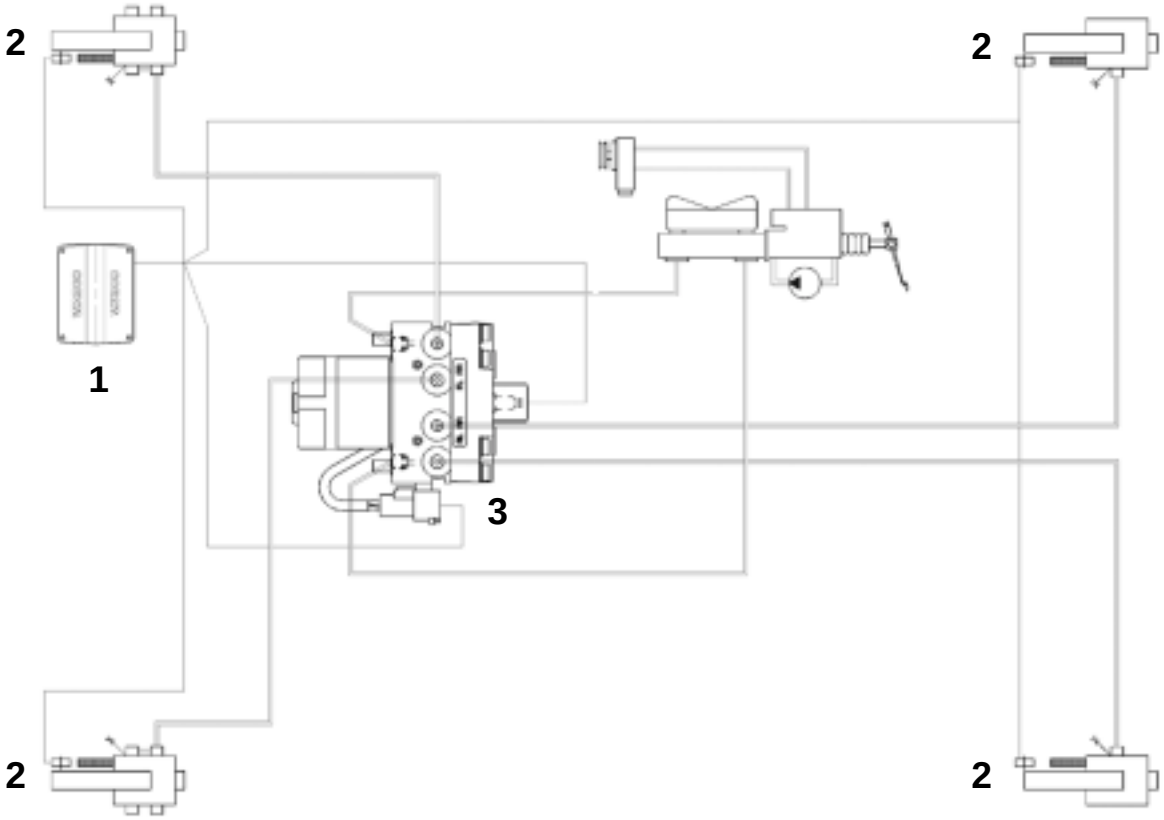


Fig. 12 Cabling and piping diagram

1. ECU
2. Speed sensor
3. ADD-ON ABS (4M) modulator

ECU 446 044 ... 0
446 109 ... 0

Task:

The electronic control unit (ECU) uses the wheel sensor signals to calculate the road speed and the wheel speeds as well as the wheel deceleration and acceleration values. If required, it activates solenoid valves in the modulator in order to prevent the vehicle's wheels from locking.

The 4-channel electronic control units have a dual-circuit structure. Each circuit monitors two diagonally opposed vehicle wheels and can be subdivided into four functional groups:

– 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.

The master circuit consists of a microcomputer. By means of a complex program, the control signals are calculated and used in logic functions. In addition, actuator signals are output for controlling the valves in the modulator.

The ECU signals to the driver with a warning light if there are any messages and, if necessary, switches off the control of one wheel, both diagonally opposed wheels or, in certain circumstances, the entire ABS system. The brake system remains fully functional in this case, it is merely that the anti-lock protection and the ETC function are partially or fully unserviceable.

Messages are permanently saved in the electronic control unit for diagnostic purposes. It is possible to read out and delete the message memory using the diagnostic connection (according to ISO standard).

The valve control units contain power transistors (output stages) which are activated by the signals coming from the master circuit and which switch the current for operating the control valves.

The non-steered axle(s) is/are controlled individually (IC). Modified individual control (MIC) is used for the steered axle.

Installation:

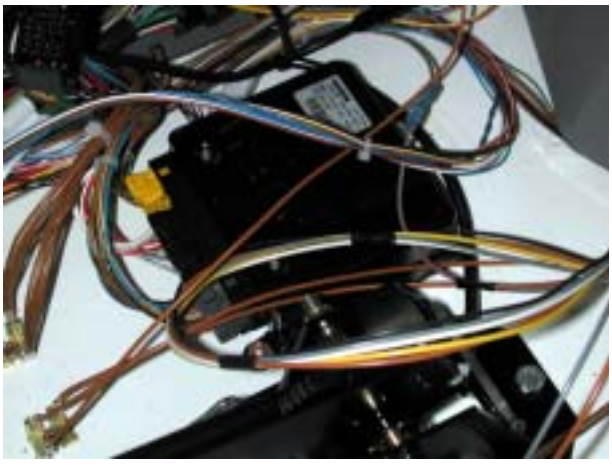


Fig. 13 Installation of the ECU in the Multicar in the area of the central tunnel

The electronic control unit is installed in the vehicle in a location where it is protected from splashing water.

Inspection:

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.

Note:

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

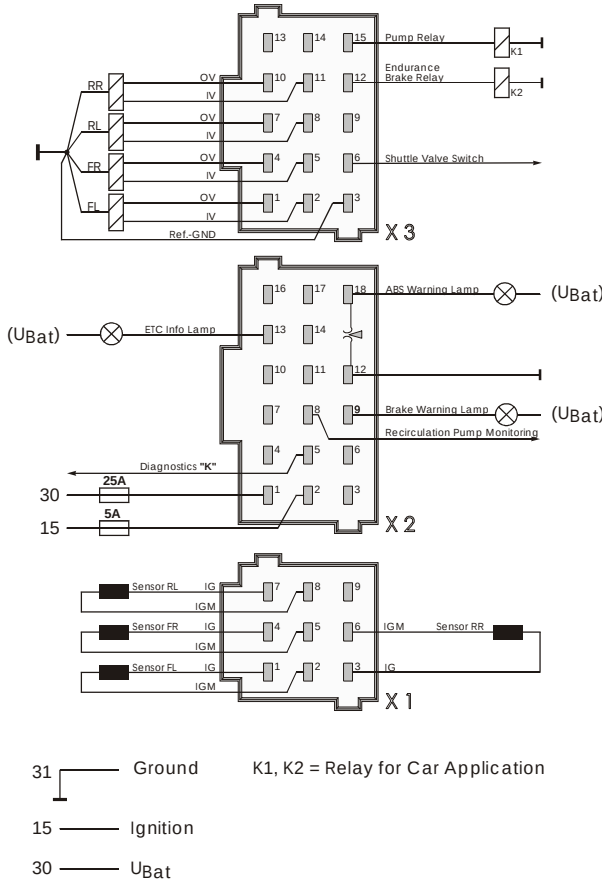


Fig. 14 Cabling diagram for maximum System configuration

Speed sensor 441 032 ... 0 and impulse wheel:

Task:

Using a proximity method, the stationary sensor detects the movement of an impulse wheel which rotates together with the vehicle's wheel. Impulse wheels for light and medium commercial vehicles have 80 teeth or fewer.

The output voltage of newer WABCO sensors has been increased for the same wheel speed by modifying the internal design of the sensor. As a result, ABS operation can still be assured even given increased air gaps and even at very slow wheel speeds. These sensors are identified by an **"S+"** on the sensor head.

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 speed sensor has been especially developed to cope with the more exacting requirements of a commercial vehicle. Good temperature stability and resistance to vibration ensure that it operates reliably even under extreme conditions.

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 and rear axles, the speed sensor is pushed into the clamping bush by hand up to the impulse wheel.
The wobble of the impulse wheel pushes the speed sensor axially outwards in the sensor hole after one or two turns of the hub by hand. It is moved out to the maximum extent of the impulse wheel wobble.

Fig. 15 Installation position of the speed sensor

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.

Technical data

Contact resistance
1150 +100/-50 ohms

Temperature range
-40 °C ... +150 °C

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: WABCO sensor grease

1 kg can Order no. 830 502 063 4

8 g tube Order no. 830 502 068 4

Maintenance:

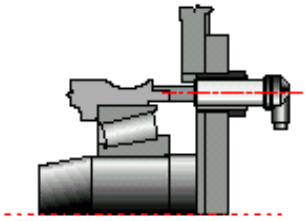


Fig. 16 Installation position of the components (sectional view)

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 speed sensor we recommend replacing the clamping bush as well.

Inspection:

The resistance of the sensor coil, the correct setting of the air gap and the assignment of the sensor to the corresponding wheel can be checked using the diagnostic controller and the corresponding program card for the system which is fitted.

ADD-ON ABS (4M) modulator 478 407 ... 0

Task

The modulator allows the brake pressure applied by the driver via the brake booster / master cylinder to pass through to the wheel brake cylinders. In addition, it is responsible for safeguarding the two brake systems in relation to one another in the event of a failure of one of these brake circuits, and to ensure brake pressure control (4 wheel channels) for ABS brake control with 2/2-way solenoid control valves.

Modulator installation

The modulator is installed in the vehicle's engine compartment below the master cylinder. All hydraulic lines to the master cylinder are to be routed upwards, while those to the wheel brake cylinders are to be routed downwards. The type, routing, length and dimensions of the line must be selected in consultation with WABCO.

WARNING NOTE

Replace the entire ABS modulator unit if it malfunctions!

Do not expose the modulator to shock loads or excessive vibration prior to its installation. Also, do not allow any compressed air to enter the hydraulic connection.

Figs. 17 and 18 Modulator installed in the vehicle's engine compartment

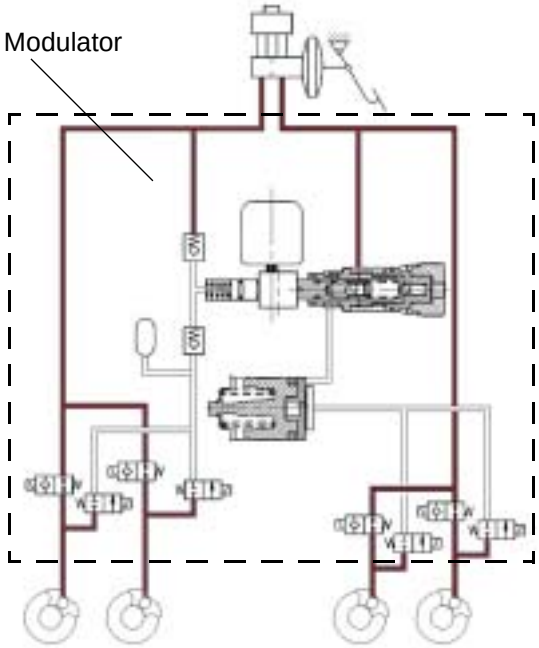


Fig. 19 Functional diagram of a modulator without ETC

6. Diagnosis

The term ”diagnosis“ refers to the following sub-functions:

- Startup at the manufacturing plant or during a modulator change
- **Startup at the end-user's premises, for example in the workshop**
- Fault storage, fault display
- Periodical checks
- Access to stored data

Diagnosis with the Diagnostic Controller

The Diagnostic Controller is a computer which can exchange data with control units (also a computer). Data includes the following:

– Stored fault messages in the ECU.

– Commands sent by the controller to the ECU which trigger certain procedures there.

A special program is needed in order to communicate with an ECU. The program is stored on the corresponding program card.

The program card must match the ECU!

The Diagnostic Controller set (446 300 331 0) consists of the following parts:

1.	Diagnostic Controller	446 300 320 0
2.	Carrier bag	446 300 022 2

Accessories:

3.	Program card	446 300 . . . 0
4.	Connection cable	446 300 329 2
5.	Multimeter cable black (not illustrated)	894 604 301 2
	Multimeter cable red (not illustrated)	894 604 302 0
6.	Keyboard	446 300 328 0

Fig. 20 Diagnostic Controller set

For notes and information about which electronic control units can be checked, visit www.wabco-auto.com on the Internet or call the hotline number 0180 223 2337.

Connecting the Diagnostic Controller to the vehicle diagnostic socket:

Attach one end of the connection cable to the Diagnostic Controller (Fig. 21) and the other end to the diagnostic socket in the vehicle's switch cabinet (Fig. 22).

Fig. 21 Diagnostic Controller with connection cable

Diagnostic socket

Fig. 22 Multicar switch cabinet

Diagnostic Controller connection

Ensure there is clear access to the diagnostic socket

Remove the protective cap

Use the connection cable (446 300 329 2) to connect the Diagnostic Controller (446 300 320 0) to the diagnostic socket

Release the handbrake, shift to neutral and switch on the ignition. Secure the vehicle to prevent it from rolling away!

There is no need to provide a power source for the Diagnostic Controller providing the ECU is powered by the vehicle's battery or another external voltage source.

Before plugging in the diagnostic card, ensure that the contact surfaces of the diagnostic card are clean. Otherwise malfunctions may occur

Refer to the booklet provided with the Diagnostic Controller or the diagnostic card for detailed operating instructions.

Respond to the questions, instructions and information displayed by the Diagnostic Controller.

To be on the safe side, check the identification data in the first menu item of the Diagnostic Controller in order to avoid subsequent communication messages. In this case, the ABS warning light and optionally the ETC light or the brake warning light come on.

Menu structure diagram taking the example of program card 446 300 784 0

Menu structure of hydraulic ABS D (4S/4M)

- 1 Diagnosis
  - 1 Diagnostic memory
  - 2 Control
    - 1 Lights
      - 1 ABS warning light
      - 2 Brake warning light *
      - 3 ETC info light *
    - 2 Pump
    - 3 Modulators
      - 1 Front right
      - 2 Front left
      - 3 Rear right
      - 4 Rear left
    - 4 Endurance brake cutoff relay *
  - 3 Measurement values
    - 1 Voltages
    - 2 Speeds
    - 3 Internal brake switch *
    - 4 ABD off switch *
  - 4 ECU data
    - 1 WABCO data
    - 2 Parameters
    - 3 Chassis number **
- 2 Startup
- 3 Multimeter
  - 1 Direct voltage
  - 2 Alternating voltage
  - 3 Resistance
- 4 Options
  - 1 Online help
  - 2 Version
  - 3 Supported ECUs
- 5 Special functions

* Only if fitted in the vehicle

** Only available after entering the PIN number

Use the keyboard to select the corresponding menu in order to download diagnostic messages from the memory.

