EBS - Electronically Controlled Braking System
5. EBS - Electronically Controlled Braking System

Introduction:
Increasing competition in the transport trade has also caused the requirements for braking systems to be increased steadily. The introduction of the Electronically controlled Braking System EBS is the logical step to meet this and other requirements. EBS permits perpetual optimized balancing of the braking forces among the individual wheel brakes, and of the towing vehicle and its trailer.

The comprehensive diagnostic and monitoring functions of the Electronically controlled Braking System are one of the basic requirements for effective fleet logistics. EBS enhances vehicle and road safety by means of reducing the stopping distance, achieving improved braking stability and monitoring the braking system. In addition, EBS considerably improves both economic efficiency and driving comfort.

Benefits of EBS

EBS Effectively Reduces Maintenance Costs.
- EBS combines a large number of functions. The objective is to reduce maintenance costs whilst maximizing braking safety, e.g. by minimizing lining wear of the wheel brakes.

- Individual control according to the wear criteria on both front and rear axles harmonizes lining wear. By evenly spreading the load across all wheel brakes, total wear is minimized. In addition, maintenance and lining change intervals coincide. Laid-up costs are drastically reduced.

System Design

For this reason, EBS will be included in new vehicle series, the pioneer being ACTROS from Daimler-Benz which has an electronically controlled air braking system fitted as standard equipment. This system by name of "Telligent® Braking System" from Daimler-Benz (formerly EPB), is a joint development by Daimler-Benz and WABCO.

Please note:
The term "Telligent® Braking System" comprises the whole of the braking system, not only its controlling system which we call EPB.

The ACTROS "Telligent® Braking System" contains some specific Daimler-Benz features for which WABCO, in applications for vehicles from other manufacturers, has substituted its own solutions. These include the following functions described in the publication in more detail:

- redundancy valve, rear axle redundancy
- special control functions in the area of brake force distribution (differential, drive-slip control DSR), lining wear control and trailer control
- testing and diagnostic methods typical for ACTROS.

Modular Design of WABCO EBS

The configuration and the structure of WABCO’s EBS permits a high degree of flexibility for the vehicle manufacturer when designing the system. For this reason, the most varied of needs can be met:
- partial or full system,
- type of redundancy,
- trailer control strategy,
- electrical interfaces, etc.

For meeting the essential requirements of the vehicle owner, WABCO recommends an EBS which comprises individual pressure control on front and rear axles and trailer control, and which provides for pneumatic redundancies in all braking circuits.

This EBS consists of a dual circuit and an overriding single-circuit electro-pneumatic circuit. This configuration is described as 2P/1E-EBS.

The single circuit electro-pneumatic part of the system consists of one central electronic control unit (central module), the axle modulator with integrated electronics for the rear axle, a brake signal transmitter with purely pneumatical integrated stroke sensors and brake switches, an electro-pneumatic control valve and two ABS valves for the front axle, plus an electro-pneumatic trailer control valve.

An expansion of this configuration by an additional axle modulator for the rear axles would then provide a 6-channel EBS. The structure of the subordinate dual-circuit pneumatic part of the system is basically identical with that of a conventional braking circuit. This part of the system serves as a backup and becomes effective only if the electro-pneumatic circuit fails.
EBS - Electronically Controlled Braking System

EBS Brake System for Track 4x2:

Legend:
1 Central Module
2 Brake Signal Transmitter
3 Proportional Relay Valve
4 Solenoid Modulator Valve - ABS
5 Rear Axle Modulator
6 Backup Valve
7 Trailer Control Valve
Function Scheme:

Legend:

1 Brake Signal Transmitter (BWG)
2 Proportional-Relay Valve
3 Solenoid Modulator Valve - ABS
4 Speed Sensor
5 Wear Sensor
6 Backup Valve
7 Rear Axle Modulator
8 Trailer Control Valve
EBS - Electronically Controlled Braking System

Central Module
446 130 . . . 0

The central module is used to control and monitor the Electronically controlled Braking System. From the signal received from the brake signal transmitter it determines the vehicle’s intended retardation. Together with the wheel speeds measured by the wheel speed sensors, the intended retardation is the input signal for EBS control which uses these readings to establish the index pressure values for the front and rear axles and the trailer control valve. The index pressure for the front axle is compared with the actual value taken, and any differences are balanced by means of the proportional relay valve.

Output of the trailer control pressure is achieved in a similar manner. In addition, the wheel speeds are evaluated to commence ABS control by modulating the brake pressures in the brake cylinders in the event of the wheels showing a tendency to lock. The central module exchanges data, via the EBS system bus, with the axle modulator (or axle modulators in 6S/6M systems).

Electrical braking systems for trailers are actuated via a data interface to ISO 11992. The central module communicates with other systems of the towing vehicle (engine control, retarder, etc.) via a vehicle data bus.

Brake Signal Transmitter
480 001 . . . 0

The brake signal transmitter is used to generate electrical and pneumatic signals to apply to, or release pressure from, the Electronically controlled Braking System (EBS). This unit is designed for two pneumatic and electrical circuits respectively. Commencement of actuation is electrically recorded. The start of actuation is electrically perceived by a double switch (1). The travel of the actuating plunger (b) is picked up and results in the pulse-width modulated output as an electrical signal. In addition, the pneumatic redundancy pressures in Circuits 1 (Port 21) and 2 (Port 22) are transmitted, that of Circuit 2 being retained slightly. Via an additional pilot connection 4 it is possible (at a customer’s specific request) to adjust the pneumatic characteristic of the 2nd circuit. In the event of one circuit failing (electrical or pneumatic), the other circuits remain operational.
Proportional Relay Valve 480 202 ... 0

In the Electronically controlled Braking System, the proportional relay valve is used as an actuator for the output of brake pressures at the front axle.

It consists of a proportional solenoid valve (a), a relay valve (b) and a pressure sensor (c). Electrical actuation and monitoring are effected by the central module of the hybrid system.

The control current determined by the electronics is converted by the proportional relay valve (a) into control pressure for the relay valve. The output pressure (port 2) of the proportional relay valve is proportional to that pressure. The pneumatic actuation of the relay valve (port 4) is effected by the redundant pressure of the brake signal transmitter (port 22).

Backup Valve 480 205 ... 0

The backup valve is used to rapidly increase or decrease the pressure for the brake cylinders on the rear axle in the case of a backup; it consists of several valve units which have to perform the following functions, among others:

- 3/2-way valve to prevent backup operation if the electro-pneumatic braking circuit is not defective
- relay valve function for improving the time response of the backup
- pressure retention in order to synchronize the commencement of pressure output on the front and rear axles in the event of a backup
- pressure reduction to avoid overbraking of the rear axle to the largest possible extent in the case of a backup.
The axle modulator controls the brake cylinder pressures on both sides of one or two rear axles. It contains two independent pneumatic pressure control channels (Channels A and B), each containing one inlet and one exhaust valve, plus one pressure sensor, sharing one electronic control unit. The index pressures and external monitoring functions are provided by the central module.

In addition, two speed sensors monitor and evaluate the wheel speeds. In the event of a tendency to lock or to spin being detected, the index value provided is adjusted.

Two sensors can be connected for monitoring lining wear.

The axle modulator has one additional port for connecting a backup pneumatic braking circuit. One double check valve per side transmits the higher of the two pressures (electro-pneumatic or redundant) to the brake cylinder.
In the Electronically controlled Braking System, the trailer control valve is used as a control element to output the hose coupling pressures.

The trailer control valve consists of a proportional solenoid valve (a), a relay valve (c), a breakaway emergency valve (d) and a pressure sensor (b). Electrical actuation and monitoring are effected by the central module.

The control current determined by the electronics is converted by the proportional solenoid valve into control pressure for the relay valve. The output pressure of the trailer control valve is proportional to that pressure.

The pneumatic actuation of the relay valve is effected by means of the backup pressure from the brake signal transmitter (port 42) and the output pressure from the hand brake valve (port 43).
The scheme on page 64 and 65 each show EC air braking systems widely used in Europe today. On a semitrailer, this braking system essentially consists of a relay emergency valve, a load-sensing valve and the ABS.

In the Vario-Compact System shown here, the ABS relay valves and the electronic control unit have been combined. Frequently, however, these components are fitted separately. On the drawbar trailer, another load-sensing valve, a third ABS relay valve, an adapter valve on the front axle and a pressure limiting valve on the rear axle are added to the components listed above. Although this EC braking system is now highly sophisticated, especially through the use of ABS, there is still room for the improvements listed below:

- Reduction of the variety/number of components and thus installations costs.
- Dispensing with the required air valves and their adjustment by introducing electronic control and the simple setting of parameters this permits.

- By using pressure control circuits which operate with a high degree of precision, it is possible to almost completely eliminate the deviations in characteristics encountered today.

- The “electrical brake line” and electronic control can considerably improve the time response and thus contribute towards reducing the stopping distance and improving the stability of the tractor-trailer combination.

- Extending the diagnostic features for the whole of the braking system, including maintenance and repair instructions.

It was these possible improvements which provided the basis for the development of an electronically controlled EBS on the trailer.

**EBS For Semitrailers 4S/2M**

1. EBS relay emergency valve
2. EBS trailer modulator
3. ABS sensor
4. Axle load sensor
5. Pressure sensor
6. Pressure switch
7. Redundancy valve

![Diagram of EBS for Semitrailers 4S/2M](image)

**Fig. 1**

**System Description**

Fig. 1 shows the standard EBS for a 3-axle semitrailer. It electronically controls lateral braking pressures. The system consists of a compact dual-circuit trailer modulator with a digital data interface to ISO 1199-2 to the EBS towing vehicle, an EBS relay emergency valve, an axle load sensor and ABS sensor. When used on drawbar trailers or semitrailers with a steering axle, a system is needed which includes an additional EBS relay valve on the steering axles, see Fig 2.

Trailers with the electronic braking system described must be compatible with both conventional towing vehicles and towing vehicles which use EBS, allowing...
pneumatic redundant braking in the event of EBS failure. This results in three possible types of operation:

**Operation with new towing vehicles with EBS and extended ISO-7638 plug-in connection with CAN interface.**

All EBS functions can be utilized. The trailer receives the index values from the towing vehicle via the data interface.

**Operation with conventional towing vehicles with ISO-7638 plug-in connection for the trailer’s ABS supply but with no CAN interface.**

All EBS functions can be utilized, with the exception of the transmission of the index values via the CAN data interface.

**Redundancy Operation**

In the event of a failure of the electrical voltage supply, ordinary pneumatic braking can always be achieved, although with no load-sensing or ABS functions. In redundancy operation, the time response is similar to that of today’s conventional braking systems. If the EBS trailer is operated pneumatically, an improved time response is achieved since electrical sensing of the actuating pressure saves time. When used with an EBS towing vehicle and actuation via CAN, the pressure in the EBS trailer builds up almost simultaneously with that in the towing vehicle.

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**EBS For Drawbar Trailers 4S/2M**

1. EBS relay emergency valve
2. EBS trailer modulator
3. ABS sensor
4. Axle load sensor
5. Pressure sensor
6. Pressure switch
7. Redundancy valve
8. EBS relay valve

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*Fig. 2*
Air Suspension Systems And ECAS (Electronically Controlled Air Suspension)
In commercial vehicles and motor coaches, more and more air-suspensions are being used.

In commercial vehicles with interchangeable platforms they achieve a considerable reduction in loading and unloading times. On coaches, ride comfort is improved by means of the spring force being adjusted to the number of passengers travelling on the coach and a boarding level which remains the same at all times.

**Air Suspension System**

When planning and designing air suspension systems, the following system types have been used to date:

- a) air suspensions with a closed air circuit
- b) air suspensions with a semi-closed air circuit
- c) air suspensions with an open air circuit.

The systems mentioned under a) and b) are mainly used in passenger cars, their benefit being that they consume a small amount of air so that the compressor can be smaller due to its lesser delivery requirements. In addition, there is little condensate or dirt. Such systems are, however, technically complex and fairly expensive to buy.

For that reason, motor coaches and commercial vehicles use air suspension systems with an open air circuit. Since this system evacuates air which is not required back to atmosphere, the air compressor has to be larger. This type of air suspension system is straightforward in terms of its circuit and the valves it uses.

Of course neither types of suspension (mechanical spring suspension elements or air suspension systems) can meet all technical requirements. Comparing both system types, however, shows that air suspensions offer significant advantages over mechanical suspensions. This applies especially where the wheel suspension elements are to be separated from other suspension members to achieve better road holding qualities.

**Benefits of Air Suspension Systems**

1. By adjusting the bellows pressure as a ratio of the load carried, the distance between the road surface and the vehicle’s superstructure will always be the same. This means that not only is the boarding or loading level constant, but also the headlight setting.

2. Due to the adjusting pressure in the bellows, spring comfort is not subject to any major changes, regardless of the load carried. The passenger on a motor coach will always perceive the same pleasant type of oscillation. Sensitive loads are carried without any major damage. An empty or partially laden vehicle will no longer ‘jump’.

3. Both steering stability and the transmission of brake forces are improved since tyre-road adhesion is always achieved for all wheels.

4. The pressure in the air suspension bellows which is dependent on the load carried is also ideal for controlling load-sensitive braking (‘ALB’).

5. In interchangeable platform operation, air suspension systems achieve efficient loading and unloading of container vehicles.

6. Protects the road surface.

In an air suspension system, the equipment for air compression, for the storage of compressed air and for pneumatic control must form a unit with the wheel suspension and other elements. The diagram on this page illustrates this for an air suspension system on semitrailers.
Purpose:
To control the pressure in the air suspension bellows in proportion to the vehicle load.
 Levelling Valve 464 006 100 0 has an additional 3/2 directional control valve which closes from a pre-defined, adjustable lever angle and which takes on an exhaust function when the lever is moved further. This “height limitation” prevents the vehicle being raised above the permissible level by means of the raise/lower valve.

Operation:
The vehicle body with its levelling valve will move down as the load on the body is increased. The linkage between the vehicle axle and the levelling valve raises both lever (f) and guide (d) via eccentric cam (e). As guide (d) moves up, it also lifts its pin, thus opening inlet valve (b), allowing air from the reservoir to flow through the valve via port 1 and check valve (a) into the air bellows which are connected to ports 21 and 22. In order to minimize air consumption, the outside of the pin is machined in such a way that the passage of air through the valve is regulated at two levels depending on the deflection of lever (f).

As the pressure in the air bellows increases, the chassis height is adjusted, and lever (f) causes inlet valve (b) to close. In this position, ports 21 and 22 are connected to each other via a transverse throttle.

When the vehicle load is decreased, the reverse process takes place. The vehicle chassis is now raised by the excess pressure in the air suspension bellows and lever (f) with eccentric cam (e) and guide (d) are pulled down. This causes the pin to be moved downwards from its seat on inlet valve (b), permitting excess pressure from the air bellows to escape to atmosphere via drilling (c) and vent holes 3. With this drop in pressure in the air bellows, the chassis height is lowered and lever (f) is returned to its normal horizontal position. As drilling (c) is blocked by the pin resting on inlet valve (b), the levelling valve is again in a balanced position.
**Raise/Lower Valve**

463 032 ... 0

**Purpose:**
To raise and lower the chassis of air-sprung semi-trailers and vehicles with interchangeable platforms (lifting facility).

**Operation:**
In the "travelling" position of the hand lever, the lifting mechanism is inoperative. The raise/lower valve allows the free passage of air from the levelling valves (ports 21 and 23) to the air suspension bellows (ports 22 and 24).

The valve also permits four more positions of the hand lever for filling and emptying the air suspension bellows for raising and lowering purposes.

To raise the chassis, the hand lever is unlocked by axial pressure and moved to the "raise" position in which ports 21 and 23 are closed, blocking the action of the levelling valves, while the suspension bellows 22 and 24 are connected to the reservoir by port 1.

When the required lift height has been attained, the hand lever is moved to the "raise stop" position in which the levelling valve ports 21 and 23 and the suspension bellows ports 22 and 24 are closed. The platform supports can now be swung into position.

It is then necessary to lower the chassis below its normal level to deposit the container or platform on the supports and to drive out the chassis. This is done with the hand lever in the "lower" position. As in the "raise" position, ports 21 and 23 are closed but air suspension bellows 22 and 24 are now exhausted through exhaust port 3.

This operation, too, is terminated by moving the lever to the "lower stop" position. Ports 21, 23, 22 and 24 are closed. Before the vehicle is driven, the hand lever must be moved to the "travelling" position to allow the levelling valves to be re-connected to the air bellows.
**Introduction:**

The letters ECAS stand for

- Electronically
- Controlled
- Air
- Suspension

ECAS is an Electronically Controlled Air Suspension system for vehicles and includes a large number of functions. The conventional system has been significantly enhanced through the use of an Electronic Control Unit (ECU):

- Reduction of air consumed whilst the vehicle is moving
- It is possible to maintain different levels (e.g. ramp operation) by means of automatic readjustment
- In the case of complex systems, installation is easier
- Additional functions such as traction help, programmable vehicle levels, tyre deflection compensator, overload protection and automatic lifting axle control can easily be integrated
- Due to large valve diameters, pressurizing and venting processes are accelerated
- Easy operation and maximum safety for those operating the system due to one single control unit
- Highly flexible system due to the fact that electronics can be programmed via operating parameters (trailing end programming)

**Clear-cut safety concept and diagnostic facility.**

With conventional air suspension systems, the valve which measures the height also controls the air bellows, whereas ECAS achieves control by means of an electronic control unit (ECU) actuating the air bellows via solenoid valves, using information received from sensors.

The ECU not only controls the normal height of the vehicle, it also, via the remote control unit, permits control of the other functions which, in conventional air suspension systems, require additional valves such as height adjustment valves and height limiting valves.

Over that, a large number of additional system functions are available.

ECAS is adjustable to suit the different types of trailer.

ECAS only works when the ignition is ON. Power supply for the trailer is normally provided via the ABS system. Connecting the ABS system is also necessary to ensure that ECAS receives the so-called C3 signal, i.e. information on the current speed of the vehicle.

To permit adjustment of the level of a trailer not connected to a towing vehicle, an optional facility for a storage battery may be provided for an additional power supply on the trailer.

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**Example for operation in a semi-trailer without lifting axle**

**Basic system:**

1. ECU (Electronic Control Unit)
2. RCU (Remote Control Unit)
3. Height Sensor
4. Solenoid Valve
5. Air Bellows
Description of operation

A Height Sensor (3) will continuously monitor the vehicle's height and send its readings to the ECU (1). In the event of the ECU finding that the normal level is not being maintained, a Solenoid Valve (4) is activated in such a way that, by pressurizing or venting, the level is adjusted accordingly.

Below a pre-defined speed (and when vehicle is stationary), the RCU (2) can be used to change the index level (useful for loading-ramp operation, for example).

An indicator lamp (situated on the front of the trailer, and visible from the truck's cab through the rear-view mirror) is used to notify the driver that the trailer is outside its normal ride height and to inform about any faults the ECU may have discovered.

Circuit diagram of basic system:

1 ECU (Electronic Control Unit)
2 RCU (Remote Control Unit)
3 Height Sensor
4 Solenoid Valve
5 Air Bellows
The Electronic Control Unit (ECU)
The Electronic Control Unit is the heart of the system and is connected with the individual components on the motor vehicle by means of a 35-pole or 25-pole plug-in terminal. The ECU is located inside the driver’s cab.

Together with a plug-in terminal for connecting the ECAS ECU for trailer’s to the other components, the ECU is mounted on the trailer’s chassis in a protective housing. This protective housing is similar to that of the ABS VARIO-C system. The ECU can be used for implementing a large number of system configurations. The plug-in terminal has a connector for every height sensor, pressure sensor and solenoid valve. Depending on the system used, parts of the terminal may not be used.

As in the ABS system, the cables are fed through glands in the lower part of the housing. To facilitate the allocation of the individual cables to the plugs, bands are taped around the cables.

Operation
The ECU contains a microprocessor which processes digital signals only. A memory managing the data is connected to this processor. The outlets to the solenoid valves and to the indicator lamp are switched via driver modules.

The ECU is responsible for
- constantly monitoring the incoming signals
- converting these signals into counts
- comparing these values (actual values) to the values stored (index values)
- computing the required controlling reaction in the event of any deviation
- actuating the solenoid valves

Furthermore, the ECU is responsible for
- managing and storing the various index values (normal levels, memory, etc.)
- data exchange with the RCU and the Diagnostic Controller
- regularly monitoring the function of all system components
- monitoring the axle loads (in systems with pressure sensors)
- plausibility testing of the signals received (for error detection)
- error recovery.

In order to ensure rapid control reaction to any changes in actual values, the microprocessor processes a fixed program in cycles of some milliseconds, with one program cycle covering all of the above tasks.

This program cannot be modified and is fixed in a program module (ROM). However, it will use values stored in a freely programmable memory. These values, the parameters, effect the computing processes and thus the ECU’s controlling reactions. They are used to communicate to the computing program the calibrating positions, the system configuration and the other preset values concerning the vehicle and functions.
**ECAS - Electronically Controlled Air Suspension**

### Solenoid Valves

Special solenoid valve blocks have been developed for the ECAS system. By combining several solenoid valves in one compact block, both space and installation time are kept to a minimum.

The solenoid valves are actuated by the ECU as a control element; they convert the voltage present into a pressurizing or venting process, i.e. they increase, reduce or maintain the air volume in the bellows.

In order to achieve a large throughput of air, pilot valves are used. The solenoids initially actuate those valves with a small nominal width, and their control pressure is then passed to the piston surfaces of the actual switching valves (NW 10 and NW 7 respectively).