Warning note

Check the brake fluid level if both the ABS light and the brake warning light come on. Take care even if the fluid level is adequate, since the locking sequence is not guaranteed.

The warning light should come on for 3 seconds when the ignition is switched on with the vehicle at a standstill. Otherwise the bulbs of the warning light or its cabling is/are defective. Replace the bulbs immediately in this case!

Note on the brake warning light

When the ignition is switched on with the vehicle at a standstill, the ABS warning light should come on as described, as well as the ETC and brake warning lights. Otherwise the bulbs of the warning light or the cabling is/are defective. Replace the bulbs immediately in this case!
Repairs in the area of the wheel sensors may result in increasing the air gap on individual sensors. To prevent releasing a vehicle for use in this situation, it is a requirement to delete the memory and to set the condition ”Sensor fault in last ignition cycle“. During the next inspection cycle of the ignition, the ABS light remains on until the vehicle exceeds 7 km/h.

- The size of all interacting tyres is allowed to deviate from the nominal value set in the parameters by ±8 %.
  Individual tyres are allowed to deviate from the nominal value by max. ±1.5 %.
- Modifications to the vehicle with the objective of increasing the overall speed or acceleration or modifications to the brake system may impair the function of the ADD-ON ABS system.

Electronic system

ECU inputs and outputs

Inputs	Connection
Wheel speed sensor front left	X 1 pin 1, X1 pin 2
Wheel speed sensor front right	X 1 pin 4, X1 pin 5
Wheel speed sensor rear left	X 1 pin 7, X1 pin 8
Wheel speed sensor rear right	X 1 pin 3, X1 pin 6
Battery voltage supply	X 2 pin 1
Ignition voltage supply	X 2 pin 2
Reference earth	X 3 pin 3
Switch for shutoff valve	X 3 pin 6
Pump monitoring	X 2 pin 8
Electronics earth	X 2 pin 12
Outputs	Connection
Brake warning light	X 2 pin 9
ABS warning light	X 2 pin 18
Outlet valve front left	X 3 pin 1
Inlet valve front left	X 3 pin 2
Outlet valve front right	X 3 pin 4
Inlet valve front right	X 3 pin 5
Outlet valve rear left	X 3 pin 7
Inlet valve rear left	X 3 pin 8
Outlet valve rear right	X 3 pin 10
Inlet valve rear right	X 3 pin 11
ETC info light	X 3 pin 13
Pump relay	X 3 pin 15
Fault number	Connection
K-line	X 2 pin 5

X 1 9-pin plug

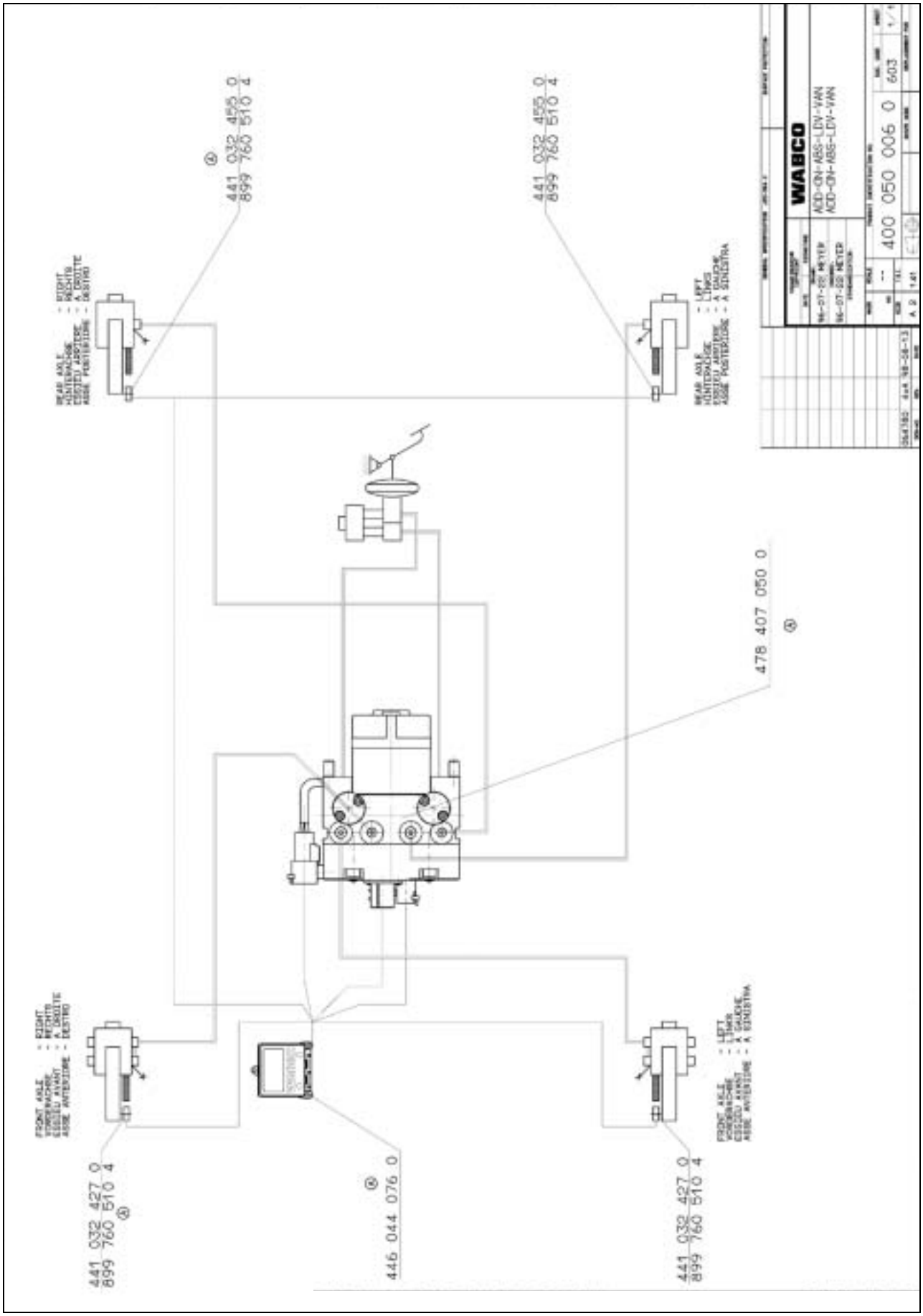
X 2 18-pin plug

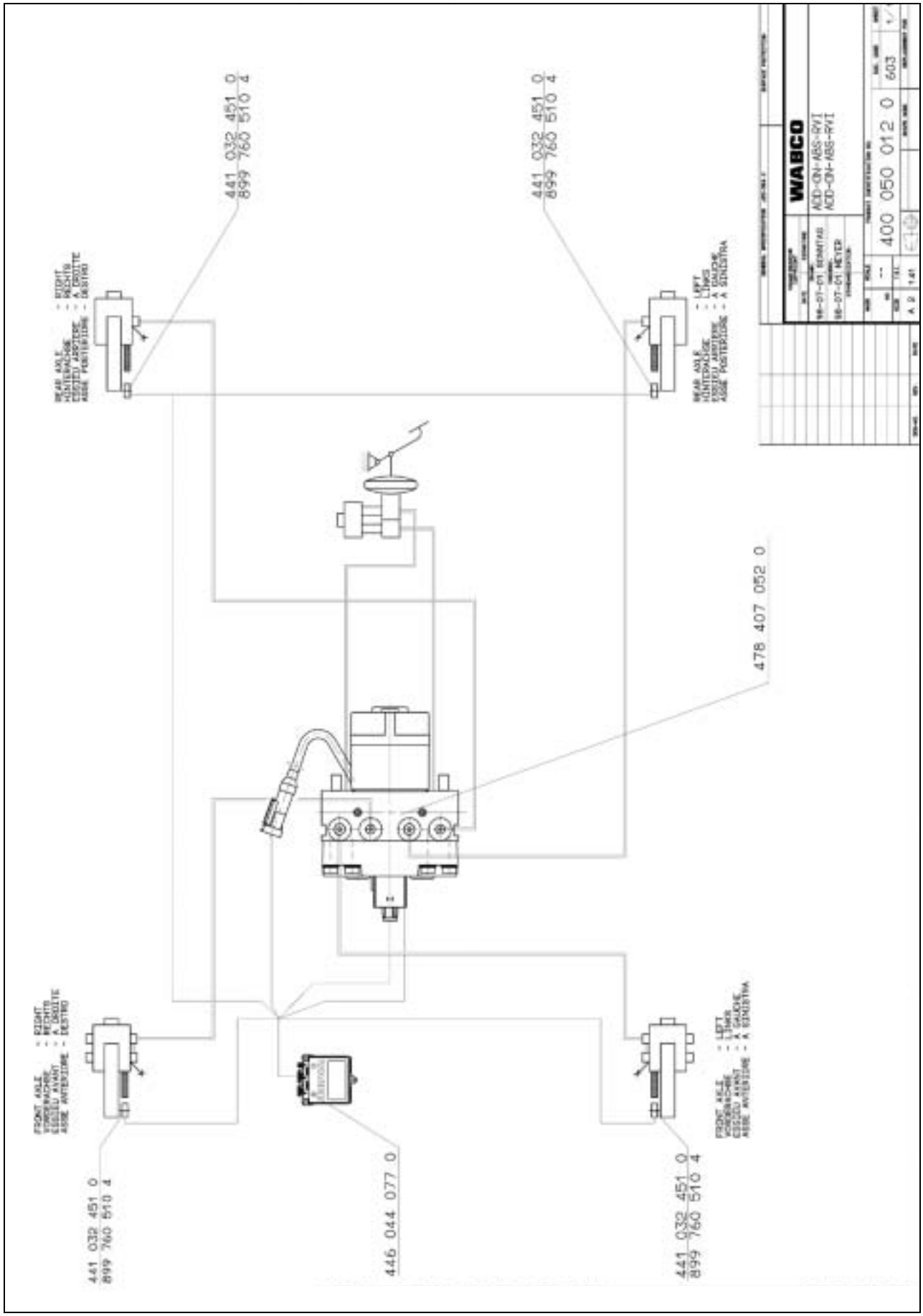
X 3 15-pin plug

List of ECU messages

This list can provide information about the type of fault and the method of rectification

Fault	Repair manual
Electronic control unit	Check the cabling and the cable plugs. Fit a new ABS electronic control unit if the fault reoccurs after the fault memory has been deleted
ABS modulator	Check the modulator cables. There is a continuous or temporary discontinuity / short circuit to battery voltage or earth in the inlet valve (IV) or outlet valve (OV) or a shared cable
ABS modulator earth connection	Check the modulator cables. There is a continuous or temporary discontinuity / short circuit to positive in the earth connection of the modulator.
Sensor air gap	Amplitude of the sensor signal too low. Check the bearing play and axial run-out of the impulse wheel, press the sensor against the impulse wheel. Check for a loose contact in the sensor cabling and plugs.
Sensor short circuit / open circuit	Check the sensor cabling. An open circuit, short circuit to battery voltage or earth or between the IG/IGM sensor cables is detected.
Pump monitoring defective or	Check the pump operation and the pump cabling.
pump cannot be switched on	Check the pump operation and the pump cabling.
Pump sticking	Check the pump operation and the pump cabling.
Pump relay fault (sticking)	Check the pump relay.
Internal fault	Fit a new ABS electronic control unit if the fault reoccurs.