Different types of solenoid valves are used, depending on the application: For controlling a single axle, one seat valve is sufficient whilst a complex sliding valve is required for controlling the lifting axle.

Both types of solenoid valves are based on a modular principle: Depending on the application, the same housing is used to accommodate different parts of valves and solenoids.

### ECAS Solenoid Valve 472 900 05 0

Valve for the axle with two height sensors

The solenoid valve shown in the illustrations below has three solenoids. One solenoid (6.1) controls a central breather valve (also known as a central 3/2 directional control valve), the others control the connection between the two air bellows (2/2 directional control valves) and the central breather valve.

This valve can be used for establishing what is known as 2-point control in which both height sensors on both sides of the axle separately control the level of both sides of the vehicle so that the body is kept horizontal even when the load is not evenly distributed.

### Design of the Valve

Solenoid 6.1 actuates a pilot valve (1), and the actuating pressure from this valve flows through hole (2) and acts on piston valve (3) of the breather valve. The pilot valve receives its pressure via port 11 (supply) and connecting hole (4).

This drawing shows the breather valve in its venting position in which air from chamber (5) can flow to port 3 via the hole of the piston valve.

As solenoid 6.1 is energized, piston valve (3) is pushed downwards, initially causing valve plate (6) to close the hole of the piston valve. The valve plate is then pushed off its seat (hence the name 'seat valve'), and supply pressure can flow into chamber (5).

The other two valves connect the air suspension bellows with chamber (5). Depending on which solenoids (6.2 or 6.3) are energized, piston valves (9) or (10) are pressurized via holes (7) or (8), opening valve plates (11) and (12) to ports 22 and 23.

A solenoid valve for control of the other axle can be fitted to port 21.
This valve is similar to the valve described above but it contains fewer parts.

Since port 14 is connected to port 21 of the valve described above, no breather valve is needed and only one pilot valve (1) is used. The piston valves (3) of both air suspension bellows valves are pressurized via two connecting holes (2) so that each pressurizing or venting process is effected evenly for both bellows via chamber (5).

If the solenoid is not energized, the valves are closed, as shown in the illustration. At this time, the only connection between the bellows is the lateral choke (7), through which any difference in pressures can gradually be compensated.

The valve is connected to the air supply via port 12. This port is needed merely to permit the pilot valve to displace the piston valve.

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ECAS Solenoid Valve
472 900 02 . 0

Valve for an axle with one height sensor

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ECAS Solenoid Valve
472 905 1 . . 0

Sliding valve with rear axle block and lifting axle block

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ECAS Solenoid Valve
472 900 05 . 0

Valve for the bus with a kneeling function
By means of the RCU the driver can influence the vehicle's level within the permissible maximum limits. However, this can only be done whilst the vehicle is either stationary or has not exceeded the driving speed parameter.

The control keys for changing the vehicle's level are accommodated in a handy housing which is connected, via a coiled cable and a socket on the vehicle, with the ECU.

There are different RCUs depending on the type of system used. The above illustration shows a unit with the largest possible number of functions. The functions of this RCU are:

- raising and lowering of the chassis
- setting normal level
- stop
- storage and actuation of two preference levels
- raising and lowering of the lifting axle, or unloading or loading the trailing axle
- switching automatic lifting axle operation on and off.

From the outside, the height sensor looks similar to WABCO's conventional levelling valve which means that it can often be fitted in the same location on the vehicle frame (the pattern of the two upper mounting bores is similar to that of the levelling valve).

The sensor housing contains a coil in which an armature is moved up and down. Via a connecting rod, the armature is connected to a cam on the lever's shaft. The lever is connected to the vehicle axle.

As the distance between the superstructure and the axle changes, the lever is turned, causing the armature to move into or out of the coil. This changes the coil's inductance.

This inductance is being measured by the electronic control unit at short intervals and converted into a height signal.
The pressure sensor produces a voltage output which is proportional to the pressure present. The measuring range lies between 0 and 10 bar; a pressure of 16 bar must not be exceeded.

The signal voltage is sent to the ECU via a connecting plug. Furthermore, the sensor must receive a supply voltage from the ECU via a third conductor. The cable harness must be encased in a hose or similar material in such a way that the housing - which is otherwise waterproof - can "breathe".

Under no circumstances should the pressure sensor be connected to the connecting line between air suspension bellows and solenoid valve since this could result in wrong readings when pressurizing or venting is in progress.

If air suspension bellows with two threaded ports, as offered by renowned manufacturers of air suspension systems, cannot be used, a special connector must be fitted.

This connector can consist of a T-shaped pipe union, with a small pipe being welded into its pressure sensor connection protruding into the inside of the bellows, thereby sensing the "settled" bellows pressure (these fittings are available from WABCO).

A normal tee-piece can be used but only when a high raise/lowering-speed is not required. Two examples:

- One axle is sensed (drawbar-trailer with one LA). The feed pipe from bellows to solenoid should be small (nominal size ø 6) but the connection between bellows and sensor large.
- Two axles are sensed (3-axle semi-trailer with one LA). Use ø 12 pipe between the sensed bellows. Fit the pressure sensor in a tee piece next to one bellows. The line from the solenoid valve should be ø 9) entering the system at the other bellows.
Clutch Servos
Clutch Servos

Clutch Servo
970 051 ... 0
Modular Series

Purpose:
To reduce the force required to push down the clutch pedal and to permit sensitive and accurate actuation of the clutch.

Design:
The clutch servo consists of three parts:
- hydraulic slave cylinder
- control valve
- pneumatic servo cylinder.

Possible variants:
- trigger valve for transmission control
- optional feature for pressure sensors
- wear indicator.

Operation:
The clutch servo is connected with the air reservoir for ancillary consumers via Port 1, and with the pedal-operated hydraulic master cylinder via Port 1-4.

a) Clutch not engaged:
During the declutching process, the air pressurized by the pedal-operated master cylinder is forced into Chambers C and D through Port 1-4. This causes piston (a) to move to the left, closing the outlet (b) and opening the inlet (c). It thus allows the compressed air to pass from Port 1 into Chamber A and from there through the duct (d) into Chamber B. Pneumatic and hydraulic pressures force piston (e) to the right, causing the clutch to disengage through the forcing lever (f). The air pressure in Chamber A balances the hydraulic pressure in Chamber D and the control valve is in its neutral position.

b) Clutch engaged
When the clutch is engaged once again, the oil from Chambers C and D returns to the pedal-operated master cylinder. Piston (a) returns to its original position on the right, the inlet (c) closes and the pressure in Chambers B and A is evacuated through the opening outlet (b) and Vent 3.

The hydraulic and pneumatic pressures at piston (e) fall, releasing the way back into the engaged position. Through duct (g), the pressure in Chamber E can rise or fall.

The pressure in Chamber B remains proportional to the hydraulic pressure in Chamber C at all times, thus giving the driver full control when engaging the clutch.

If the air pressure is insufficient, it is possible to declutch solely with the hydraulic pressure acting on piston (e). However, this requires greater force to be applied to the clutch pedal.

The design of the modular series includes automatic readjustment of the clutch, and some variants also have a mechanical wear indicator.

For vehicles with Electronic Drive Control (EAS), clutch servos from the 970 051 4.. 0 series have a pressure sensor fitted.

EAS is a system which permits pulling of and changing gear with standard aggregates without a clutch pedal having to be actuated. The driver can either change gear manually by actuating a master unit similar to EPS, or the process can be automatic through the electronic control unit.
**Clutch Servo**

**970 051 . . . 0**

**Special Design**

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**Purpose:**
To reduce the clutch pedal effort and to provide a smooth and precise clutch operation.

**Design:**
The clutch servo consists of two parts:

- a servo device: hydraulically controlled pneumatic control valve
- an actuating unit: differential cylinder under hydraulic and pneumatic pressure which transmits force to the clutch mechanism.

**Operation:**
The clutch servo is connected to the auxiliary reservoir via port 1, and via port 1-4 to the pedal actuated hydraulic master cylinder.

**Clutch disengagement position:**
When disengaging the clutch, the oil forced by the pedal actuated clutch master cylinder enters through port 1-4 into chambers (C) and (D). Piston (a) moves to the right, closes outlet (b), opens inlet (c) allowing the compressed air from port 1, to enter into chamber (A), and to flow through channel (g) into chamber (B).

Forced by the pneumatic pressure, piston (f) moves to the right causing the clutch to disengage by means of a push rod connected to the clutch actuating lever. The pneumatic pressure in chamber (A) balances the hydraulic force in chamber (D) closing inlet (c).

**Clutch engagement position:**
When reengaging the clutch, the oil in chambers (C) and (D) is returned to the pedal controlled clutch master cylinder. Piston (a) returns to the right, closes inlet (c), opens outlet (b) and allows the compressed air to be vented from chambers (A) and (B) to the atmosphere through port 3. The hydraulic and pneumatic pressures on pistons (e and f) decrease, allowing them to return to the left, to the clutch engagement position. The air pressure partially returning through channel (d) compensates for the vacuum in chamber (E).

At all times, the pneumatic pressure in chamber (B) remains proportional to the hydraulic pressure in chamber (C) thus giving the driver full control of the clutch engagement.

If there is insufficient compressed air, clutch disengagement is still possible with the hydraulic pressure acting on piston (e). However, this requires greater pedal effort.

The spring behind piston (e) compensates for clutch friction wear.
Air Braking Systems In Agricultural Vehicles
Air Braking Systems In Agricultural Vehicles

Brief Description Of The Different Air Braking Systems

In the single-line braking system, a single air line between the tractor and its trailer is used to fill the air reservoirs on the trailer while the vehicle is in motion, and as the trailer is braked the pressure in that line is reduced.

In the twin-line braking system, there is one line each between the tractor and its trailer, one for filling the trailer’s air reservoirs and one for controlling the braking process (by reducing the pressure). The benefit of such a system is that the supply of compressed air on the trailer is also being topped up during the braking process.

In a combined single and twin-line braking system, this system can use either the principle of the single-line or the twin-line system. Towing vehicles with a single-line and a twin-line connection for the trailer thus permit both trailers with a single-line or with a twin-line braking system to be connected.

It is important to remember that the brakes of a trailer with a single-line system cannot be operated if it is used behind a tractor with a twin-line braking system; the same also applies vice-versa.

Benefits Of A Twin-Line Air Braking System

- The operating pressure and thus the additional braking force can be sensitively graded. The same also applies to long downhill gradients.
- Because of its adjustable predominance on the relay emergency valve, the tractor-trailer combination remains stretched-out and the trailer does not run up to its tractor.
- Less wear on the tractor’s brakes and thus longer life and lower maintenance cost.
- Any slight leakage does not effect the performance. The compressor always supplies sufficient compressed air for the braking system, also during the braking process.
- Unintentional disconnection of the trailer from the tractor causes the trailer to be braked automatically (breakaway brake).
- High level of safety and enhanced ride comfort. The jerking common with trailers which have had overrun brakes fitted is prevented.
- It is not possible to mismatch hose couplings due to the built-in mismatch-safeguard.
- Non-polluting because the medium, air, can be emitted directly to atmosphere.
- Easy and simple to retrofit the air braking system.