441 032 455 0
899 760 510 4
441 032 455 0
899 760 510 4
478 407 050 0
441 032 427 0
899 760 510 4
446 044 076 0
441 032 427 0
899 760 510 4
WABCO
ADD-ON-ABS-LDV-VAN
ADD-ON-ABS-LDV-VAN
400 050 006 0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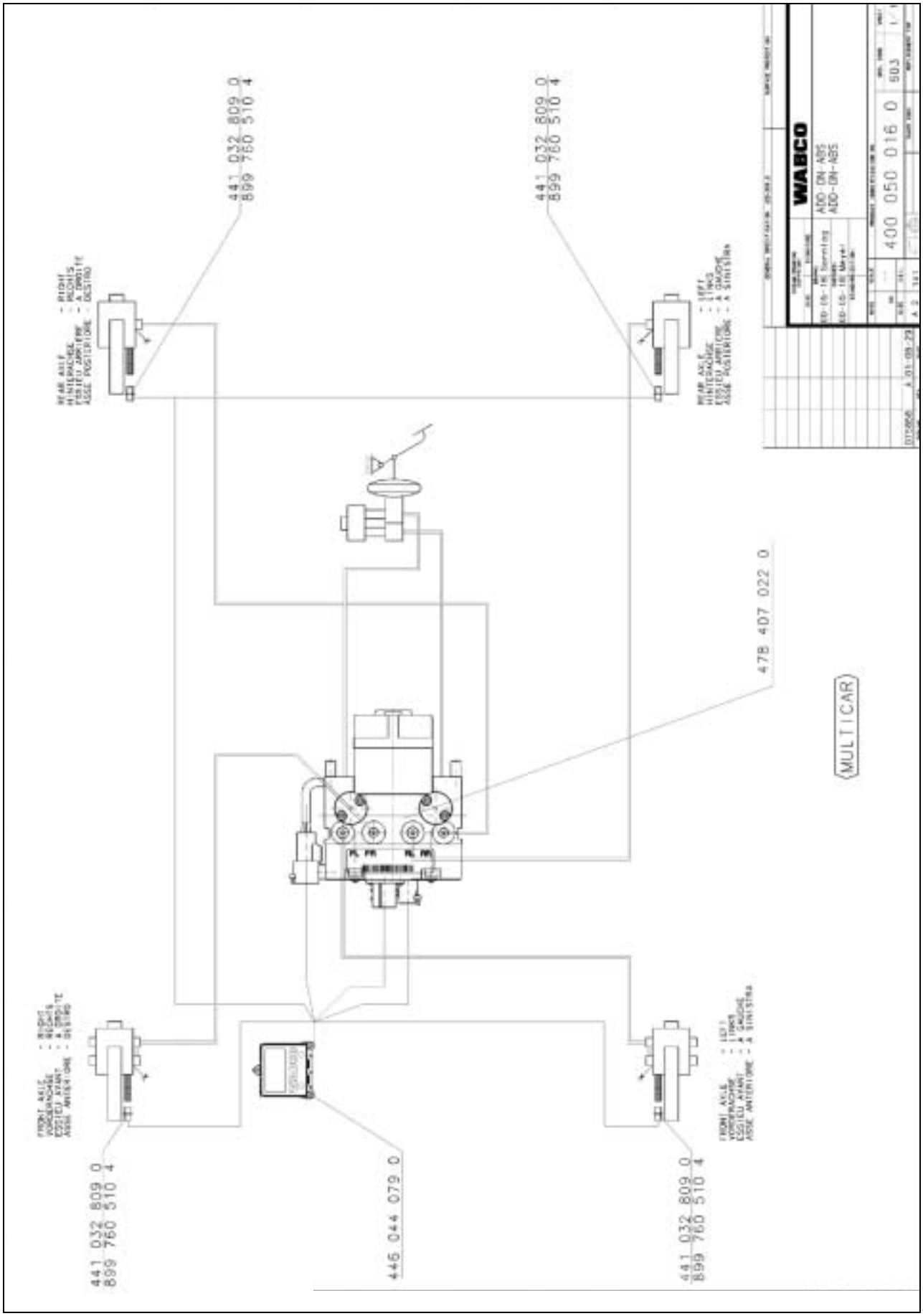
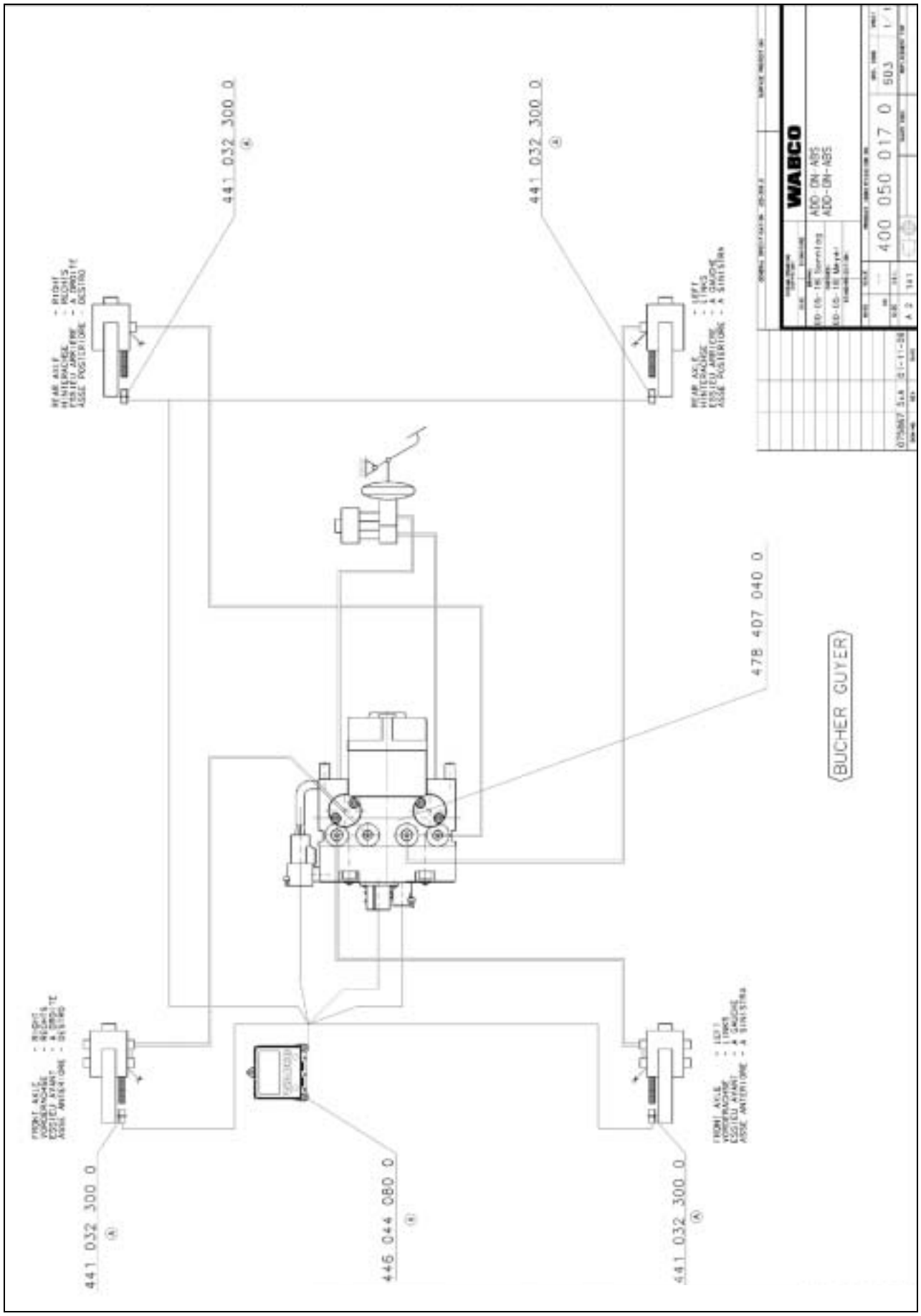
899 760 510 4
441 032 451 0
899 760 510 4
478 407 052 0
446 044 077 0
441 032 451 0
899 760 510 4
441 032 451 0
899 760 510 4
WABCO
400 050 012 0


441 032 809 0
899 760 510 4
441 032 809 0
899 760 510 4
478 407 022 0
MULTICAR
446 044 079 0
441 032 809 0
899 760 510 4
441 032 809 0
899 760 510 4
WABCO
400 050 016 0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441 032 300 0
478 407 040 0
446 044 080 0
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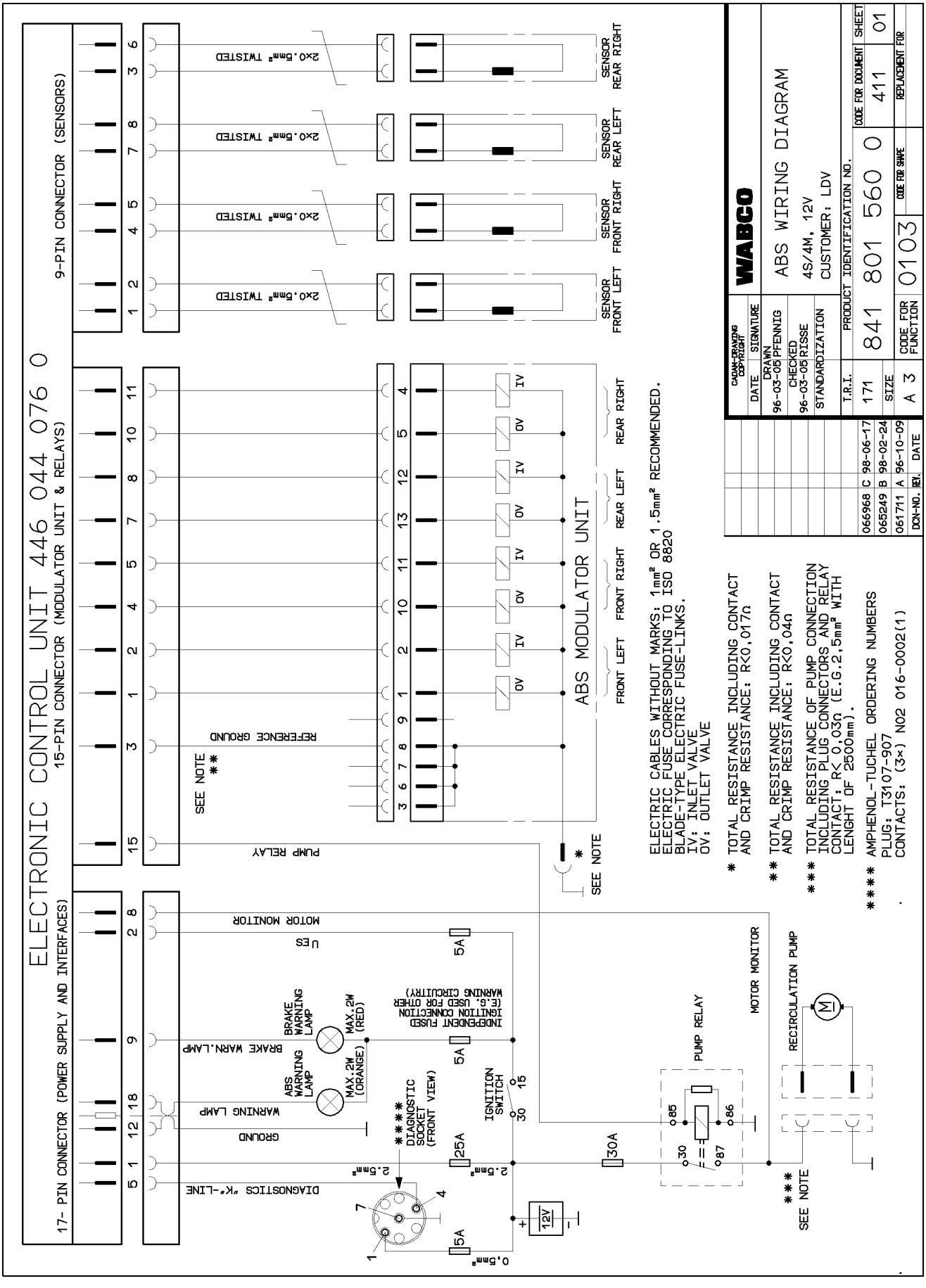
441 032 300 0
BUCHER GUYER
WABCO
400 050 017 0
ABS DN ABS
ADB-DN-ABS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17- PIN CONNECTOR (POWER SUPPLY AND INTERFACES)
15-PIN CONNECTOR (MODULATOR UNIT & RELAYS)
9-PIN CONNECTOR (SENSORS)
ABS MODULATOR UNIT
SENSOR FRONT LEFT
SENSOR FRONT RIGHT
SENSOR REAR LEFT
SENSOR REAR RIGHT
2x0,5mm² TWISTED
REFERENCE GROUND
SEE NOTE **
PUMP RELAY
SEE NOTE *
MOTOR MONITOR
BRAKE WARN.LAMP
WARNING LAMP
GROUND
DIAGNOSTICS „K"-LINE
BRAKE WARNING LAMP
MAX.2W (RED)
ABS WARNING LAMP
MAX.2W (ORANGE)
INDEPENDENT FUSED IGNITION CONNECTION (E.G. USED FOR OTHER WARNING CIRCUITRY)
IGNITION SWITCH
DIAGNOSTIC SOCKET (FRONT VIEW)
PUMP RELAY
RECIRCULATION PUMP
MOTOR MONITOR
SEE NOTE ***
12V
5A
25A
30A
2,5mm²
0,5mm²
ELECTRIC CABLES WITHOUT MARKS: 1mm² OR 1.5mm² RECOMMENDED.
ELECTRIC FUSE CORRESPONDING TO ISO 8820
BLADE-TYPE ELECTRIC FUSE-LINKS.
IV: INLET VALVE
OV: OUTLET VALVE
* TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,017Ω
** TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,04Ω
*** TOTAL RESISTANCE OF PUMP CONNECTION INCLUDING PLUG CONNECTORS AND RELAY CONTACT: R< 0,03Ω (E.G.2,5mm² WITH LENGHT OF 2500mm).
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DATE SIGNATURE
DRAWN 96-03-08 PFENNIG
CHECKED 96-03-05 RISSE
STANDARDIZATION
WABCO
ABS WIRING DIAGRAM
4S/4M, 12V
CUSTOMER: LDV
T.R.I. 171
PRODUCT IDENTIFICATION NO. 841 801 560 0
CODE FOR DOCUMENT 411
SHEET 01
SIZE A 3
CODE FOR FUNCTION 0103
CODE FOR SHAPE
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065249 B 98-02-24
061711 A 96-10-09
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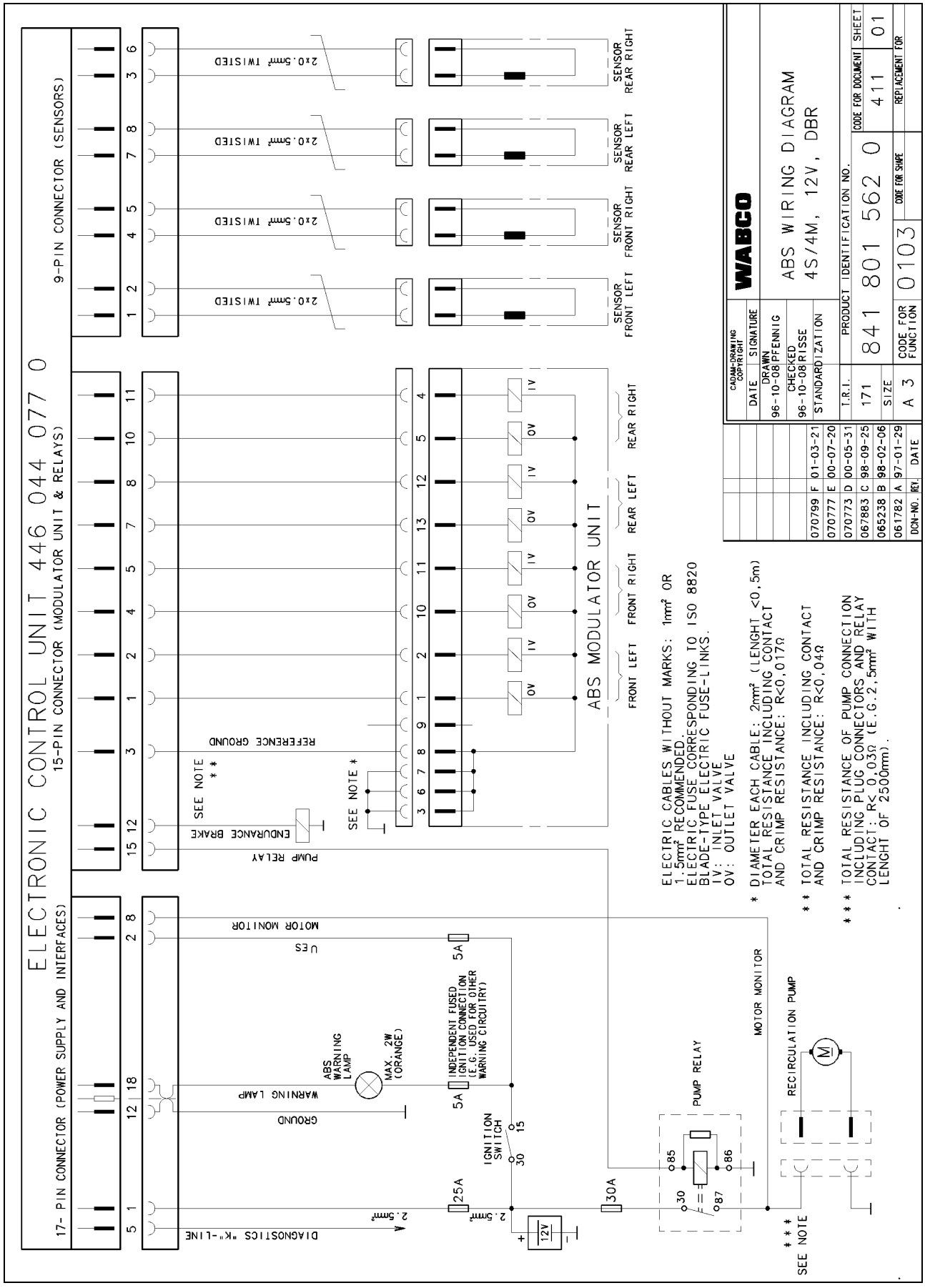
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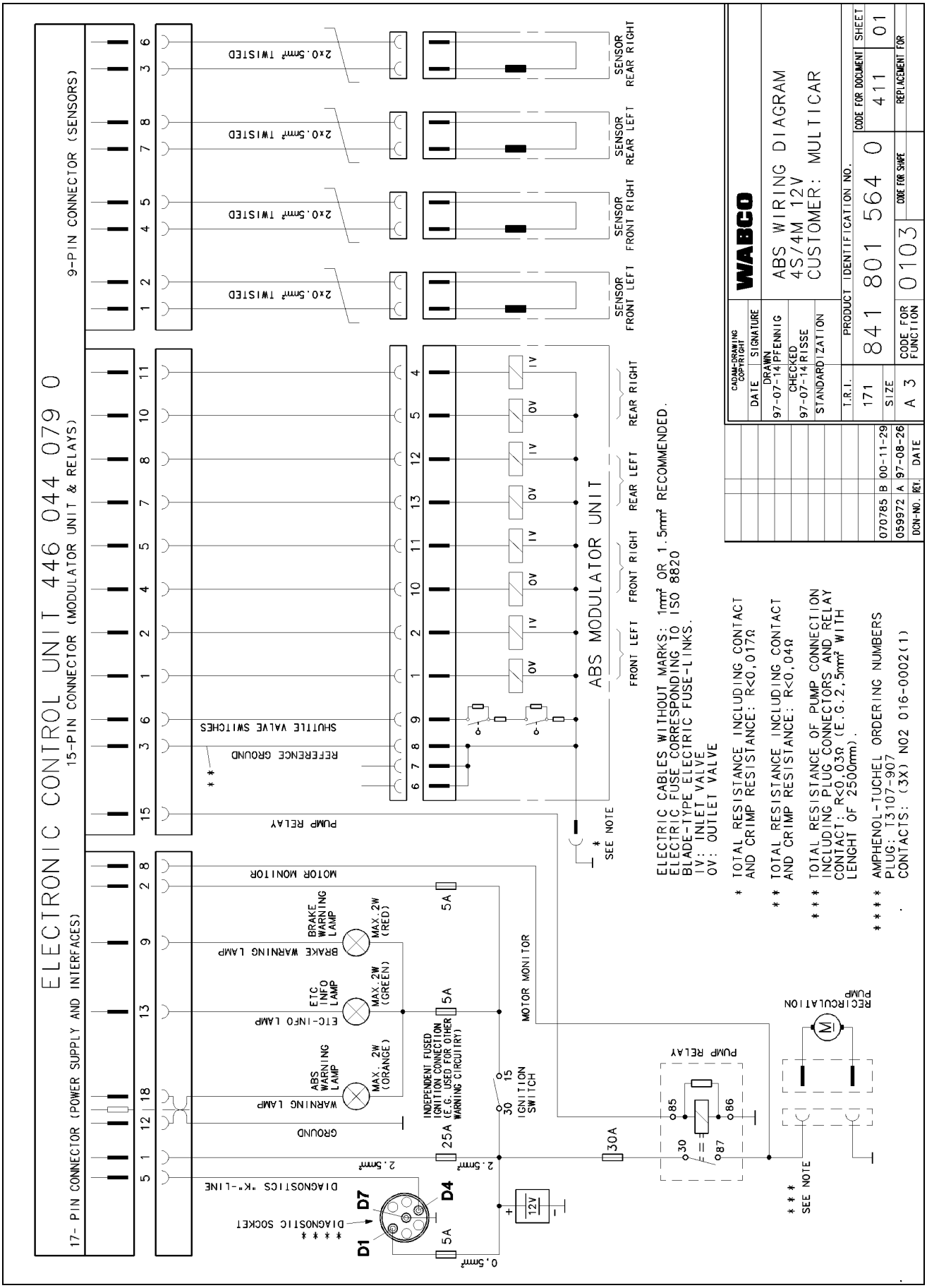
15-PIN CONNECTOR (MODULATOR UNIT & RELAYS)
9-PIN CONNECTOR (SENSORS)
ABS MODULATOR UNIT
SENSOR FRONT LEFT
SENSOR FRONT RIGHT
SENSOR REAR LEFT
SENSOR REAR RIGHT
2x0.5mm² TWISTED
FRONT LEFT
FRONT RIGHT
REAR LEFT
REAR RIGHT
REFERENCE GROUND
ENDURANCE BRAKE
PUMP RELAY
SEE NOTE * *
SEE NOTE *
MOTOR MONITOR
WARNING LAMP
GROUND
ABS WARNING LAMP
MAX. 2W (ORANGE)
INDEPENDENT FUSED IGNITION CONNECTION (E.G. USED FOR OTHER WARNING CIRCUITRY)
IGNITION SWITCH
PUMP RELAY
RECIRCULATION PUMP
DIAGNOSTICS "K"-LINE
SEE NOTE * * *
ELECTRIC CABLES WITHOUT MARKS: 1mm² OR 1.5mm² RECOMMENDED.
ELECTRIC FUSE CORRESPONDING TO ISO 8820 BLADE-TYPE ELECTRIC FUSE-LINKS.
IV: INLET VALVE
OV: OUTLET VALVE
* DIAMETER EACH CABLE: 2mm² (LENGHT <0,5m) TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,017Ω
** TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,04Ω
*** TOTAL RESISTANCE OF PUMP CONNECTION INCLUDING PLUG CONNECTORS AND RELAY CONTACT: R< 0,03Ω (E.G.2,5mm² WITH LENGHT OF 2500mm).
WABCO
ABS WIRING DIAGRAM 4S/4M, 12V, DBR
841 801 562 0
411 01
0103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15-PIN CONNECTOR (MODULATOR UNIT & RELAYS)
9-PIN CONNECTOR (SENSORS)
ABS MODULATOR UNIT
SENSOR FRONT LEFT
SENSOR FRONT RIGHT
SENSOR REAR LEFT
SENSOR REAR RIGHT
2x0.5mm² TWISTED
FRONT LEFT
FRONT RIGHT
REAR LEFT
REAR RIGHT
SHUTTLE VALVE SWITCHES
REFERENCE GROUND
PUMP RELAY
SEE NOTE
MOTOR MONITOR
BRAKE WARNING LAMP
MAX.2W (RED)
ETC-INFO LAMP
MAX.2W (GREEN)
ABS WARNING LAMP
MAX. 2W (ORANGE)
WARNING LAMP
GROUND
INDEPENDENT FUSED IGNITION CONNECTION (E.G. USED FOR OTHER WARNING CIRCUITRY)
IGNITION SWITCH
MOTOR MONITOR
PUMP RELAY
RECIRCULATION PUMP
DIAGNOSTICS "K"-LINE
DIAGNOSTIC SOCKET
D1 D7 D4
12V
5A
25A
30A
2.5mm²
0.5mm²
ELECTRIC CABLES WITHOUT MARKS: 1mm² OR 1.5mm² RECOMMENDED.
ELECTRIC FUSE CORRESPONDING TO ISO 8820
BLADE-TYPE ELECTRIC FUSE-LINKS.
IV: INLET VALVE
OV: OUTLET VALVE
* TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,017Ω
** TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,04Ω
*** TOTAL RESISTANCE OF PUMP CONNECTION INCLUDING PLUG CONNECTORS AND RELAY CONTACT: R<0,03Ω (E.G.2,5mm² WITH LENGHT OF 2500mm).
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4S/4M 12V
CUSTOMER: MULTICAR
CADAM-DRAWING COPYRIGHT
DATE SIGNATURE
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CHECKED 97-07-14 RISSE
STANDARDIZATION
T.R.I. 171
PRODUCT IDENTIFICATION NO. 841 801 564 0
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CODE FOR FUNCTION 0103
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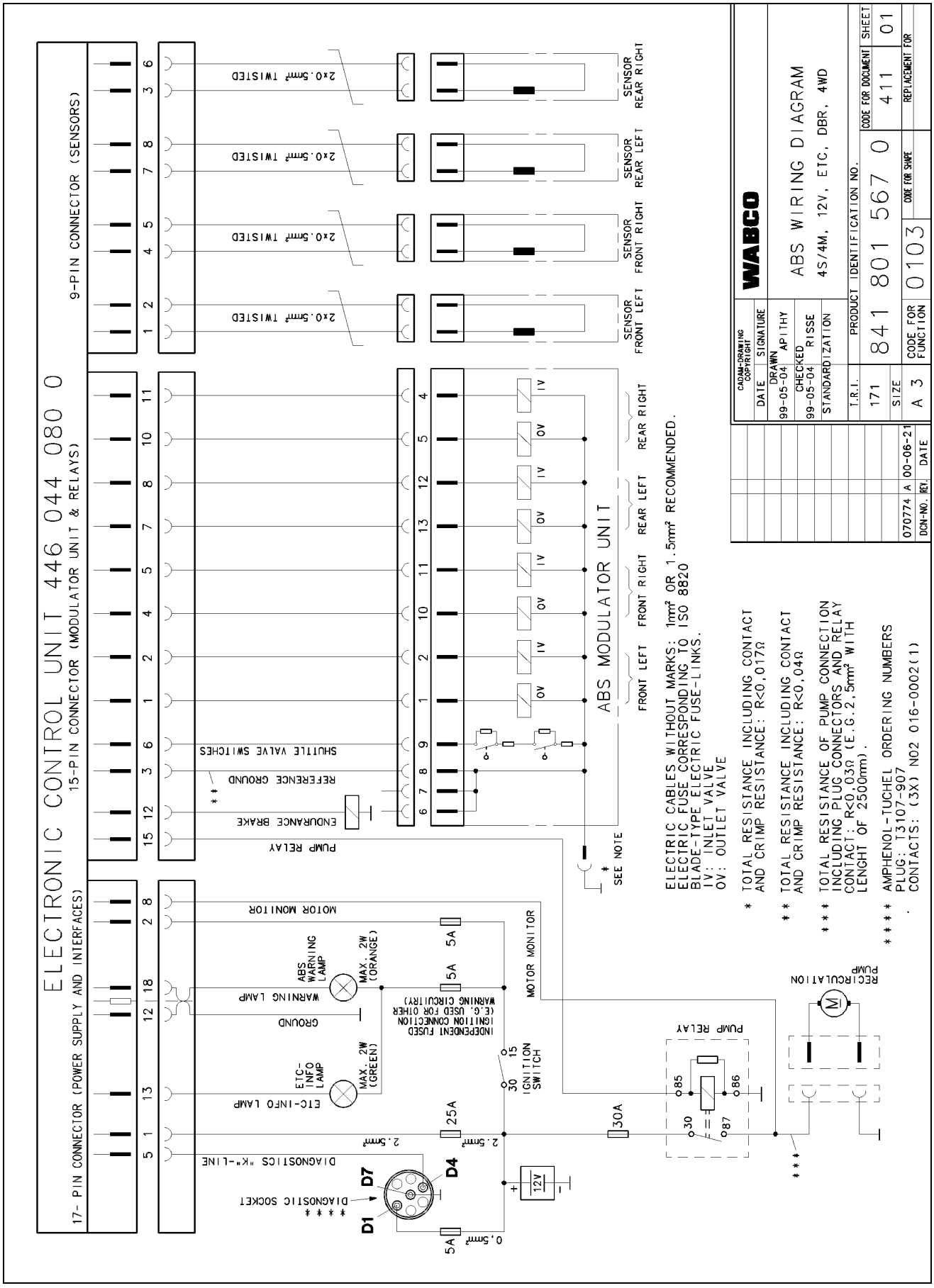
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15-PIN CONNECTOR (MODULATOR UNIT & RELAYS)
9-PIN CONNECTOR (SENSORS)
ABS MODULATOR UNIT
SEE NOTE
SENSOR FRONT LEFT
SENSOR FRONT RIGHT
SENSOR REAR LEFT
SENSOR REAR RIGHT
2x0.5mm² TWISTED
FRONT LEFT
FRONT RIGHT
REAR LEFT
REAR RIGHT
0V
1V
SHUTTLE VALVE SWITCHES
REFERENCE GROUND
ENDURANCE BRAKE
PUMP RELAY
MOTOR MONITOR
ABS WARNING LAMP
MAX. 2W (ORANGE)
WARNING LAMP
GROUND
INDEPENDENT FUSED IGNITION CONNECTION (E.G. USED FOR OTHER WARNING CIRCUITRY)
ETC-INFO LAMP
MAX. 2W (GREEN)
IGNITION SWITCH
DIAGNOSTICS "K"-LINE
DIAGNOSTIC SOCKET
RECIRCULATION PUMP
12V
5A
25A
30A
2.5mm²
0.5mm²
D1
D4
D7
ELECTRIC CABLES WITHOUT MARKS: 1mm² OR 1.5mm² RECOMMENDED.
ELECTRIC FUSE CORRESPONDING TO ISO 8820
BLADE-TYPE ELECTRIC FUSE-LINKS.
IV: INLET VALVE
OV: OUTLET VALVE
* TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,017Ω
** TOTAL RESISTANCE INCLUDING CONTACT AND CRIMP RESISTANCE: R<0,04Ω
*** TOTAL RESISTANCE OF PUMP CONNECTION INCLUDING PLUG CONNECTORS AND RELAY CONTACT: R<0,03Ω (E.G. 2,5mm² WITH LENGHT OF 2500mm).
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WABCO
ABS WIRING DIAGRAM
4S/4M, 12V, ETC, DBR, 4WD
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99-05-04 RISSE
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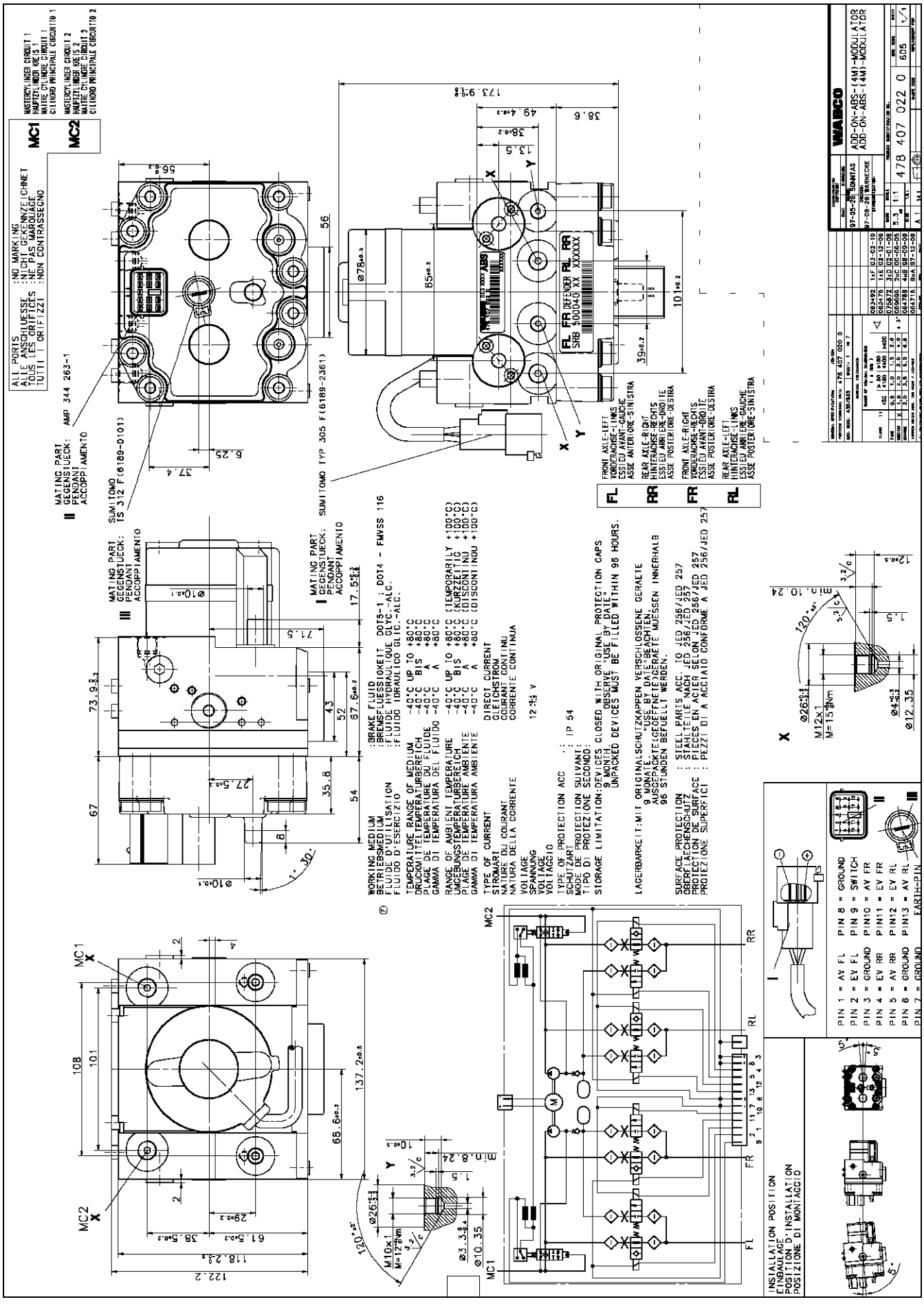
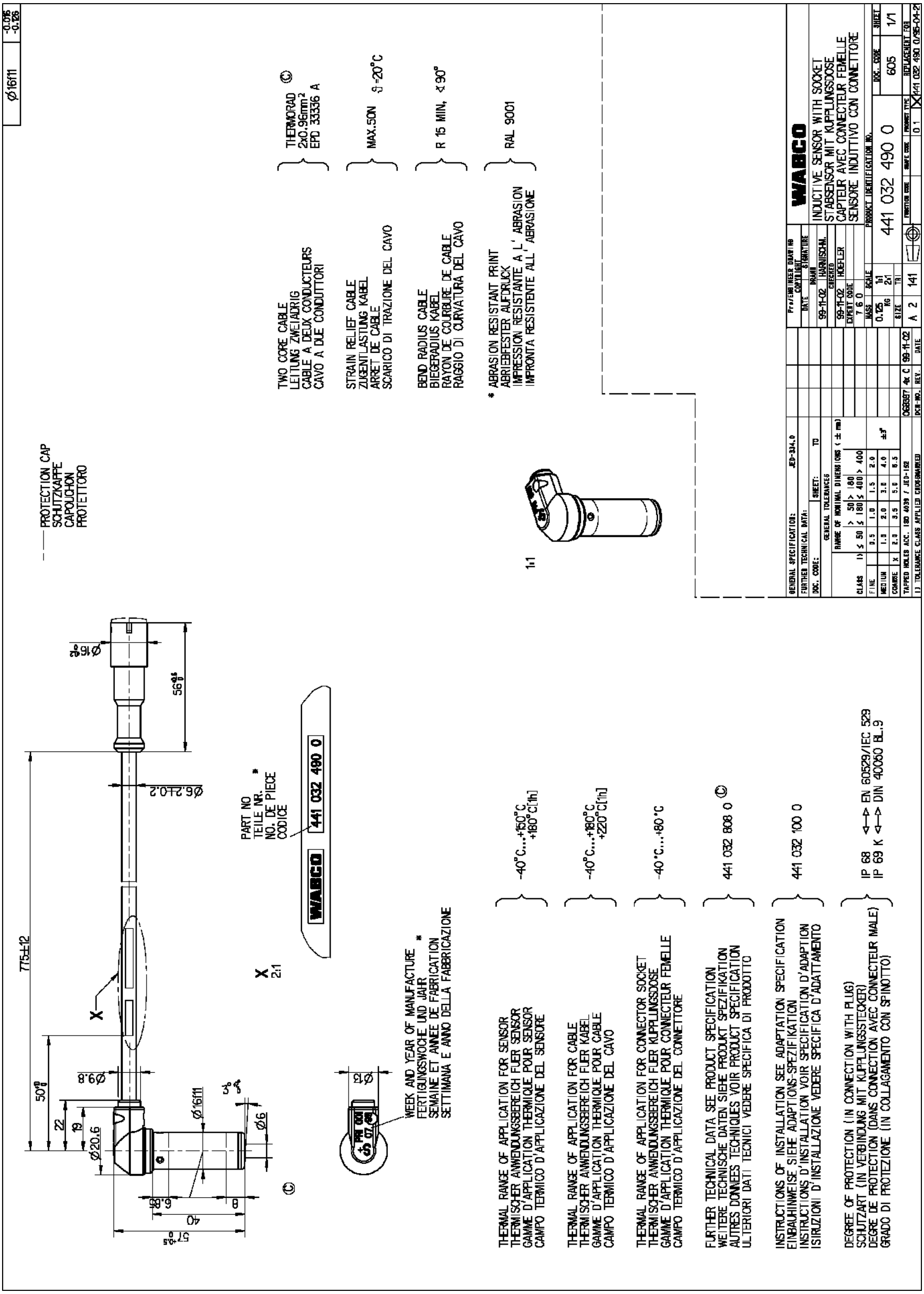
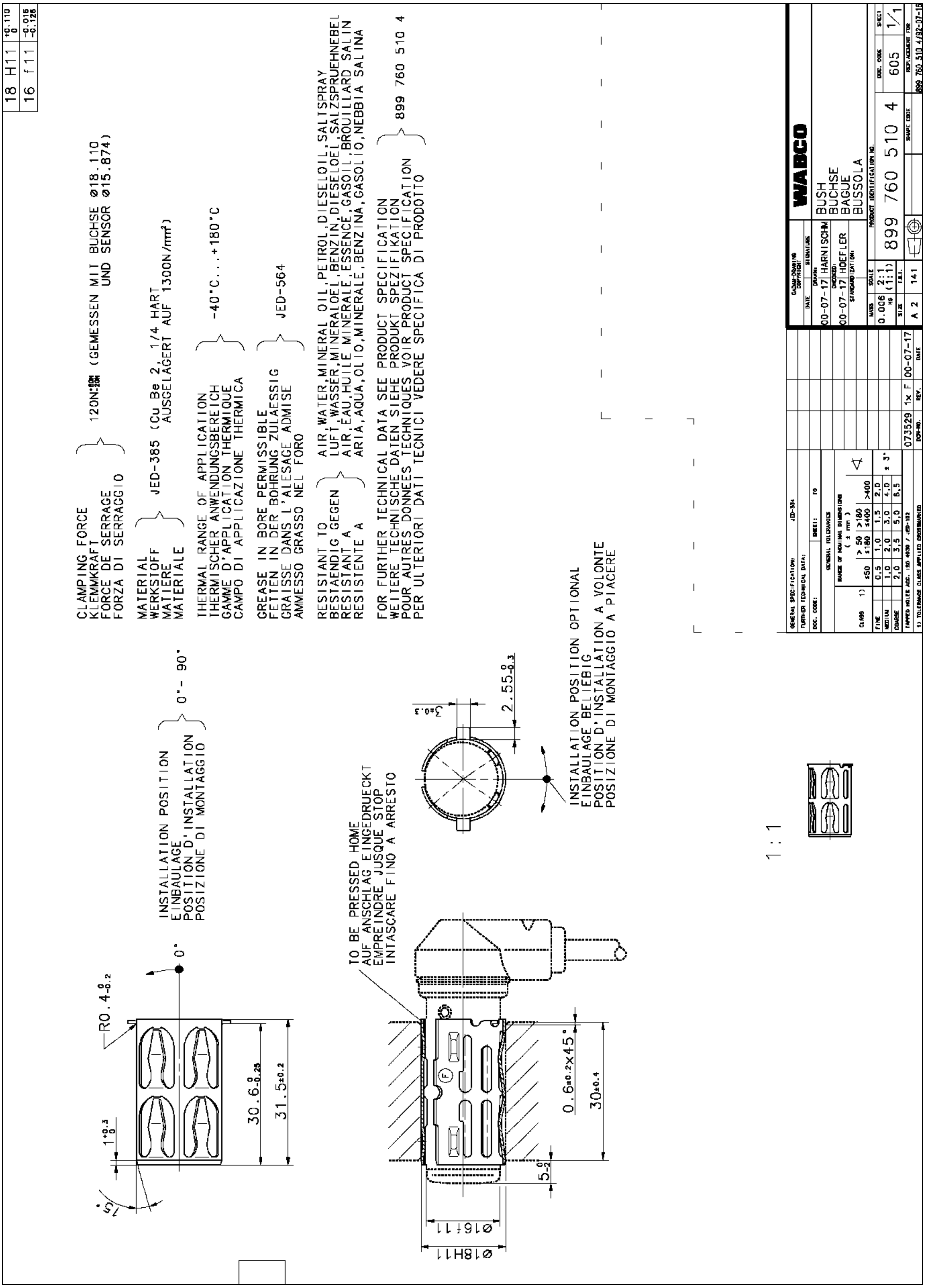
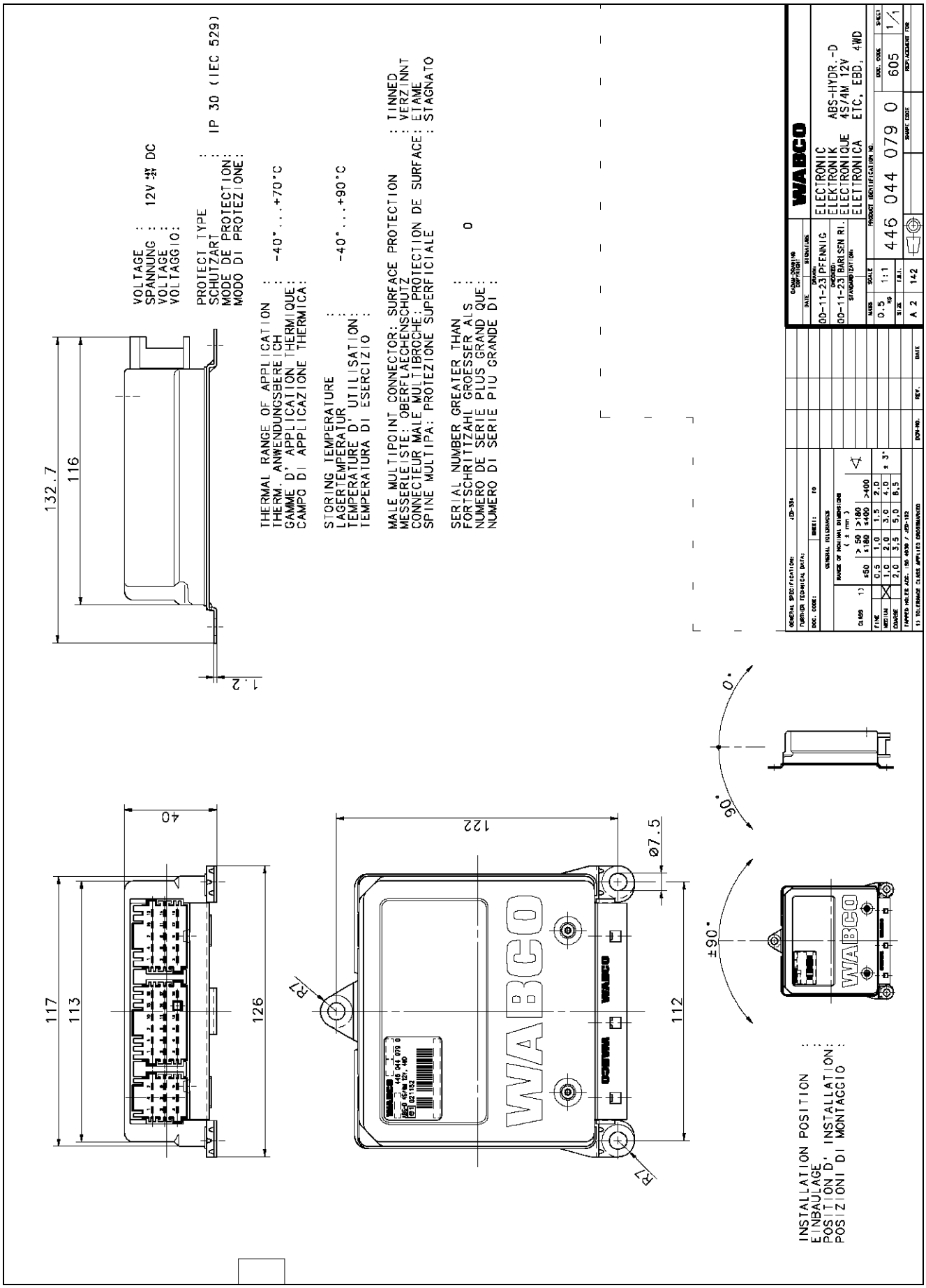