Design of the Air Braking System

The air braking system shown in the illustration is a high pressure braking system (HPR) whose pressure level is controlled by an unloader valve (2). This supply pressure of 14 bar is limited to 7.3 bar by the pressure limiting valve (4) located downstream from the air reservoir, thus in effect achieving a normal pressure braking system (NPR). The trailer’s braking system (in this illustration it is a dual line braking system) is actuated by the master cylinder (7) via an air/hydraulic dual line trailer control valve (8).
Air Braking Systems In Agricultural Vehicles

Operation:

Driving Position
The compressed air from the compressor (1) flows via the unloader valve (2) which automatically controls the operating pressure of the tractor’s air compression system, into the air reservoir (3). The supply pressure reading is shown on the pressure gauge (5).

From the air reservoir (3), the air flows via the pressure limiting valve (4), set to 7.3 bar, to the dual line trailer control valve (8), the 3/2 way valve (6), the single line trailer control valve (9) and on to the supply hose coupling. In the trailer control valve (9), the pressure is limited to 5.3 bar which reaches the hose coupling (11) (single line).

If a dual line trailer is attached, the supply pressure of 7.3 bar flows via the hose couplings (10) to the trailer passing the line filter (15), the relay emergency valve (16) and finally the air reservoir (22).

To supply a second trailer with compressed air, two additional hose couplings (23 and 24) have been provided on the trailer. These are connected to the supply and pilot lines downstream from the relay emergency valve (16).

Braking Position
When the brake pedals are actuated, the 3/2 way valve (6) is opened and the trailer control valve (8) receives the supply pressure of 7.3 bar.

This causes a small amount of pressure to reach the relay emergency valve (16) through the pilot line, actuating it. The trailer’s air supply now flows from the air reservoir (22) through the relay emergency valve, the adapter valve (17) and the load-sensing valve (18) to the brake cylinders (20) on the front axle, and through the pressure limiting valve (19) and the load-sensing valve (18) to the brake cylinders on the rear axle.

When the brake pedal is pushed down further, pressure is built up in the hydraulic master cylinder (7) which increases the actuating pressure at the trailer control valve (8). Depending on the level of hydraulic pressure, the trailer control valve (8) also builds up the pressure in the pilot line leading to the relay emergency valve (16) and, through the load-sensing valves (18), transmitted to the brake cylinders as a ratio of the load carried.

When the hydraulic braking pressure in the tractor’s braking system has been reduced, the air pressure in the pilot line leading to the relay emergency valve also falls, causing the pressure in the brake chambers (20) to be reduced via the adjusting valve and the load sensing valves. The passage in the 3/2 way valve is closed once again, and the supply pressure of 5.3 bar (single line) begins to build up in the line between the trailer control valve (9) and the hose coupling (11).
Compressed Air Generating System:

normal line and dual line system hydraulically actuated

Legend:
1 Compressor
2 Combined Unloader
3 Air Reservoir 20 l
4 Drain Valve
5 Pressure Gauge
7 Trailer Control Valve, single line
8 Hose Coupling, supply line
9 Hose Coupling, control line
10 Hose Coupling, single line
11 Trailer Control Valve
12 3/2-Directional Control Valve
13 Master Cylinder

Pressure Limiting Valve
973 503 . . . 0

Purpose:
Limitation of output pressure.

Operation:
Compressed air directed into chamber A through high-pressure port 1 flows through inlet (j) and chamber B to low-pressure port 2. Pressure is thereby also brought to bear via hole (c) on diaphragm piston (b), which is initially retained in its lower position by compression spring (a).

When pressure in chamber B reaches the level to which the low-pressure side is adjusted, diaphragm piston (b) overcomes the force of spring (a) and moves upwards with spring-loaded valve (i), thus closing inlet (j).

If pressure in chamber B rises above the set level, diaphragm piston (b) moves further upwards and is thereby lifted off valve (i). Excess compressed air escapes to atmosphere through hole (h) of valve (i) and exhaust 3.

If pressure starts to drop in the low-pressure line, this relieves diaphragm piston (b) of pressure so that it moves downwards and pushes valve (i) open until a sufficient quantity of compressed air has been supplied through inlet (j).

Should the pressure in the high-pressure line rise above the maximum permitted level, safety valve (g) opens against the force of compression spring (f) and allows the excess compressed air to escape to atmosphere through hole (e) and dust cover (d). Pressure in the low-pressure line is not affected by this process.

The pressure existing in the low-pressure line is fully retained when the high-pressure line is evacuated.

The line at low-pressure port 2 can be evacuated only through equipment connected on that side.
3/2-Directional Control Valve
563 020 . . . 0

**Purpose:**
To alternately control the pilot line with the supply line or the exhaust upon actuation of the brake.

**Operation:**
When the tractor's brake pedals are actuated, Piston (a) is forced to its upper position by the spring force. The compressed air from the supply line at Port P2 now reaches Port A and from there the downstream trailer control valve. This causes a brake pressure to be output for the trailer even before the hydraulic tractor brake becomes effective.

When the tractor's brake is released, Piston (a) is pushed downward once again by the brake pedal and the passage is closed. The compressed air from the pilot line is now reduced via the opened passage to Port R2.

Shut-Off Cock
452 002 . . . 0 and 952 002 . . . 0

**Purpose:**
To shut off an air line and vent the downstream line.

**Operation:**
When the lever (a) is parallel to the longitudinal axis of the stop cock the eccentric shaft (c) pushes valve (d) to the left against the spring (e). Air passes unrestricted from port 1 through the inlet (f) to the line leading from port 2. If the lever (a) is turned through 90 degrees to its stop, the spring (e) moves valve (d) to the right and the inlet (f) is closed. The line leading from port 2 is vented through the exhaust drilling (b).
Purpose:
To control the dual line braking system of the trailer in connection with the trailer's hydraulic master brake cylinder or its hydraulic transmitter.

Variant 252 provides for additional pneumatic actuation, causing trailer brake pressure to be activated even before the tractor's brake becomes effective.

Operation:
In the release position, Compression Spring (e) pushes Valve Sleeve (d) onto Inlet (c), keeping it closed. Port 2 is connected with Exhaust 3 via Outlet (b).

When the brake pedal is depressed, the hydraulic control pressure will act on Piston (h) via Port 4, displacing that piston, together with Graduating Piston (a), to the right. Outlet (b) is closed, Inlet (c) opens and the compressed air present at Port 1 flows to the relay emergency valve via Port 2. The compressed air acting on Graduating Piston (a) moves it to the left against the hydraulic control pressure, and Inlet (c) is closed. A final position has now been reached.

Some dual circuit Variants is also fitted with an additional pneumatic control port. This permits an upstream 3/2-way valve to pressurize Port 42 and thus Chamber A with an actuating pressure of 7.3 bar when the brake pedal is depressed. Piston (a) closes Outlet (b), opening Inlet (c). Thus a small amount of actuating pressure reaches the relay emergency valve via Port 2 before actuating pressure builds up at Port 4.

Any increase in the hydraulic actuating pressure will also cause the pressure at Port 2 to be increased. As the brake pedal is released, Ports 4 and 42 will be depressurized, causing the pressure in Port 2 to return Graduating Piston (a) to its original position. Outlet (b) opens, and Port 2 is vented via Exhaust 3.

The Trailer Control Valve also has a Hand Brake Lever (f) which, as the hand brake is actuated, will push Piston (a) against Valve Sleeve (d), thus opening Inlet (c), causing full braking of the trailer.
Purpose:
To control the single or dual line braking system of the trailer in connection with the trailer's hydraulic master brake cylinder or its hydraulic transmitter.

Operation:
In the valve's release position, Compression Spring (e) pushes Valve Sleeve (d) onto Inlet (c). The air supplied via Port 1 flows via Hole A into Chamber B, raising Piston (h) which takes with it Piston (k) and Valve (i). Inlet (l) is opened, permitting the air supplied to flow via Port Z into the trailer's (single) control line. When the forces of Pistons (h and k) are balanced, Inlet (l) is closed and the pressure at Port Z is limited to 5.2 bar. Port 2 is vented via Outlet (b) and Exhaust 31.

When the brake pedal is depressed, the hydraulic control pressure will act on Piston (m) via Port 4, displacing that piston, together with Graduating Piston (a), to the right. Outlet (b) is closed, Inlet (c) opens and the compressed air can now flow via Port 2 to the control line trailer's dual line braking system. The compressed air acting on Graduating Piston (a) moves it against the hydraulic control pressure, and Inlet (c) is closed. A final position has now been reached. At the same time, the pressurized Piston (h) is pushed downwards. Outlet (j) is opened, and Port Z is partially vented via Exhaust 32. A final braking position has been reached when the force in Chamber B acting on the underside of Piston (h) is greater than the force acting on the top of Pistons (h and k). Piston (h) is raised to a point where Outlet (j) and Inlet (l) are closed.

When the brake pedal is released, Port 4 is depressurized, causing the pressure in Port 2 to return Graduating Piston (a) to its original position, opening Outlet (b). Port 2 is vented via Exhaust 31. At the same time, the pressure acting on the top of Piston (h) is reduced and the supply pressure in Chamber B pushes it to its top end position. Via opened Inlet (l), Port Z is once again pressurized up to 5.2 bar.

The Trailer Control Valve also has a Hand Brake Lever (f) which, as the hand brake is actuated, will push Piston (a) against Valve Sleeve (d), thus opening Inlet (c), causing full braking of the trailer.
Purpose:
To control the single line air braking system of the trailer in combination with the trailer control valve attached to the foot brake lever for the tractor’s dual line trailer braking system and for limiting the output pressure to 5.2 bar.

Operation:
In the release position, Compression Spring (a) will hold Diaphragm Piston with Valve Sleeve (c) in its lower end position. Outlet (d) is closed and Inlet (e) open. The compressed air from the tractor’s air reservoir flows via Port 1 to Port 2 and reaches the relay emergency valve via the hose couplings. At the same time, the compressed air flows, via Hole C, into Chamber D below Piston (h), and via Hole A into Chamber E above Piston (h). As soon as the pressure in Chamber B and in the line to the trailer has reached 5.2 bar, Valve (g) is forced downwards against the force of Compression Spring (f) until Inlet (e) is closed.

When the tractor’s foot brake is actuated, the output pressure from the trailer control valve which is affixed to the foot brake lever for the dual line trailer braking system will, via Port 4, reach Chamber F where a pressure will now build up below the Cup Collar which forces Diaphragm Piston (b) with Valve Sleeve (c) upwards against the force of Compression Spring (a). Outlet (d) opens. Through Valve Sleeve (c) and Exhaust Hole 3, sufficient air will now be emitted to atmosphere to achieve the abrupt reduction in pressure required for advanced retardation of the trailer.