WABCO
ADD-ON-ABS-(4M)-MODULATOR
478 407 022 0
MC1
MC2
ALL PORTS :NO MARKING
ALLE ANSCHLUESSE :NICHT GEKENNZEICHNET
TOUS LES ORIFICES :NE PAS MARQUAGE
TUTTI I ORIFIZZI :NON CONTRASSEGNO
MATING PART
GEGENSTUECK: AMP 344 263-1
PENDANT
ACCOPPIAMENTO
SUMITOMO
TS 312 F(6189-0101)
SUMITOMO TYP 305 F(6189-2361)
WORKING MEDIUM
BETRIEBSMEDIUM :BREMSFLUESSIGKEIT DOT3-1 ; DOT4 - FMVSS 116
FLUIDE D'UTILISATION :FLUIDE HYDRAULIQUE GLYC.-ALC.
FLUIDO D'ESERCIZIO :FLUIDO IDRAULICO GLIC.-ALC.
TEMPERATURE RANGE OF MEDIUM
DRUCKMITTELTEMPERATURBEREICH -40°C UP TO +80°C
PLAGE DE TEMPERATURE DU FLUIDE -40°C BIS +80°C
GAMMA DI TEMPERATURA DEL FLUIDO -40°C A +80°C
RANGE OF AMBIENT TEMPERATURE -40°C UP TO +80°C (TEMPORARILY +100°C)
UMGEBUNGSTEMPERATURBEREICH -40°C BIS +80°C (KURZZEITIG +100°C)
PLAGE DE TEMPERATURE AMBIENTE -40°C A +80°C (DISCONTINU +100°C)
GAMMA DI TEMPERATURA AMBIENTE -40°C A +80°C (DISCONTINUO +100°C)
TYPE OF CURRENT DIRECT CURRENT
STROMART GLEICHSTROM
NATURE DU COURANT COURANT CONTINU
NATURA DELLA CORRENTE CORRENTE CONTINUA
VOLTAGE 12 V
SPANNUNG
VOLTAGE
VOLTAGGIO
TYPE OF PROTECTION ACC. : IP 54
SCHUTZART
MODE DE PROTECTION SUIVANT
TIPO DI PROTEZIONE SECONDO
STORAGE LIMITATION: DEVICES CLOSED WITH ORIGINAL PROTECTION CAPS
UNPACKED DEVICES MUST BE FILLED WITHIN 96 HOURS.
LAGERBARKEIT: MIT ORIGINALSCHUTZKAPPEN VERSCHLOSSENE GERAETE
9 MONATE.
AUSSERHALB GEOEFFNETE GERAETE MUESSEN INNERHALB
96 STUNDEN BEFUELLT WERDEN.
SURFACE PROTECTION : STEEL PARTS ACC. TO JED 256/JED 257
OBERFLAECHENSCHUTZ : STAHLTEILE NACH JED 256/JED 257
PROTECTION DE SURFACE : PIECES EN ACIER SELON JED 256/JED 257
PROTEZIONE SUPERFICI : PEZZI DI A ACCIAIO CONFORME A JED 256/JED 257
FRONT AXLE-LEFT
VORDERACHSE-LINKS
ESSIEU AVANT-GAUCHE
ASSE ANTERIORE-SINISTRA
REAR AXLE-RIGHT
HINTERACHSE-RECHTS
ESSIEU ARRIERE-DROITE
ASSE POSTERIORE-DESTRA
FRONT AXLE-RIGHT
VORDERACHSE-RECHTS
ESSIEU AVANT-DROITE
ASSE POSTERIORE-DESTRA
REAR AXLE-LEFT
HINTERACHSE-LINKS
ESSIEU ARRIERE-GAUCHE
ASSE POSTERIORE-SINISTRA
PIN 1 = AV FL PIN 8 = GROUND
PIN 2 = EV FL PIN 9 = SWITCH
PIN 3 = GROUND PIN10 = AV FR
PIN 4 = EV RR PIN11 = EV FR
PIN 5 = AV RR PIN12 = EV RL
PIN 6 = GROUND PIN13 = AV RL
PIN 7 = GROUND EARTH-PIN
INSTALLATION POSITION
EINBAULAGE
POSITION D'INSTALLATION
POSIZIONE DI MONTAGGIO