At the same time, the pressure in Chamber D will fall and Piston (h) is forced downwards by the supply pressure in Chamber E acting on its upper portion. It takes with it Valve Sleeve (c) which in turn closes Outlet (d) as it settles on the double cone valve.

As described above, the increased braking effect of the tractor causes the pressure of the trailer’s control line to be further reduced whilst the advanced retardation of the trailer is maintained. When the tractor brake is released, the pressure in Chamber F is reduced once again, causing Diaphragm Piston (b) and Valve Sleeve (c) being forced downwards through the force of Compression Spring (a). Inlet (e) opens and the supply air present at Port 1 flows to the trailer’s control line via Port 2.
Purpose:
To control the braking forces of the trailer's brake cylinders as a ratio of the load setting.

Operation:
When the brakes are applied, the pressure from the flanged relay emergency valve arriving at Port 1 flows into Chamber A and through the opened inlet (d) and Chamber B to Port 2 and thus to the trailer's brake cylinders. At the same time, pressure is applied to the piston (e) which is initially being held in its upper end position by the spring (f). The force of the spring (f) is dependent on the position of the lever (g) - together with the cam (j) - which is either 'empty', 'half load, or 'full load (or even 1/4 load' or '¾ load', on some vehicles). As soon as the control pressure in the cylinders and on the piston (e) corresponding to the load setting has been reached, the piston (e), together with valve (c) and spring-loaded valve (a) will slide downwards, closing inlets (b and d). This prevents the pressure in the cylinders from rising further.

In the event of any leakages in the trailer's braking system, the drop in pressure will cause valve (a) to be raised by the piston (e). Inlet (b) opens and more compressed air is supplied accordingly.

When the tractor's brakes are released, Port 1 and Chamber A become pressureless. The higher pressure in Chamber B raises valve (c) and with valve(a). Inlet (d) opens and the brake cylinders are evacuated through Port 1 and the relay emergency valve. The reduction in the pressure acting on piston (e) causes that piston to be returned to its upper end position by the spring (f).

The 'release' position which a number of variants of this load apportioning valve have is used to release the brake when no trailer is attached. To achieve this, the shape of the cam (j) relaxes the spring (f) to the point where piston (e) moves downward, opening the outlet of the valve (a). The compressed air from the brake cylinders can escape to atmosphere through the axial hole in piston (e) and Vent 3.

The adjuster screw (i) is used to adjust the pressure reaching the cylinders from the load apportioning valve in the 'empty' position. When the lever of the load apportioning valve is in its 'full load' position, that screw is accessible after removing the cap in Vent 3 and permits the initial tension of the spring (f) to be adjusted. Unscrewing the screw (i) causes the pressure in the cylinders to be increased, screwing it in causes that pressure to be reduced. The pressure can be similarly adjusted for the 'half load' position. To do this, the 'release' position is selected, and the adjustment is achieved by turning screw (h). On load apportioning valves which do not have a 'release' position, screw (h) is reached by selecting the 'empty' position and unscrewing the screw on the side of the bottom housing (this screw being found only on those variants).

When turning the screws (h or i), the load apportioning valve must always be pressureless.
ETS and MTS - Electronic Door Control System For Motor Coaches
9. ETS - Electronic Door Control System For Motor Coaches

Introduction

Due to more stringent safety regulations, the motor buses of urban public transport and the motor coaches of private operators in Germany have had to have safety controls fitted since the early eighties to protect their passengers and to reduce the hazard of accidents in workshops. The two major criteria which have had to be met since then are:

- features for opening and closing doors to protect both persons and objects
- features for the prevention of sudden door movements after re-pressurizing of cylinders.

Although these demands focusing on improvements in technical safety were met by the introduction of the two WABCO systems, following the pressureless and the pressure-reduced principle, it very soon turned out that - in terms of the number of appliances fitted and ease of maintenance - there was still room for further improvements.

This caused WABCO to develop an electronically controlled system which fully takes into account the following key requirements:

- safety for passengers
- reduction of the safety hazard in the workshop
- easy to use by workshop staff
- reduction of system cost
- no service or maintenance required.

The development, focusing on these demands, resulted in the Electronic Door Control System which has been produced since late 1987 and is known by the abbreviation *ETS*.

The most important improvements which have been achieved are as follows:

- elimination of the limit and drum-type switches
- no more adjustment work to be done by the vehicle manufacturer or transport company
- development of a standard system accepted by all bus manufacturers in terms of their respective safety policies
- use of ETS in combination with simple, time-tested pneumatic actuators
- reduction of jamming forces.

System Design of ETS

Pneumatic Control

Compared with the pressureless and the pressure-reduced circuits, the use of ETS achieves a considerable reduction in the number of components fitted. They are replaced by a single door valve which has two key attributes:

- increasing and decreasing the pressure in the cylinder chambers (4/2 function = ordinary door operation)
- reducing door slamming after re-pressurizing the cylinders following the actuation of the emergency cock. The door continues to be ‘powerless’ after this process. The door leaves can be moved by hand to prevent any hazard to passengers.
Fig. 1
Example for an ETS system with rotary drive

The layout of an ETS door control system shown above illustrates how the various door components are connected. This example shows a system with a rotary drive, i.e. the door operating cylinder is mounted directly to the rotary pillar of the door leaf.

In this example, the door is monitored by a dynamic pressure switch in addition to the displacement transducer. The dynamic pressure switch is actuated by a pressure pulse from the rubber seal of the main front edge. The ETS ECU has a separate inlet for this function.

Fig. 2
ETS system with linear door drive

This diagram shows the pneumatic connection with a linear cylinder drive. The electrical circuit is identical to that of the rotary drive.

In both types of drive, the opening and closing speeds of the door leaves can be adjusted by means of suitable throttles or panels. For details on such adjustments, please refer to the vehicle documents provided by the vehicle manufacturer.
9. ETS - Electronic Door Control System
For Motor Coaches

ETS - ECU
446 020...0

Electronic Control
Electrical control is achieved by an electronic control unit with a micro-controller inside. It is available in two basic versions:

- actuation control by the driver only
- automatic system for automatic door actuation.

Both types of ECU contain identical computer programmes. Adjustment to the various functions is made by means of a special programming process. The type of ECU can be identified by the plug-in connectors:

The ordinary control unit has a 25-pole terminal, as does the automatic control unit which, however, also has a 15-pole socket for the automatic functions and a two-way (manual-automatic) switch.

4/2-Way Cock
(Emergency Cock)
952 003...0

Purpose:
The emergency cock is needed to evacuate the air in the door operating cylinders in a hazard situation, for the purpose of repairs, or if the door operating system has failed to permit the door leaves to be moved by hand. At the same time, it actuates the door valve in such a way that when the door operating system is pressurized once more, the door operating cylinders are rendered ‘powerless’. Variant 952 003 031 0 of this emergency cock has a switch for actuating a warning facility.

Operation:
In the normal position of the T-handle (a), compressed air from the supply line flows through Port 1, through the 4/2-way cock and on through Ports 2 into the operating lines.

By turning the handle (a) through 90° into the emergency position, the supply line is cut off and the operating lines are evacuated through Port 3.
**Purpose:**

In normal operation, the door valve acts like a 4/2-way valve and is used to alternately pressurize the chambers of the door operating cylinders. Unlike older systems, the door of the vehicle - if it makes contact with an obstacle while opening - becomes ‘powerless’ which means that the door valve simultaneously pressurizes all chambers of the cylinder, causing the door to stop. This prevents people getting jammed, and the door leaves can be pushed by hand.

**Operation:**

*Opening And Closing of Doors*

To switch the door valve to ‘open’, a button on the dashboard has to be pushed. This causes the ECU (outlet PIN 15) to close the electric circuit to Solenoid A of the door valve, and the armature moves upward. The compressed air in hole (b) flows into chamber (c), acting on piston (a) which is forced to the right, also pushing piston (f) into its end position on the right. In this position, Port 11 (energy supply) is connected with Port 21/22 and the compressed air flows through the door valve into the opening chamber of the door operating cylinders. Since Port 23/24 is connected with Vent 3, the doors open.

When the driver pushes the door button on the dashboard once more, the door valve is reversed into the ‘close’ position by energizing Solenoid B (piston (f) moves piston (a) into its left end position). The closing chambers of the door operating cylinders are pressurized, or the opening chambers are evacuated. The doors close.

*Jamming Protection: Reversal When Closing the Door*

If a person or an object gets jammed between the main front edges of the doors, the motion of the door is impeded. Via the electronic displacement transducer (potentiometer), this impediment is detected and processed in the electronics. The door’s electronics now reverse the door valve to its opening direction and the doors are opened by the reversal process. After the driver has again pushed the button on the dashboard, thus providing another switching pulse, the door cylinders are pressurized in their closing direction and the doors will close.

*Jamming Protection: Reversal When Opening the Door*

In order to comply with the guidelines for automatic doors and for doors on motor coaches actuated by the driver, the construction must be such to ensure that passengers who are located within the door area on the vehicle cannot get jammed as the doors open.

For this purpose, Solenoid C of the door valve is used, together with the electronic displacement transducers. If a person or an object is jammed by the back edge of the opening door, this impediment is perceived by the electronic displacement transducer and processed by the electronics. Solenoid C of the door valve is energized. The valve reverses and pressurizes chamber (g); both pistons (a and f) are in their end positions and both sides of the door operating cylinders are pressurized through Ports 21/22 and 23/24. This causes the door operating cylinders to be virtually ‘powerless’. The door leaves are brought to a stop and can be moved by hand.

In this context it is important to know that - due to the difference in the surfaces of the pistons of the door operating cylinder - the door leaves slowly move to their open position when the obstacle has been removed. However, the door can now be closed at any time when the driver pushes the button on the dashboard.

*Actuation of Emergency Cock*

When the emergency cock is actuated, the door valve is actuated pneumatically through Port 4. The door operating system is evacuated via the emergency cock. The door operating cylinders are pressureless, so that the door does not move and can be opened manually. If the door is to be operated once again it is sufficient to return the emergency cock to its normal position. Through the door valve (pneumatically operated via Port 4) all chambers of the door operating cylinders are pressurized - as described under ‘Jamming Protection: Reversal When Opening the Door’. The driver can then close the door again by pushing the button on the dashboard.
Door Operating Cylinder for single-phase closing motions with damping on both sides
422 802 . . . 0

Purpose:
To open and close hinged and folding doors.

Operation:
When the door valve is actuated, the compressed air flows through Port 12 into Chamber A. The pressure building up there forces the piston (c) and the pressure bar (d) to the right, opening the hinged door. At the same time, Chamber B is evacuated through Port 11 and the upstream door valve.

When the door valve is actuated once again, Chamber B is pressurized through Port 11 and the pressure in Chamber A is reduced through Port 12. The alternating increase in pressure on the piston (c) forces it, together with the pressure bar (d), back to the left, and the hinged door closes.

The speed of the opening and closing process can be adjusted by means of the throttle screws (a and f). To prevent heavy and noisy impact of the door as it opens or closes, the door operating cylinder has two additional throttles (b and e) which achieve a buffering effect (slowing the motion towards the end).