PROTECTION CAP
SCHUTZKAPPE
CAPOUCHON
PROTETTORO
PART NO
TEILE NR. *
NO. DE PIECE
CODICE
WABCO 441 032 490 0
WEEK AND YEAR OF MANUFACTURE
FERTIGUNGSWOCHE UND JAHR *
SEMAINE ET ANNEE DE FABRICATION
SETTIMANA E ANNO DELLA FABBRICAZIONE
THERMAL RANGE OF APPLICATION FOR SENSOR
THERMISCHER ANWENDUNGSBEREICH FUER SENSOR
GAMME D'APPLICATION THERMIQUE POUR SENSOR
CAMPO TERMICO D'APPLICAZIONE DEL SENSORE
-40°C...+150°C +180°C[1h]
THERMAL RANGE OF APPLICATION FOR CABLE
THERMISCHER ANWENDUNGSBEREICH FUER KABEL
GAMME D'APPLICATION THERMIQUE POUR CABLE
CAMPO TERMICO D'APPLICAZIONE DEL CAVO
-40°C...+180°C +220°C[1h]
THERMAL RANGE OF APPLICATION FOR CONNECTOR SOCKET
THERMISCHER ANWENDUNGSBEREICH FUER KUPPLUNGSDOSE
GAMME D'APPLICATION THERMIQUE POUR CONNECTEUR FEMELLE
CAMPO TERMICO D'APPLICAZIONE DEL CONNETTORE
-40°C...+80°C
FURTHER TECHNICAL DATA SEE PRODUCT SPECIFICATION
WEITERE TECHNISCHE DATEN SIEHE PRODUKT SPEZIFIKATION
AUTRES DONNEES TECHNIQUES VOIR PRODUCT SPECIFICATION
ULTERIORI DATI TECNICI VEDERE SPECIFICA DI PRODOTTO
441 032 808 0 ©
INSTRUCTIONS OF INSTALLATION SEE ADAPTATION SPECIFICATION
EINBAUHINWEISE SIEHE ADAPTIONS-SPEZIFIKATION
INSTRUCTIONS D'INSTALLATION VOIR SPECIFICATION D'ADAPTION
ISIRUZIONI D'INSTALLAZIONE VEDERE SPECIFICA D'ADATTAMENTO
441 032 100 0
DEGREE OF PROTECTION (IN CONNECTION WITH PLUG)
SCHUTZART (IN VERBINDUNG MIT KUPPLUNGSSTECKER)
DEGRE DE PROTECTION (DANS CONNECTION AVEC CONNECTEUR MALE)
GRADO DI PROTEZIONE (IN COLLAGAMENTO CON SPINOTTO)
IP 68 ⟺ EN 60529/IEC 529
IP 69 K ⟺ DIN 40050 BL.9
TWO CORE CABLE
LEITUNG ZWEIADRIG
CABLE A DEUX CONDUCTEURS
CAVO A DUE CONDUTTORI
THERMORAD © 2x0.96mm² EPD 33336 A
STRAIN RELIEF CABLE
ZUGENTLASTUNG KABEL
ARRET DE CABLE
SCARICO DI TRAZIONE DEL CAVO
MAX.50N ϑ=20°C
BEND RADIUS CABLE
BIEGERADIUS KABEL
RAYON DE COURBURE DE CABLE
RAGGIO DI CURVATURA DEL CAVO
R 15 MIN, ∢90°
* ABRASION RESISTANT PRINT
ABRIEBFESTER AUFDRUCK
IMPRESSION RESISTANTE A L' ABRASION
IMPRONTA RESISTENTE ALL' ABRASIONE
RAL 9001
INDUCTIVE SENSOR WITH SOCKET
STABSENSOR MIT KUPPLUNGSDOSE
CAPTEUR AVEC CONNECTEUR FEMELLE
SENSORE INDUTTIVO CON CONNETTORE
441 032 490 0
WABCO
775±12
Ø16f11
Ø6.2±0.2
Ø20.6
Ø9.8
Ø6
Ø13
X 2:1
1:1


18 H11 +0.110 0
16 f11 -0.016 -0.126
CLAMPING FORCE
KLEMMKRAFT
FORCE DE SERRAGE
FORZA DI SERRAGGIO
120N±50N/20N (GEMESSEN MIT BUCHSE Ø18.110 UND SENSOR Ø15.874)
MATERIAL
WERKSTOFF
MATIERE
MATERIALE
JED-385 (Cu Be 2, 1/4 HART AUSGELAGERT AUF 1300N/mm²)
THERMAL RANGE OF APPLICATION
THERMISCHER ANWENDUNGSBEREICH
GAMME D'APPLICATION THERMIQUE
CAMPO DI APPLICAZIONE THERMICA
-40°C...+180°C
GREASE IN BORE PERMISSIBLE
FETTEN IN DER BOHRUNG ZULAESSIG
GRAISSE DANS L'ALESAGE ADMISE
AMMESSO GRASSO NEL FORO
JED-564
RESISTANT TO
BESTAENDIG GEGEN
RESISTANT A
RESISTENTE A
AIR, WATER, MINERAL OIL, PETROL, DIESELOIL, SALTSPRAY
LUFT, WASSER, MINERALOEL, BENZIN, DIESELOEL, SALZSPRUEHNEBEL
AIR, EAU, HUILE MINERALE, ESSENCE, GASOIL, BROUILLARD SALIN
ARIA, AQUA, OLIO, MINERALE, BENZINA, GASOLIO, NEBBIA SALINA
FOR FURTHER TECHNICAL DATA SEE PRODUCT SPECIFICATION
WEITERE TECHNISCHE DATEN SIEHE PRODUKT SPEZIFIKATION
POUR AUTRES DONNEES TECHNIQUES VOIR PRODUCT SPECIFICATION
PER ULTERIORI DATI TECNICI VEDERE SPECIFICA DI PRODOTTO
899 760 510 4
INSTALLATION POSITION
EINBAULAGE
POSITION D'INSTALLATION
POSIZIONE DI MONTAGGIO
0° - 90°
TO BE PRESSED HOME
AUF ANSCHLAG EINGEDRUECKT
EMPREINDRE JUSQUE STOP
INTASCARE FINO A ARRESTO
INSTALLATION POSITION OPTIONAL
EINBAULAGE BELIEBIG
POSITION D'INSTALLATION A VOLONTE
POSIZIONE DI MONTAGGIO A PIACERE
R0.4 0/-0.2
1 +0.3/0
30.6 0/-0.25
31.5±0.2
0.6±0.2x45°
30±0.4
5 0/-2
Ø16f11
Ø18H11
2.55 0/-0.3
3±0.3
0°
15°
1:1
WABCO
BUSH
BUCHSE
BAGUE
BUSSOLA
00-07-17 HARNISCHM
00-07-17 HOEFLER
0.006
2:1 (1:1)
899 760 510 4
605
1/1
A 2
14.1
073529 1x F 00-07-17
899 760 510 4/92-07-15
JED-384
FINE 0.5 1.0 1.5 2.0
MEDIUM 1.0 2.0 3.0 4.0
COARSE 2.0 3.5 5.0 6.5
≤50 >50 ≤180 >180 ≤400 >400
±3°


VOLTAGE : 12V -25% DC
SPANNUNG :
VOLTAGE :
VOLTAGGIO:
PROTECT TYPE : IP 30 (IEC 529)
SCHUTZART :
MODE DE PROTECTION:
MODO DI PROTEZIONE:
THERMAL RANGE OF APPLICATION : -40°...+70°C
THERM. ANWENDUNGSBEREICH :
GAMME D' APPLICATION THERMIQUE:
CAMPO DI APPLICAZIONE THERMICA:
STORING TEMPERATURE : -40°...+90°C
LAGERTEMPERATUR :
TEMPERATURE D' UTILISATION:
TEMPERATURA DI ESERCIZIO :
MALE MULTIPOINT CONNECTOR: SURFACE PROTECTION : TINNED
MESSERLEISTE: OBERFLAECHENSCHUTZ : VERZINNT
CONNECTEUR MALE MULTIBROCHE: PROTECTION DE SURFACE: ETAME
SPINE MULTIPA: PROTEZIONE SUPERFICIALE : STAGNATO
SERIAL NUMBER GREATER THAN : 0
FORTSCHRITTZAHL GROESSER ALS :
NUMERO DE SERIE PLUS GRAND QUE:
NUMERO DI SERIE PIU GRANDE DI :
WABCO
ELECTRONIC
ELEKTRONIK
ELECTRONIQUE
ELETTRONICA
ABS-HYDR.-D
4S/4M 12V
ETC, EBD, 4WD
446 044 079 0
605
1/1
132.7
116
40
117
113
126
122
112
Ø7.5
0°
90°
±90°
INSTALLATION POSITION
EINBAULAGE
POSITION D' INSTALLATION
POSIZIONI DI MONTAGGIO

8. Workshop instructions

This chapter describes tips and tricks for use by authorised workshop personnel.

Information about system maintenance

Daily checks

Check the fill level in the brake fluid tank.

Check the warning and info lights function correctly when the ignition is switched on.

Check the effectiveness of the brake system before setting off.

Note

See the vehicle manufacturer's maintenance schedule for the service intervals of the hydraulic brake system.

SAFETY NOTE

This modern, complex system offers an increased level of reliability and improves both active road safety and the braking performance of the vehicle.

As a result, we strongly advise against conducting repairs on the ADD-ON ABS system. Brakes are a primary safety component, incorrect work on brakes may result in them failing to operate. Only trained personnel are allowed to perform any maintenance and repair work on the brake system.

Make sure brake fluid does not come into contact with the vehicle's paintwork since it may result in separation of the paint.

Danger!

Take care when handling brake fluid.

Danger of poisoning

- ☞ Always keep brake fluid sealed in its original container and, in particular, keep it safely out of the reach of children.
- ☞ The brake fluid should be changed every 15,000 miles (25,000 km) or every 18 months. Always select the shorter of the two intervals. Only use approved brake fluid (see the Maintenance Manual).

Important

- ☞ Contamination of the brake fluid may result in failure of the brake system!
  Take care to maintain absolute cleanliness when working on the brake system!
- ☞ Follow the vehicle manufacturer's instructions concerning checking and topping up brake fluid!

Environmental!

Collect draining or spilled brake fluid in a suitable container and dispose of it in an environmentally friendly manner!

8.1 Brake system fault table

A troubleshooting table has been prepared to facilitate the task of troubleshooting.

This table does not show all faults which may occur. However, the faults shown are representative of those reported by our customers. We are grateful for any further information from users of the HABS system.

Fault	Cause	Remedy
Long brake pedal travel, springy pedal feel	Air in the brake system Not enough brake fluid Vapour bubble formation - old brake fluid	Bleed the brake Top up brake fluid Change brake fluid
Braking effect decreasing	Line leaking Pads worn Brake master cylinder defective	Check and seal line Fit new pads Fit new brake master cylinder
Wheels lock during braking although ABS warning light is out	ABS warning light defective or system fault	Fit new bulb Connect Diagnostic Controller
Vehicle swerves although ETC display is out	ETC light defective or system fault	Fit new bulb Connect Diagnostic Controller
ETC display continuously lit	Failure of a component No correct ECU assignment	Connect Diagnostic Controller
ABS display lit	Malfunction of components	Connect Diagnostic Controller
Pump runs continuously	System fault	Connect Diagnostic Controller
Brake acts on one side	Pads hardened / oily Brake piston does not move freely Brake calliper tubes dirty	Fit new pads Repair / replace brake piston Clean guides and callipers
Brake gets hot when driving	Brake piston does not move freely Brake calliper tubes dirty	Repair / replace brake piston Clean guides and callipers
Brake pulsing	ABS control active Face run-out of brake disc	Normal function Check brake disc and repair / replace if necessary
Brake squeaks	Possibly due to high atmospheric humidity Unsuitable brake pad Brake calliper tubes dirty Brake piston does not move freely	No remedy required Use genuine brake pads Clean guides and callipers Repair / replace brake piston

8.2 Changing brake fluid

It is necessary to maintain the most stringent cleanliness and precision when working on the brake system.