The compressed air displaced by the front end of the piston (c) in the door’s opening motion initially escapes evenly through throttle (f) and Port 11. However, approx. 40 mm before the end of the stroke has been reached it has to pass the buffer throttle (e) since the reinforced part of the pressure bar (d) protruding into the radial seal (g) prevents a further evacuation of Chamber B through throttle (f). The buffer effect for the closing door is achieved in a similar manner. The compressed air initially escaping evenly from Chamber A through throttle (a) and Port 12 is forced past buffer throttle (b) approx. 40 mm before the end of the stroke.

The door operating cylinder has been designed in such a way that by switching over the lines from the door valve ending at Ports 11 and 12, the motions are reversed. The door will then open when the piston rod is retracted, and close when the piston rod is extended.
Door Cylinder for single phase closing motion with damping when piston rod extends or retracts 422 808 . . . 0

**Purpose:**
To open and close slide glide and bifold doors for buses. Application is specifically for doors equipped with reverse control system.

**Operation:**
Upon activating the door valve, compressed air flows via port 12 into chamber (A). The pressure build up moves piston (a) as well as piston rod (b) to the right thereby opening the attached door. Simultaneously, chamber (B) is vented via port 11 and the subsequent solenoid door valve. At the same time, the two ports of the reverse switch, which are connected to ports 41 and 42, are pressurized or vented.

Reactivating the door valve, pressurizes chamber (B) via port 11, and chamber (A) pressure decreases via port 12. Due to the pressure differences acting upon piston (a), piston (a) and piston rod (b) move this time to the left and close the attached door. Also the reverse control switch is pressurized or vented as in the door opening process.

The door cylinder is equipped with an adjustable throttle (d) which produces considerable damping as the piston rod nears the end of its motion preventing the attached door from slamming.

**Fig. A with damping as the piston rod approaches full extension:**
During the initial phase of door opening, displaced air escapes unhindered via bore (C), however, at approximately 40 mm before the end of the stroke, the wider diameter segment of the piston rod penetrates the radial seal, preventing further venting of chamber (B) via bore (C), instead forcing air to vent through the damping throttle, which is adjustable by set screw (d).

**Fig. B with damping as the piston rod approaches full retraction:**
Approximately 40 mm before the end of the stroke, the inner bore of piston rod (b) surrounds and seals tube (e), now forcing compressed air in chamber (A) to vent through throttle (d), which is adjustable by set screw (d).
9. ETS - Electronic Door Control System
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Pressure Switch
441 014 . . 0

The pressure switch is used to switch solenoid valves or indicator lamps off and on. Correspondingly, there is an on-switch and an off-switch.

The switch position is dependent upon the detail function of the facility to be controlled. The pressure switch is not adjustable within the respective series.

For purpose and operation, please refer to Page 99.

Displacement Transducer
446 020 4 . . 0

The displacement transducer (sensor) is a displacement-controlled potentiometer. In the opening process, the voltage rises from approx. 0.9 volts to approx. 14 volts whilst in the closing process it falls from approx. 14 volts to approx. 0.9 volts. These voltage variations are detected and processed by the door’s electronics. If the door hits an obstacle as it opens or closes, the electronics perceive this immediately and actuate the door valve 372 060 . . 0 accordingly.
System MTS:

MTS was developed and first used in 1997 based on the experience acquired with ETS. The special feature of this system is that it can be used with any door model. Inward swivelling doors, outward swinging doors and swivel sliding doors with pneumatic or electrical drive can be combined with one another without problems!

Another innovation is also the connection to the vehicle electric unit. Here, it is possible to use a CAN data bus. Therefore, only two lines are required to control up to 5 motor coach doors.

For vehicles without a central data bus, conventional cabling can be used as an alternative. However, contrary to other systems, the lines must only be connected to the electronic control unit of the first door.

Whether you are using a CAN or conventional cabling, the individual doors must be connected via the system CAN bus and signal processing is centralised in the control unit on the first door. This also enables you to avoid the complicated relay interconnections inherent in traditional control.

Many parameters can be set in the software, in order to easily adapt control to specific customer requirements. For all vehicle doors this data is stored on the control unit of the first door. This way, the electronic control units on all the other doors can be changed without taking the parameters into account.

Naturally, the MTS system can perform a diagnosis: diagnosis takes place via the vehicle CAN bus or via a separate "K" line, regardless of the type of connection used.

If Pneumatic doors are used, they are monitored via pressure switches and newly developed potentiometers which are fitted directly on the heel post. Due to mechanical coding, these sensors do not require any settings. Electrically driven doors can equally be monitored with the help of these potentiometers; alternatively, pulse generators installed in the engine can be used together with an index switch.

A simple start-up program is used to balance all the tolerances while using each door for the first time. For this you only need to move the doors once to the two stop positions by pressing the workshop push buttons continuously.

The well-proven ETS principle was developed for pneumatically driven doors. As a result, the damping mechanism integrated into the cylinders is no longer necessary. This function is now performed by the door control valve. Since it is electronically controlled, damping is possible at any moment. Apart from the cost-related advantages, this also results in much more flexible adaptability to the movement of the different doors. This also prevents misadjustments, thereby increasing operational safety.

MTS system principle:

Connection to a vehicle with CAN data bus

Connection to a vehicle with conventional cabling
MTS control electronics

Emergency control  Door control valve  Pressure sensing  Distance sensing
powerless  closed  open

Cylinder without end position damping

Distance sensor in front

Distance sensor behind

Signals to vehicle and/or other doors

Front door wing

Back door wing

Cylinder without end position damping

Signal to door peripheral equipment

Values such as nozzle given as examples diameter, etc. are simply (ACTUAL)!
For more details, see the model description of each door!

Solenoid

Function

A
Door OPEN
A and C
Door OPEN choked (END POSITION)
B
Door CLOSED
B and C
Door CLOSED choked (END POSITION)
C
Door POWERLESS
MTS - Modular Door Control
For Motor Coaches

MTS electronic control unit
446 190 . . . 0

MTS electronic control units have 60 PINs, divided into 5 different 3-series plugs (6, 9, 12, 15 and 18 PINs), which makes confusion impossible. Special care was taken to combine functional groups as much as possible, and to avoid double pinning.

9-pin: CAN data bus interfaces of the vehicle and system bus, diagnosis interface, address inputs

18-pin:* power supply, drive (valves and/or engines), sensor analysis

15-pin: door-specific functions, e.g. workshop push button, feeling wing edge, ramp, entrance lighting, automatic functions, etc.

12-pin:* used only on door 1 for conventional connection, for instance, of driver's pushbuttons, fault indication light, halt brake, red/green indicator, etc., if no CAN vehicle data bus is available. It is also possible here to connect a driver's pushbutton for door 3 (not allowed by Germany lt. § 35e of StVZO!)

There are differences on the plug side, between pneumatic door controls and electronic door controls, especially with regard to the composition of the 18-pin plug.

For MTS-P, 1 or 2 door control valves, 1 or 2 position sensors and 2 or 4 pressure switches are connected, depending on the number of door wings and/or the required function.

For MTS-E, 1 or 2 engines with 2-channel incremental indicators and the corresponding limit switches or analogue position sensors can be connected accordingly. The power supply connection and speed signal connection are identical (only on door 1).

6-pin:* used only on door 1 for conventional connection (mostly) of automatic functions, for instance door release, baby carriage function, stop request output, etc. if no CAN vehicle data bus is available.

*) For pneumatic doors, an under-equipped MTS variant ("extension module") is available for use only on door 2. The 6-pin and 12-pin plug have no function here. The extension module can only control one door control valve.

MTS door sensor
446 190 15 . 0
4/3 solenoid valve
(MTS door control valve)
472 600 . . . 0

A switch-selected exhaust air throttle was added to the MTS valve in addition to the functions described on page 141 (door control valve). Since the cylinders are controlled by the electronic control unit, they are braked before reaching the respective end positions.

Door operating cylinder exhaustion takes place without restriction if solenoids A, B, and C are idle, since pressure is exerted on the diaphragm (g).

MTS - door operating cylinder
422 812 . . . 0

An additional solenoid C is actuated by the electronic control unit to brake the door operating cylinder, depending on the direction of movement (one of the external solenoids A or B is activated). Air is supplied to the chamber (h), exerts pressure on the diaphragm (g) and the latter closes the passage to exhaust 3. Now, exhaust air from the door operating cylinder can only escape into the atmosphere via the adjustable throttle.

The compressed air expelled from the door control valve flows through port 12 into the cylinder and moves the piston to the right. Pressure is reduced at the same time from chamber B via port 11 and the connected door control valve.

If the door control valve is activated again, chamber B is pressurized via port 11 and the pressure in chamber A is reduced via port 12. Due to the changing piston pressurisation, the piston moves back to the left together with the push rod and the linked door closes.
In normal position, air supply flows through port 1 via the cock and enters the door control valve through port 2. Port 4 is connected to exhaust (port 3).

If the emergency cock is moved 90° to the emergency position, air supply then flows to port 4 and the downstream door control valve is pneumatically switched to "powerless function" (pressure is reduced from both door operating cylinder sides).

At the same time, the electronic control unit receives an emergency cock activation signal via the integrated switch.

To prevent the door wings from moving suddenly after emergency cock reset, the door control valve always pressurises both cylinder sides simultaneously after a "powerless function".
Installation Of Pipes And Screw Unions
10. Installation Of Pipes And Screw Unions

General Informations

The dimensions and versions of the butt-joint couplings are mainly based on DIN standards 74 313 to 74 319. Push-in couplings correspond mainly to DIN standard 2353. Butt-joint couplings are approved for use up to a pressure of 10 bar, push-in couplings up to a pressure of 100 bar.

Steel couplings are used for steel and nylon pipes. The surface of adaptors and nuts are bonderized and oiled or bright galvanized and yellow passivated.

For copper pipes, brass couplings are available.

General Information for Steel Pipes

Push in couplings are used for the following pipe diameters:

<table>
<thead>
<tr>
<th>Road vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 1 Instrumentation lines and control lines</td>
</tr>
<tr>
<td>8 x 1 Engine exhaust brake, door actuating devices, special equipment</td>
</tr>
<tr>
<td>10 x 1 Control lines</td>
</tr>
<tr>
<td>12 x 1 Brake lines and supply lines</td>
</tr>
</tbody>
</table>

Consisting of the following parts:

1 Connector
2 Sealing washer (internal)
3 Thrust ring
4 Cutting ring
5 Pipe nut

The function of the cutting ring is the same in both kinds of couplings. When the pipe nut is tightened, the cutting ring is compressed by the internal taper of the connector and cuts into the outer wall of the pipe to create a collar and form a sealed joint. The additional thrust ring in butt-joint couplings is sealed with a sealing washer normally made of fiber, or of zinc in couplings exposed to high temperatures.

Important:
Before fitting the coupling, check the thread for damage. Any damaged threads must be reworked. In order to prevent the thread seizing, it should be greased using graphite grease, Part No. 830 503 004 4 (50 gramme tube).

Butt joint couplings are used for the following pipe diameters:

<table>
<thead>
<tr>
<th>Road vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 x 1.5 Brake lines and supply lines</td>
</tr>
<tr>
<td>18 x 2 Connection from compressor to pressure regulator, supply lines</td>
</tr>
</tbody>
</table>

Since all sealing washers settle under load, the fittings of new vehicles or installations must be retightened after a short time. The same also applies after the replacement of devices, since new sealing washers must always be used. Before retightening unions, first loosen the pipe nut to avoid damaging the pipe.

Any non-compliance could lead to loss of pressure within the system and thus to brake failure!
Installation Of Pipes And Screw Unions

Assembly Instructions for Steel Pipe

The pipe must be cut off at right angles. A pipe saw-jig should be used.

After sawing the pipe, the resulting burrs and swarf must be carefully removed. In order to avoid these parts getting into the piping system after fitting, thus destroying valve seats or blocking filters, either of which would cause failure of the braking system.

Important:
Do not use a pipe cutter!
This would mean that no right angle is achieved in cutting and would result in excessive burrs, both inside and out.

As a consequence:
The internal diameter would be reduced and the union not being tight.

Push in Couplings

With pipes with an external diameter up to 10 mm, it is advisable to screw the connector of the coupling into the device and to assemble the pipe directly at the place of installation.

The prepared pipe end, with pipe nut and cutting ring, is pushed directly into the connector and the pipe nut is screwed on by hand until contact with the cutting ring is felt.

The pipe must now be pushed against the stop in the connector and the pipe nut must be tightened by about three-quarters of a turn, where by the pipe must not rotate with the nut. Since the cutting ring has now gripped the pipe, further pushing of the pipe is unnecessary. Final tightening is effected by turning the nut by about one turn. Then loosen the pipe nut and check whether the cutting ring has penetrated the outer skin of the pipe and the raised collar is visible in front of the edge. If necessary, the pipe nut must be tightened further.

It does not matter if the cutting ring can be rotated on the pipe end.

After completion of the joint, or after loosening, the pipe nut is to be tightened with a normal spanner, without applying any excessive force.

Push in Couplings

Before tightening the pipe nut

After tightening the pipe nut

1 Butt end
3 Cutting ring
2 Internal taper
4 Visible collar

A mark made on the pipe nut makes it easier to count the specified number of turns.
10. Installation Of Pipes And Screw Unions

Butt joint Couplings

Pre-assembly must be carried out in a vice. The screw spanner must have a length which is approximately 15 times the width across flats. If necessary, it should be extended using a pipe.

Tighten the coupling in the vice first. Screw on pipe nut by hand up to stop at cutting ring. Press pipe with thrust ring against front side of connector. Then tighten pipe nut with a 3/4 turn (Caution: Pipe must not turn at the same time!).

The cutting ring now grips the pipe end and further pressing is no longer necessary. Final tightening is carried out if the pipe nut is tightened again with a 3/4 turn. The ring now cuts into the pipe, visibly bunching in front of its first cutting edge.

Final tightening is facilitated if the pipe nut is loosened a number of times, so that oil can find its way again between the friction surfaces.

During final assembly, please see that each pipe end the corresponding thrust ring get back to the coupling where pre-assembly has been carried out.

Instructions for Bending and Fitting of Pipes

Basically pipe for braking systems must never be hotworked since this will destroy the surface protection, and the scaling of the pipe can cause breakdowns.

Bending of the pipe is best carried out with a commercial pipe bender.

These pre-assemblies in large numbers require an enormous amount of time if they are to be produced in the way described above. In such cases, a pre-assembly unit is advisable. With it the cutting rings can be fitted quickly. The device is not tied to one work-place but can be used where desired.

Insert thrust ring and sealing washer.

After tightening the pipe nut

1 Visible collar
2 Sealing washer
3 Thrust ring
4 Cutting ring
Assembly Instructions:

for Throttle Inserts
By the use of throttled inserts, the charging and exhausting time can be adjusted to the particular requirements. The throttle can be inserted into the push-in coupling, if the pipe nut has first been loosened and the pipe pulled out. Please make sure that the pipe end is shortened by the thickness of the insert’s rim.

for Copper Pipe
The assembly instructions above are intended for the use of steel pipe. If soft-annealed copper pipe (Cu soft) is to be used, sleeve inserts must be used in the pipe ends to prevent crushing the pipe when tightening the pipe nut.

The insert is to be lightly driven into the pipe until it is flush with the pipe end. The teeth on the insert are pressed into the inner wall of the pipe so that the insert prevented from moving or failing out during assembly of the pipe.

The bending radius must never be less than 2D. The pipe end behind the bend should, as far as possible, have a total length of at least 2H.

When fitting the pipes, care must be taken that they are without stresses after the pipe nuts have been tightened. This means that before tightening, the pipes fit so well that the tightening process does not serve to position them properly.

Any non-compliance of this could result in damage to the units, e.g. cause fissures in the cylinder base.

Hose Couplings
Within a compressed air installation the transition from pipe to hose, or conversely from hose to pipe, will repeatedly occur if moving parts have to be connected. If the pipe ends cannot be formed into a satisfactory standard hose nozzle, a hose coupling must be used for such a joint. It is not permissible to push the hose onto a plain cut-off pipe end.

Any non-compliance can result in the hose slipping off the pipe when pressurized. This would result in a sudden failure of the braking system.

Cut off hose at right-angles and push onto the hose nozzle as far as the stop. The hose must be secured with a hose clamp.

The tools illustrated in the comments on steel pipes are available from ERMETO ARMATUREN GMBH, D-33652 Bielefeld, Germany.
Use and Installation in
Automotive Vehicles

The physical and mechanical properties of nylon pipe are very different from those of steel pipe.

Extensive tests and sample installations in motor vehicles using various grades of nylon have shown that because of the special properties of the material, flexible nylon pipe of black polyamide 11 are best suited for pneumatic braking systems and associated equipment.

Properties
Material
Black polyamide 11, flexible, resistant to heat and light, even to intense ultra-violet radiation.

Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at +20°C</td>
<td>1.04 g/cm³</td>
</tr>
<tr>
<td>Moisture absorption at +20°C</td>
<td>0.5 to 1.9%</td>
</tr>
<tr>
<td>(between 30 and 100% relative air humidity)</td>
<td></td>
</tr>
<tr>
<td>Specific heat</td>
<td>2.44 J/gK</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>1.05 kJ/m.h.K.</td>
</tr>
<tr>
<td>Linear coefficient of expansion between -20°C and +100°C</td>
<td>15 x 10⁻⁵ (1/°C)</td>
</tr>
<tr>
<td>Melting point</td>
<td>+186°C</td>
</tr>
</tbody>
</table>

Mechanical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>4800 N/cm²</td>
</tr>
<tr>
<td>Elongation at rupture at 20°C</td>
<td>250%</td>
</tr>
<tr>
<td>Elastic elongation</td>
<td>3.7%</td>
</tr>
</tbody>
</table>

Pipe Dimensions

<table>
<thead>
<tr>
<th>Pipe Dimensions</th>
<th>min. Bursting Pressure in bar</th>
<th>max. Working Pressure at 20°C in bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 1</td>
<td>81</td>
<td>27</td>
</tr>
<tr>
<td>8 x 1</td>
<td>57</td>
<td>19</td>
</tr>
<tr>
<td>10 x 1</td>
<td>45</td>
<td>15</td>
</tr>
<tr>
<td>12 x 1,5</td>
<td>57</td>
<td>19</td>
</tr>
<tr>
<td>15 x 1,5</td>
<td>45</td>
<td>15</td>
</tr>
<tr>
<td>18 x 2</td>
<td>51</td>
<td>17</td>
</tr>
</tbody>
</table>

Permissible Temperatures

In normal vehicle operation, temperatures of -40 °C to +60 °C are permissible.

The indicated temperature of +60 °C during continuous loading for the flexible grade was selected so that no changes in the properties of the material occur. At temperatures over +60 °C the softening agent contained in this material can slowly disappear and the material assumes the properties of the semi-rigid grade.

The physical properties of the semi-rigid and flexible pipes are the same. The values for mechanical properties such as tensile strength, elastic elongation and working pressures are higher in the case of semi-rigid pipe. By reason of their greater mechanical resistance to deformation (bending), semi-rigid pipes are more difficult to lay than flexible ones.

Because of the limited temperature loading capacity of polyamide 11, it is advisable not to use nylon pipe in the vicinity of the engine or exhaust system. Particular care should be taken when welding to ensure that the pipes are not damaged, and if necessary they should first be dismantled.

If a sprayed vehicle is dried in a braking chamber or using radiant heaters, the unpressurised pipework must not be subjected to temperatures up to 130 °C for longer than 60 minutes.

In order to avoid damage to nylon pipes when welding, a plate should be fitted on the vehicle:

WABCO Tecalan nylon pipes

Caution during welding operations.

Permissible exposure to heat of unpressurised lines:
Not more than 130°C for 60 minutes.

WABCO

Available in German only.
Part Number 899 144 050 4
Chemical Resistance
Polyamide 11 is resistant to all media used in the motor vehicle such as petroleum products, oils and greases. The tubes are also resistant to alkalis, unchlorinated solvents, organic and inorganic acids and diluted oxidising agents. (The use of cleaning agents containing chlorine should be avoided). Advice on resistance to chemicals other than those indicated can be given on request.

Change in Length
When installing nylon pipes particular attention should be paid to their change in length at different temperatures. The change in length of the pipe is approximately 13 times that for a steel pipe.

The coefficients of expansion are:

For steel pipes 1.15 x 10⁻⁵ per °C
For nylon pipes 15 x 10⁻⁵ per °C

This indicates a change of length per metre of 1.5 mm for every 10 °C difference in temperature. This change in length must not be restricted by the fittings holding the pipe.

To fasten the pipes in position, plastic-lined pipe clamps or clamps made entirely of plastic should be used. It should be possible for the pipe to move easily in the fastenings, so that temperature induced changes in length can be distributed uniformly over the entire length of the pipe. The pipe should be clamped at approximately 50 cm intervals.

Couplings
The range of coupling from Wabco used in vehicles can also be used for nylon pipes. Clamping rings represent similarly effective unions for pipes. To ensure good seal and tight fit of the couplings, sleeve inserts should be used for all assemblies with cutting rings and thrust rings. The sleeves should not be forced or driven in, as otherwise the pipes expand and the cutting rings can no longer be pushed on.

The couplings are made push-in couplings and buttjoint couplings.

The function of the cutting ring is the same in both kinds of union.

When the pipe nut is tightened, the cutting ring is compressed by the internal taper of the connector and cuts into the outer wall of the pipe - to create a collar and form a sealed joint. The pipe sealed by the firm fit of the cutting ring on the internal taper. The additional thrust ring in butt-joint couplings is sealed with a sealing washer, which normally consists of fiber.