Tools required:

- See manufacturer
- We recommend an excess pressure or vacuum filling and bleeding system.

Brake fluid absorbs moisture from the air through pores in brake hoses and through the vent hole in the expansion tank.
As a result, the brake fluid should be changed every 18 months or every 25,000 km (15,000 miles).

☞ Never try to suck up brake fluid using a hose and your mouth.
Only fill brake fluid into containers intended for it.

☞ Do not allow brake fluid to come into contact with mineral oil. Even small traces of mineral oil render the brake fluid useless.

Air may get into the brake system during any repair to the brake system which involves opening the system. In this case, you must bleed the brake system.
If the brake pedal feels spongy, this is also a symptom that there is air in the lines.
In this case, repair any possible leaks or bleed the system.

If you do not have a bleeding device available, you must bleed the brake system by pumping the brake pedal (i.e. at least two people are required for this job).

Bleed each wheel brake separately if you have to bleed the entire system. This is always the case if you have reason to believe that there is air in every single brake cylinder.

If only one brake calliper has been replaced or overhauled, it is generally sufficient to bleed the brake calliper in question.

Important
Observe the brake fluid level in the expansion tank during the bleeding procedure and top up the fluid if necessary.
Make sure the level does not drop below the MIN mark, otherwise air will be drawn into the system.

Only ever top up with new brake fluid.

As a rule, bleed the longest brake line first. Refer to the information from the vehicle manufacturer for the precise sequence for bleeding. The most important factors in this case are the lengths and assignments of the brake lines.

1. Remove the dust cap from the bleed valve. Clean the valve, connect a clean drain house and insert the other end of the hose into a half-full bottle. Make sure the end of the hose is below the level of fluid in the bottle, otherwise air can get back into the system.

2. Get an assistant to pump the brake pedal until it is possible to feel resistance at the pedal. If there is adequate pressure available now, fully depress the brake pedal and hold it there.

   If you have a filling and bleeding device available, now connect it to the expansion tank. Refer to the instructions provided by the manufacturer of the device for detailed information.

3. Open the bleed valve on the brake calliper until brake fluid emerges in a controllable flow. Ensure the end of the hose always remains below the level of the brake fluid.

4. Close the bleeder valve as soon as the fluid pressure drops.

5. Repeat the pumping procedure until an appropriate pressure can once again be felt at the brake pedal. Now depress the pedal fully and hold it there.

6. The system or the one brake line has been bled if only light coloured brake fluid (old brake fluid is darker in colour) without air bubbles can be seen any longer.

7. Following correct completion of the bleeding procedure, pull off the bleed hose, wipe away surplus brake fluid, check the valve tightening torque is correct (see manufacturer's specifications), check the valve is leak-tight and replace the dust cap on the valve.

8. Bleed the other brake cylinders in the same way.

9. After bleeding, park the vehicle on a level surface and top up the brake fluid in the expansion tank to the MAX line.

Safety check

☞ Have you tightened all brake lines and their screw fittings?

☞ Have you secured the brake lines in the holders provided for them?

☞ Have you topped up enough brake fluid (manufacturer's specifications)?

☞ Perform a leak test with the engine running, involving pressing the brake pedal down with a force of at least 200 N (20 kg) and holding it for 10 seconds.

☞ Then check the brake system for leaks.

Note

See the vehicle manufacturer's maintenance schedule for the service intervals of the hydraulic brake system.

- ☞ Do not use mineral oil-based brake fluid
- ☞ Only top up with genuine brake fluid
- ☞ Note the vehicle manufacturer's instructions if the brake fluid level is too low
  (check lamps light up)
- ☞ Check the brake fluid level every day and top it up if necessary!
  The need to top up brake fluid relatively frequently is an indication that there is a leak in the brake system.
- ☞ Change the brake fluid at least every 25,000 km (15,000 miles) or every 18 months (note the vehicle manufacturer's instructions).

8.3 Fitting a new modulator

Removal:

Note - The service brake is unserviceable during removal of the modulator.

- ☞ Release the parking brake, shift to neutral, switch off the ignition and secure the vehicle to prevent it from rolling away.
- ☞ Disconnect the earth cable from the battery and remove it.
- ☞ Disconnect electrical cables to the modulator and remove them.
- ☞ Place a container under the hydraulic lines before unscrewing them, in order to collect any brake fluid which leaks out.
- ☞ Wipe away surplus brake fluid from other engine components.
- ☞ Keep blotting material to hand in case of any brake fluid spills.
- ☞ Mark the ends of the pipe to identify their connections on the modulator.
- ☞ Release and unscrew the hydraulic lines.
- ☞ Working carefully to avoid kinking the pipes, bend the lines away from the modulator. If necessary, release the pipe clips and dismantle the pipe as far as possible.
- ☞ Use suitable caps to close off the ends of the lines in order to prevent dirt getting into them.
- ☞ Unfasten and unscrew the modulator retaining screws.

Installation:

- ☞ Fit the modulator and tighten the retaining screws.
- ☞ Fit the pipelines onto the modulator observing the identification markings.
- ☞ Fit the pipe attachments.
- ☞ Wipe away any surplus brake fluid.
- ☞ Reconnect the electrical connections to the modulator.
- ☞ Reattach the earth cable to the battery.
- ☞ Bleed the brake system as described in the section on changing the brake fluid.

Safety check

- ☞ Have you tightened all pipelines and their screw fittings?
- ☞ Have you put the hydraulic lines and electrical cables back in the holders provided for them and have you fitted them correctly?
- ☞ Have you wiped up surplus brake fluid?
- ☞ Have you topped up enough brake fluid (note the manufacturer's specifications)?
- ☞ Perform a leak test with the engine running, involving pressing the brake pedal down with a force of at least 200 N (20 kg) and holding it for 10 seconds.
- ☞ Then check the brake system for leaks.
- ☞ Check the function of the brake system!

8.4 Fitting a new speed sensor

Removal:

- ☞ Release the parking brake, shift to neutral, switch off the ignition and secure the vehicle to prevent it from rolling away.
- ☞ Disconnect the earth cable from the battery and remove it.
- ☞ Set the steering to the required position.
- ☞ Unscrew the wheel studs with the vehicle still on the ground.
- ☞ Raise the vehicle and remove the wheel.
- ☞ Remove the speed sensor cable from its holders.
- ☞ Disconnect the speed sensor plug.
- ☞ Pull the sensor and clamping bush from their hole.

Installation:

- ☞ Clean the hole for the sensor
- ☞ Apply WABCO sensor grease order no. 830 502 063 4 or 830 502 068 4 to the hole and the clamping bush
- ☞ Install the new clamping bush
- ☞ By hand, push the sensor into the clamping bush as far as the stop on the impulse wheel (do not use a hammer)
- ☞ Reconnect the plug
- ☞ Fit the sensor cable back in its holder. Take care that the cable is not looped around the brake calliper and make sure there are no unsecured lengths of cable
- ☞ Clean the rim centring pin and apply a light coat of bearing grease if necessary
- ☞ Fit the removed wheel back on
- ☞ Turn the wheel through one rotation by hand. The wobble of the impulse wheel pushes the sensor out of the hole by the equivalent amount
- ☞ Lower the vehicle back down
- ☞ Set the setting to straight ahead
- ☞ Tighten the wheel studs
- ☞ Attach the earth cable to the battery

Safety check

- ☞ Have you fitted the sensor cable in all the holders?
- ☞ Have you fitted the sensor plug connection?
- ☞ Have you fitted and tightened all wheel studs?
- ☞ Have you removed the jack?
- ☞ Check the function of the brake system!

8.5 Fitting a new ECU

Removal:

- ☞ Release the parking brake, shift to neutral, switch off the ignition and secure the vehicle to prevent it from rolling away
- ☞ Disconnect the earth cable from the battery and remove it
- ☞ Open access to the ECU
- ☞ Remove electrical cables from their holders if necessary
- ☞ Disconnect the electrical cables from the ECU and remove them
- ☞ Release and unscrew the retaining screws.
- ☞ Remove the ECU

Installation:

- ☞ Insert the ECU
- ☞ Screw in and tighten the retaining screws
- ☞ Reattach the electrical cables to the ECU
- ☞ Fit the electrical cables into their holders
- ☞ Refit all other parts which were removed
- ☞ Attach the earth cable to the battery

Safety check

- ☞ Have you fitted the electrical cables into their holders?
- ☞ Have you fitted the plug connection onto the ECU?
- ☞ Check the function of the brake system!

9. Concept

This chapter presents information for companies installing the system in their vehicles.

9.1 Tasks of the brake

The service brake of a vehicle must perform the following tasks:

- It should reduce the speed of the vehicle, if necessary bringing it to a halt. The actuation force should be low and the response time short.
- It should keep the vehicle speed at 30 km/h on long downhill gradients (7 % downhill gradient, 6 km in length) (endurance brake, third brake).
- It should prevent the vehicle from rolling away from a standstill, even on a gradient (parking brake). The parking brake must serve as an auxiliary brake in the event of failure of the service brake.

Structure and function of the hydraulic brake system

Fig. 23 shows the structure of the main parts of a hydraulic brake system with ABS. Brake fluid is used in the hydraulic brake system in order to transmit forces.

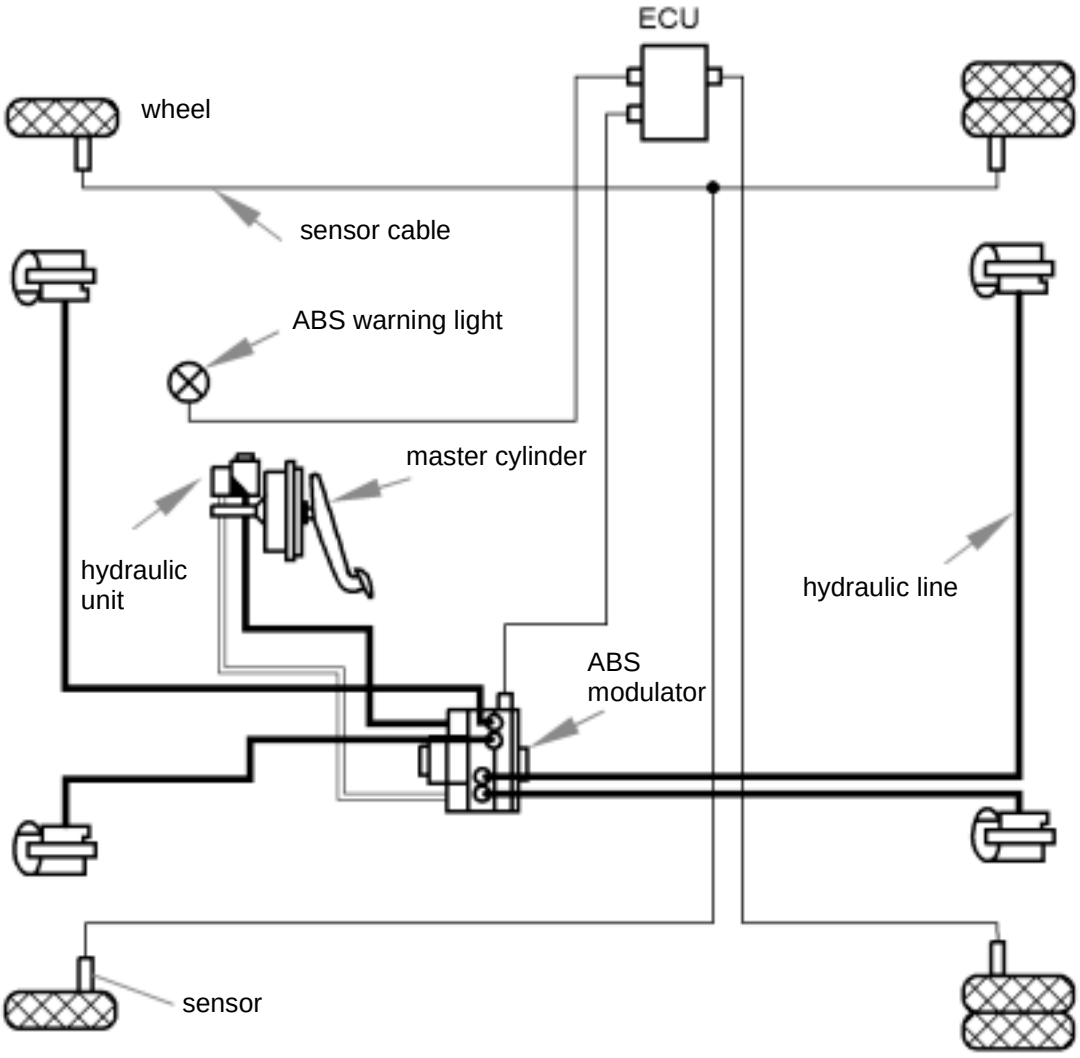
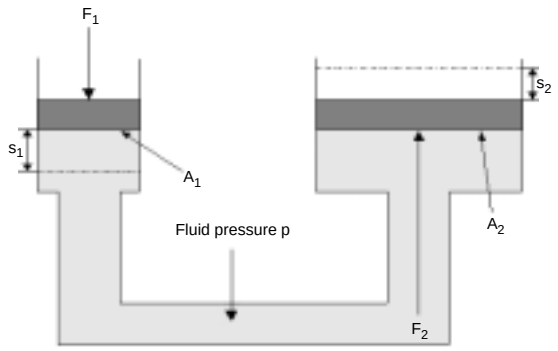


Fig. 23 Structure of a hydraulic ABS system

9.2 Physical principle

The mode of operation of the hydraulic brake system is based on Pascal's principle (Blaise Pascal, the French mathematician and philosopher, 1623 to 1662).



F: Piston force s: Piston travel
A: Piston area
Fig. 24 Hydraulic force transmission

When a force is applied to an enclosed fluid, the resulting fluid pressure is equal throughout the fluid.

9.3 Formulae

The laws of hydraulic force transmission apply in this case.

V = Displaced volume in cm^3

A_1 = Area of the master piston in cm^2

s_1 = Travel of the master piston in cm

A_2 = Area of the slave piston in cm^2

s_2 = Travel of the slave piston in cm

$$V = A_1 \times s_1 = A_2 \times s_2$$

P = Pressure in N/ cm^2

F_1 = Force acting on the master piston in N

F_2 = Force acting on the slave piston in N

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

9.4 Legal provisions

The requirements, the nominal condition, the types and monitoring intervals of the brake system are defined in the **motor vehicle construction and use regulations** (StVZO in Germany).

Excerpts from StVZO § 41

Regulations for the service and parking brake

Motor vehicles must have 2 independent brake systems or one brake system with two independent operating devices, each of which can take effect if the other fails. It must be easy to adjust the brakes or they must have an automatic adjustment device.