Before fitting male couplings, the threads of the connecting pieces should be checked for damage. Damaged threads must be rectified. In order to prevent the thread seizing it is advisable to smear it with graphite grease before screwing in. The seal can be made with fiber or aluminium sealing rings or with thrust rings and O-rings. Do not use hemp or liquid jointing compounds.

Since all sealing washers settle under load, the couplings of new vehicles or installations must be retightened after a short time. The same also applies after the replacement of devices, since new sealing washers must always be used. Before retightening fittings first loosen the pipe nut to avoid damaging the pipe.

When assembling the coupling it is important that the end of the pipe is trimmed at right angles and inserted into the coupling as far as the stop. To trim the pipe property at right angles, use can be made of cutting devices which can be obtained for pipes with an external diameter of up to 22 mm.
Assembly Instructions on Nylon Pipes

Push-in couplings used for the following pipe diameters:

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 1</td>
<td>As instrumentation lines</td>
</tr>
<tr>
<td>8 x 1</td>
<td>As auxiliary systems, e.g., air suspensions</td>
</tr>
<tr>
<td>10 x 1</td>
<td>As control lines with limited volumetric throughput</td>
</tr>
<tr>
<td>12 x 1.5</td>
<td>As control lines with larger volumetric throughput, as general lines within a brake system or as lines to the brake actuator.</td>
</tr>
</tbody>
</table>

Consisting of the following parts:

1 Connector with internal taper
2 Sleeve insert
3 Cutting ring
4 Pipe nut

Butt-joint couplings are used for the following pipe diameters:

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 x 1.5</td>
<td>Lines for general supply and to braking cylinders in braking systems.</td>
</tr>
<tr>
<td>18 x 2</td>
<td>Supply line between air reservoir and relay valve for high air flow.</td>
</tr>
</tbody>
</table>

Consisting of the following parts:

1 Connector
2 Sealing washer
3 Thrust ring
4 Sleeve insert
5 Cutting ring
6 Pipe nut

Push-in Couplings

For pipes with an external diameter of up to 10 mm, it is advisable to screw the thread of the coupling into the device and to assemble the pipes directly at the place of installation.

The prepared pipe end, with insert, pipe nut and cutting ring, is pushed directly into the connector and the pipe nut is screwed up by hand until contact with the cutting ring is felt. (Figure see page 153)

The pipe must now be pushed against the stop in the connector and the pipe nut must be tightened according to the torque table below. The pipe must not rotate with the nut.

Table of permissible tightening torques

<table>
<thead>
<tr>
<th>Pipe Dimensions</th>
<th>Tightening Torque</th>
<th>Loosening Forces at</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 1</td>
<td>13 to 14 Nm</td>
<td>13 Nm = 460 N</td>
</tr>
<tr>
<td>8 x 1</td>
<td>15 to 18 Nm</td>
<td>15 Nm = 580 N</td>
</tr>
<tr>
<td>10 x 1</td>
<td>20 to 30 Nm</td>
<td>20 Nm = 870 N</td>
</tr>
<tr>
<td>12 x 1.5</td>
<td>25 to 35 Nm</td>
<td>30 Nm = 1200 N</td>
</tr>
</tbody>
</table>

If the indicated torques are not achieved, the force required for loosening is reduced, and if they are exceeded the sleeve insert will be deformed.

Before tightening the pipe nut

After tightening the pipe nut

1 Sleeve insert
2 Butt end
3 Internal taper
4 Cutting ring
5 Visible collar
The following method can be used to keep as close as possible to the correct tightening torques when they cannot be accurately measured:

Tighten the pipe nut of the coupling finger tight and then 1½ to 1¾ turns with a spanner. It is necessary for the thread to be in good condition.

Then loosen the pipe nut and check whether the cutting ring has penetrated the outer skin of the pipe and the raised collar is visible in front of the edge.

**Butt-joint Couplings**

Butt-joint couplings are assembled as described under push-in couplings. An additional thrust ring and sealing washer, however, must be used.

After tightening the pipe nut

1. Visible collar
2. Sealing washer
3. Thrust ring
4. Cutting ring
5. Sleeve insert

**Table of permissible tightening torques:**

<table>
<thead>
<tr>
<th>Pipe dimensions</th>
<th>Tightening torques</th>
<th>Loosening forces at</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 x 1.5</td>
<td>30 to 45 Nm</td>
<td>30 Nm = 2100 N</td>
</tr>
<tr>
<td>18 x 2</td>
<td>40 to 60 Nm</td>
<td>40 Nm = 2450 N</td>
</tr>
</tbody>
</table>

**Bending of Nylon Pipes**

The pipe can be bent cold, keeping to the bending radii indicated below. Since, however, it has a tendency to straighten, it should be fastened before and after each bend.

To avoid kinking, the minimum bending radi shown in the following table must be adhered to.

**Technical Inspection of the Braking System**

Inspecting authorities have given their approval in principle to the use of nylon pipe for pneumatic lines in vehicles as an alternative to the steel pipe and brake hose previously used. This approval is subject to the connection that suitable material is used for this purpose, and that the installation instructions applicable to nylon piping are complied with.

By marking their nylon pipe with the inscription „WABCO-TECALAN“, WABCO provide a guarantee that the material is suitable in accordance with terms of delivery. Correct installation of the nylon piping can be checked at the time of final inspection of the vehicle using the installation instructions mentioned above.
General Comments

The connecting elements offer the following benefits:

- A high degree of leakage protection: Cascade dynamic sealing
- No corrosion since the individual components are made of brass or stainless steel.
- Quick assembly since no time-consuming fitting of sleeves, fastening of union nuts and reworking in the case of leakages is needed.
- The seal against the pipe is effected by means of a special seal located in front of the clamping element which means that the clamping element cannot damage the sealing area on the plastic pipe. The seal prevents both air getting out and dirt getting in.
- The threaded screw-in portions have an integrated seal suitable for threaded connections to DIN 3852 and for connections the type of VOSS plug-in unions.
- The throughput resistance is similar to that of the cutting-ring coupling.
- Operating temperature range -45°C to +100°C (peak +125°C).
- Integral Air Passage (Sunnest inner supporting ring wall thickness) for better and quicker brake response.

Applications

The quick connection fitting system is suitable for all air lines in vehicles using plastic pipes.

Any type of plastic pipe can be used:

<table>
<thead>
<tr>
<th>WABCO Part number</th>
<th>External-Ø x wall thickness</th>
<th>Operating pressure at 20°C in bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>828 251 908 6</td>
<td>6 x 1</td>
<td>27</td>
</tr>
<tr>
<td>828 251 907 6</td>
<td>8 x 1</td>
<td>19</td>
</tr>
<tr>
<td>828 251 906 6</td>
<td>10 x 1</td>
<td>15</td>
</tr>
<tr>
<td>828 251 905 6</td>
<td>12 x 1.5</td>
<td>19</td>
</tr>
<tr>
<td>828 251 904 6</td>
<td>15 x 1.5</td>
<td>15</td>
</tr>
<tr>
<td>828 251 903 6</td>
<td>18 x 2</td>
<td>17</td>
</tr>
</tbody>
</table>
Assembly Instructions:

**Tube in a Connector**

All Connectors are stamped with tube dimension, and a batch number.

The pipes must be cut at right angle. A maximum deviation of 5° is permissible.

The pipe must be pushed fully home into the push-in connector. No tool is needed. Whilst pushing in the pipe, turn it slightly.

It is advisable to mark the length pushed in to be able to check it later.

![Diagram of a connector with markings](Image)

*The push-in lengths and the forces required for pushing the pipe into the the push-in connectors are shown in the table below.*

**Push-In lengths:**

<table>
<thead>
<tr>
<th>External pipe-Ø x wall thickness</th>
<th>Push-In length in mm (± 0.5)</th>
<th>Push-In forces in N</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 1</td>
<td>20</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>8 x 1</td>
<td>21</td>
<td>&lt; 120</td>
</tr>
<tr>
<td>10 x 1</td>
<td>25</td>
<td>&lt; 120</td>
</tr>
<tr>
<td>10 x 1.25</td>
<td>25</td>
<td>&lt; 120</td>
</tr>
<tr>
<td>10 x 1.5</td>
<td>25</td>
<td>&lt; 120</td>
</tr>
<tr>
<td>12 x 1.5</td>
<td>25</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>15 x 1.5</td>
<td>27</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>15 x 2</td>
<td>27</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>16 x 2</td>
<td>27</td>
<td>&lt; 180</td>
</tr>
<tr>
<td>18 x 2</td>
<td>28</td>
<td>&lt; 200</td>
</tr>
</tbody>
</table>

After inserting the pipe, check the clamp by applying a pulling force of at least 20 to 50 N.

**Tightening torques**

<table>
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<th>Tightening torques</th>
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<tr>
<td>M 10 x 1</td>
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<tr>
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<td>22 - 26 Nm</td>
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<tr>
<td>M 14 x 1.5</td>
<td>26 - 30 Nm</td>
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<tr>
<td>M 16 x 1.5</td>
<td>32 - 38 Nm</td>
</tr>
<tr>
<td>M 22 x 1.5</td>
<td>36 - 44 Nm</td>
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**General Comments**

For reasons of safety, the connection cannot be severed once the pipe has been pushed in.

If the unit is to be exchanged, the connection must be unscrewed from the unit. The connection will turn on the pipe in the process. In the event of the sealing ring between the unit and the connection joint being damaged, it must be replaced.

For elbows and tees fixed to the unit by means of a counter-nut, the same O-rings and compression rings are used as for the cutting-ring couplings.
Assembly Instructions: For the RO Connection
The range includes two sizes of RO connectors: RO 13 and RO 15.

The RO connection: Plug-In Pivot (male RO) and Plug-On Swivel part (female RO) = Building Block (Turnable).

The Plug-In Pivots are straight parts where as the Plug-In Swivel parts are numerous form parts: Elbows, Tees; Crosses . . .

The connection should be done manually by plugging the two parts together to the bottom, with a combined rotation.

A twisting pull should then be applied for control.

Because of the swivelling of the building block (turnable), the RO connection must not be used:

- Between the truck and it’s trailer, or the axles and the trailer chassis.
- To connect a brake device precariously balanced.

When a RO connection is already used in a kit (swivelling combination). A male/female screwed connection with a counternut for firm locking after orientation, being the alternative solution.

Replacement and interchangeability
The interchangeability is possible provided that:

- The threads used are in accordance to ISO 4039-1 or ISO 4039-2 (metric).
- The tubes used are in accordance with DIN 74 324/ DIN 73 378 or NFR 12-632 (metric) or ISO 7628.

Only the connection RO (between pivots and swivel parts) is not interchangeable with parts from other manufacturers because of an exclusive design.

The WABCO quick connection fitting system can consequently be used in replacement of both:

- Traditional 24° screwed compression fittings range (with nuts and sleeves).
- All types of other quick connection fitting systems.
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