The brake (service brake) on motor vehicles - except for motorcycles - must achieve an average deceleration of at least 2.5 m/s²; however, an average deceleration of 1.5 m/s² is sufficient for motor vehicles with a maximum design speed not in excess of 25 km/h.

In motor vehicles - except for motorcycles - the operating device of the other brake must be lockable. The parking brake must attain an average deceleration of at least 1.5 m/s².

Excerpts from § 41b

Automatic anti-lock system

(1) An automatic anti-lock system is that part of a service brake which automatically controls the slip in the direction of rotation of the wheel on one or more wheels of the vehicle during braking.

(2) The following vehicles with a maximum design speed in excess of 60 km/h must be equipped with an anti-lock system:

1. Heavy goods vehicles and semitrailers with a total weight of more than 3.5 t,

2. Trailers with a gross vehicle weight of more than 3.5 t; this only applies to semitrailers if the gross vehicle weight reduced by the vertical load borne by the semitrailer tractor is in excess of 3.5 t,

3. Buses,

4. Tractor vehicles with a gross vehicle weight of more than 3.5 t,

Other vehicles with chassis design features that are equivalent to the vehicles named in numbers 1 to 4 must also be equipped with an anti-lock system.

9.5 Classification of vehicles according to EC Directive 98/12/EC

Class M: Motor vehicles designed for passenger transport with at least 4 wheels or with 3 wheels and a total weight in excess of 1 t:

- Class M_1 Vehicles designed for passenger transport which have a maximum of 8 seats in addition to the driver's seat;

- Class M_2 Vehicles designed for passenger transport which have more than 8 seats in addition to the driver's seat and the total weight of which is not in excess of 5 t;

- Class M_3 Vehicles designed for passenger transport which have more than 8 seats in addition to the driver's seat and the total weight of which is in excess of 5 t;

Class N: Motor vehicles designed for goods transport with at least 4 wheels or with 3 wheels and a total weight in excess of 1 t:

- Class N_1 Vehicles designed for goods transport with a total weight not in excess of 3.5 t;

- Class N_2 Vehicles designed for goods transport with a total weight in excess of 3.5 t but not in excess of 12 t;

- Class N_3 Vehicles designed for goods transport with a total weight in excess of 12 t;

Class O: Trailers (including semitrailers);

- Class O_1 Trailers with a total weight not in excess of 0.75 t;

- Class O_2 Trailers with a total weight in excess of 0.75 t but not in excess of 3.5 t;

- Class O_3 Trailers with a total weight in excess of 3.5 t but not in excess of 10 t;

- Class O_4 Trailers with a total weight in excess of 10 t.

9.6 Physical principles of braking

A vehicle has the kinetic energy E at a particular speed. The energy depends on the mass of the vehicle m_F and the road speed v:

$$E = \frac{1}{2} \times m_F \times v^2$$

E = Kinetic energy in Nm

m_F = Vehicle mass in kg

v = Road speed in m/s

Doubling the mass with the road speed constant results in twice the kinetic energy. Doubling the road speed with the mass constant results in four times the kinetic energy.

The **braking procedure** converts the kinetic energy into thermal energy (friction heat).

The friction heat results from pressing the brake shoes against the rotating brake drums or pressing the brake pads against the rotating brake discs.

The braking deceleration a is the difference between the original road speed v_1 and the road speed v_2 after braking, divided by the braking time t.

$$a = \frac{v_1 - v_2}{t}$$

a = Braking deceleration in m/s²

v_1 and v_2 = Road speed in m/s

t = Braking time in s

The vehicle attains the best deceleration values when the tyres remain in contact with the carriageway due to static friction.

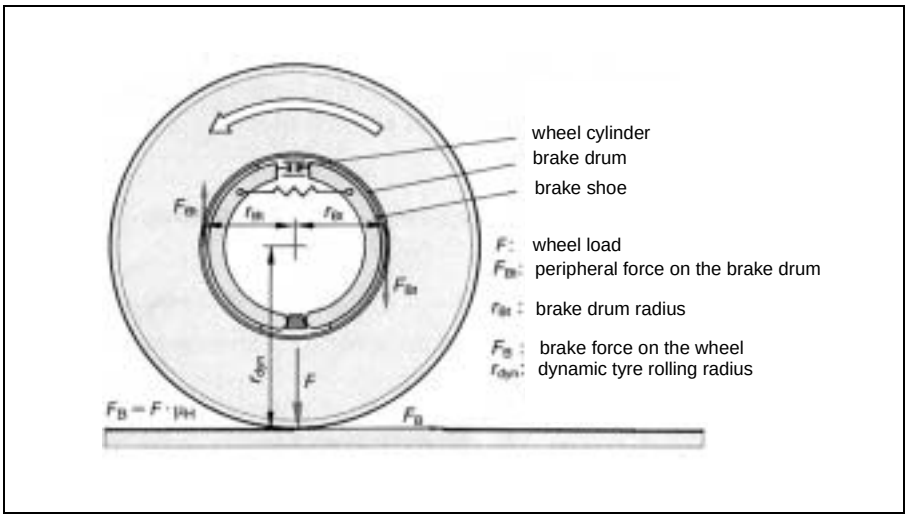


Fig. 25 Forces on the wheel and on the brake

The wheels lock if the contact force between the brake shoe and the brake drum / brake pad and brake disc increases so much that the static friction between the wheel and the carriageway is no longer sufficient to maintain the braking procedure. Dynamic friction then occurs between the carriageway and the tyres. The following disadvantages result when the wheels are locked:

- Steering of the vehicle is no longer assured, the vehicle tends to swerve (skid),
- less braking deceleration and
- greater tyre wear.

The brake force coefficient μ_B:

The brake force coefficient (adhesion) between the wheel and the carriageway determines what braking forces can be transmitted. It depends on the brake slip between the tyres and the road and is also influenced by, amongst other factors:

– The condition of the road and the tyres

– The wheel or axle load

– The speed of the vehicle

– The temperature

– The tyre inclination or the amount of cornering force utilised.

The cornering force coefficient μ_S:

Maintaining lateral stability is a major prerequisite for ensuring that the vehicle can still be steered. 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:

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

Where:

V_F = Vehicle speed

V_R = Wheel circumferential speed

Explanation of slip curves (μ_B and μ_S):

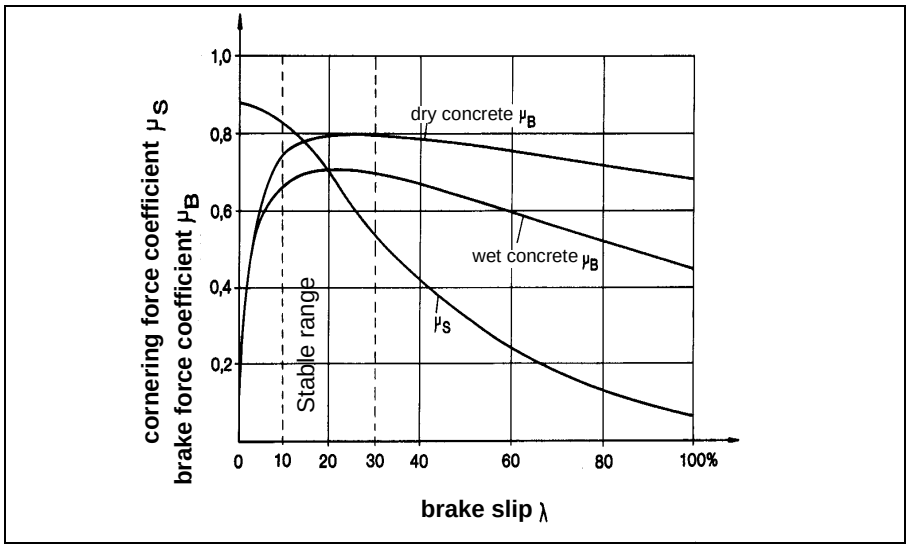


Fig. 26 Slip curves

Fig. 26 shows the relationship between the brake force coefficient μ_B, the cornering force coefficient μ_S and the brake slip 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 the unstable area of the μ-λ curve is reached (approx. 30% to 100%) due to excessive braking forces, the wheel is overbraked and locks (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.

9.7 Time sequence of the braking procedure

The total braking time t_{tot} is the sum of the time slices as shown in Fig. 27
The response time t_R is the time between when the danger is detected and when the brake pedal is pressed.

It varies depending on the speed of the driver's reactions. Special affects such as tiredness, the influence of alcohol, etc. can make it significantly longer. The play in the brake system is overcome during the response time t_A (e.g. air gap between the brake shoe and brake drum / brake pad and brake disc).
The buildup time t_{sw} is the time which passes until the brake force reaches its maximum amount. The braking time t is made up of the response time t_a, the buildup time t_{sw} and the delay time t_v (the time it takes for the brakes to take effect).

The length of the braking travel is dependent on the actuation force and, to a large extent, on the following parameters:

- Vehicle speed
- Composition of the carriageway and condition of the tyres
- Coefficient of friction between the brake shoe and brake drum / brake pad and brake disc.

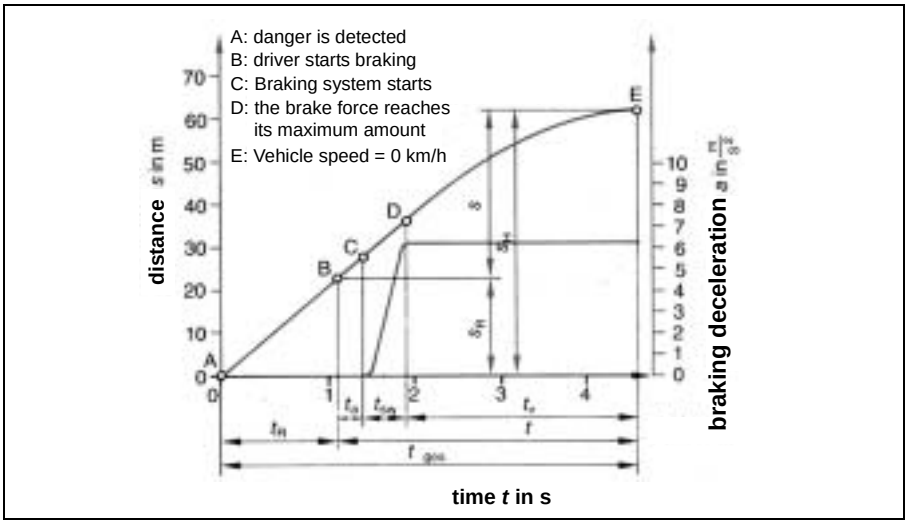


Fig. 27 Time sequence of the braking procedure

9.8 Driving with the ADD-ON anti-lock brake system

After the ignition is switched on, the ADD-ON system checks its function automatically for the first time. This can be felt as a slight movement of the brake pedal indicating that the valves and the modulator pump are being checked. In every braking situation during which the deceleration of one or more wheels is relatively rapid in comparison to the vehicle speed, ABS checks whether the wheel is starting to lock and controls the brake pressure in order to keep the wheel turning during the braking procedure.

The braking procedure is controlled by electronically activated valves when ABS is working. The functioning of the valves and the modulator pump can be felt as a movement or pulsing at the brake pedal. At the same time, the driver hears the noise of the modulator operating. If the pedal frequently vibrates whenever the brake pedal is pressed, this indicates a hazardous road surface or that an inappropriately high level of force is being applied at the brake pedal. Also, further downwards movement of the pedal is felt to be hard from the point when ABS takes over control. However, the force applied to the brake pedal can be altered to influence the braking procedure whilst ABS control is operating.

The force applied to the brake pedal with the foot should be maintained as during non-ABS braking, since the friction of the road surface may change and ABS can react to this accordingly. The EBD function also operates during partial braking if the rear axle is tending to lock before the front axle. The EBD function is not audible, however the driver feels a slight pulsation at the brake pedal.

9.9 Points to bear in mind

- A four-channel ADD-ON ABS system controls the individual wheels in accordance with the amount of adhesion under each tyre. As a result, it makes it possible to keep control of the vehicle even when the coefficients of friction are varying rapidly and are markedly different from wheel to wheel.
- The ADD-ON ABS system even operates at very slow speed (the slowest measurable speed is 1.8 km/h). As a result, the vehicle normally comes to a halt in the last control cycle.
- The ADD-ON ABS system prevents excessive tyre wear. This applies in particular to bald spots which would otherwise be produced due to emergency braking on surfaces with a high coefficient of friction.
- The vehicle can still be steered and remains stable during braking on all surfaces where braking without ABS would lead to blocking of the wheels and a loss of control over the vehicle. ABS functions on all surfaces providing there is sufficient friction to allow the wheels to continue turning in coasting or freewheel mode.
- The safety circuit of the ECU constantly monitors that the electronic and electrical functions are intact.

The system is partially or completely shut off, depending on the nature of the fault.

9.10 Impulse wheel specification

WABCO itself does not offer impulse wheels in its product range. As a result, some information concerning such wheels is presented here.

Function

The impulse wheel attached to the rotating wheel induces an alternating voltage in the stationary speed sensor. The electronic control unit calculates the wheel speed based on the frequency of this voltage. Refer to WABCO Product Specification 895 905 000 4 for dimensions and tolerances.

Material

WABCO recommends that impulse wheels should be made from ferromagnetic materials.

Sample materials:		
Free-cutting steels:	9S20K	9SMn28
Annealing steels:	C35K	C45K
Sinterised material:	Sint DO2	
Stainless steels:	X6Cr17	
	X6CrMo17	

These designations are based on the old DIN standard.

Surface protection

Surface protection in terms of resistance to corrosion and high temperatures must be adapted to the conditions where the products are used (e.g. front or rear axle, disc or drum brake, open or closed brake). Furthermore, it must offer adequate resistance to abrasion in order to prevent damage to the surface when the impulse wheel spins against the sensor.

General number of teeth

The number of teeth relates to impulse wheels which rotate at the speed of the wheel. Contact WABCO to define the number of teeth in case of tyre circumferences which are outside the specified ranges.

60 teeth

For cars, light goods vehicles and trailers

80 teeth

For low-loader axles, light goods vehicles and trailers

100 teeth

For buses, medium and heavy goods vehicle and trailers

120 teeth

For special goods vehicles such as mobile trains, open-cast mining dump trucks, etc. with very large wheels.

Assembly

The impulse wheel adapter should be configured so that work can be performed on the hub bearing/seals and other vehicle maintenance work can be conducted near to the wheel brake without having to remove the impulse wheel. There is no need to arrange the impulse wheel inside the sealed area of the wheel hub, but this is permitted. The impulse wheel should normally be connected to the hub using a press fit H8/s7. The impulse wheel or the hub should be equipped with a suitably chamfered edge in order to allow the wheel to be pressed on. The impulse wheel can also be heated to facilitate installation. Suitable equipment or tools must be used to ensure that there is no risk of damaging the tooth edges. This also applies to maintenance work, e.g. when removing the hub.