Purpose of Braking Systems

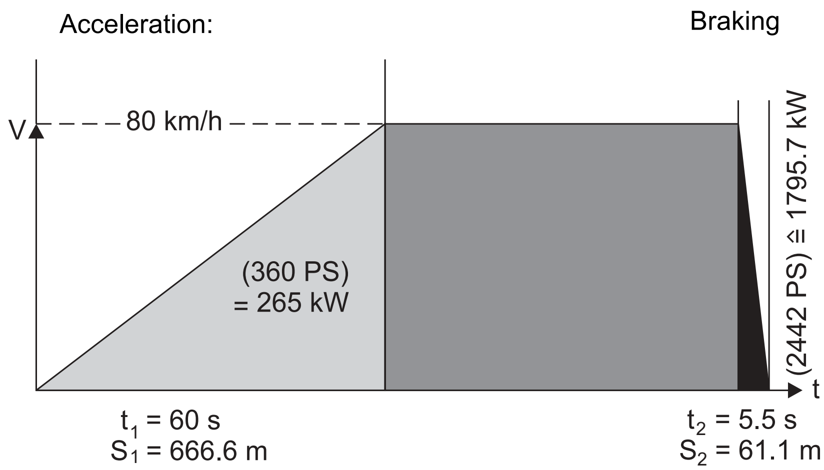
Today all vehicles must have braking systems whose effectivity must meet certain legal requirements

The purpose of these braking systems is:

1. to reduce the speed
2. to stop the vehicle
3. to keep the vehicle stationary
4. to keep the speed constant on downhill gradients

Braking Performance

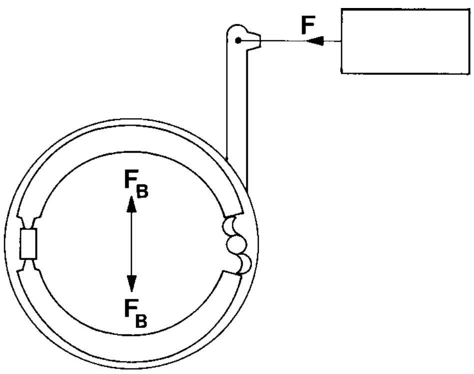
Like shown in diagram below, the braking performance of a modern truck is about ten times its engine performance.



When the brakes are actuated, the kinetic energy of a vehicle is converted into thermal energy in the wheel brake by means of friction.

The generation of heat is inevitable and must be considered critical if it reaches a magnitude which significantly reduces or even eliminates the braking effect (brake fade).

The amount of heat generated essentially depends on two factors:



1. Vehicle mass
A vehicle of twice the weight of another will require twice as much braking energy. Twice the amount of heat will be delivered.

2. The speed of the vehicle
Doubling the speed requires four times the braking energy and thus produces four times the amount of heat.

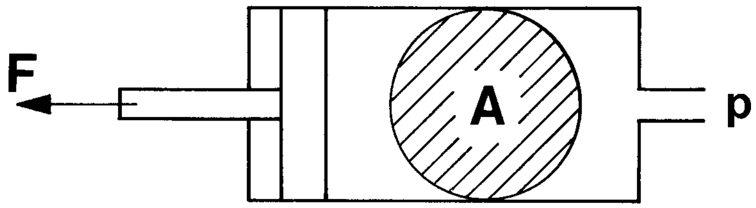
The heat is produced by friction between:

1. brake linings and drum
2. Tyres and road surface

In order to generate the required friction, the brake blocks with the brake linings must be pressed against the inner surfaces of the drums This requires a certain force F.

Force F of the brake cylinder

Force F delivered by the brake cylinder is generated with the input of compressed air at pressure p acting on piston surface A.



Force = area × pressure

$F = A \times p$

In technical documents, the pressure is always given in bar.

$$1\ \text{bar} = \frac{10\ \text{N}}{\text{cm}^2} \quad \text{which means} \quad 6\ \text{bar} = \frac{60\ \text{N}}{\text{cm}^2}$$

For a surface of 155 cm² (24" cylinder) and a pressure 6 bar the computation for the force would be as follows:

$$F = \frac{60\ \text{N} \times 155\ \text{cm}^2}{\text{cm}^2} = 9300\ \text{N force at brake lever}$$

This shows that energy is transformed in the brake cylinder. Compressed air from the air reservoirs is transformed into mechanical energy for braking.

Device Control/Function

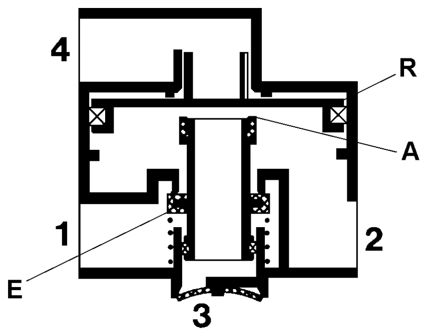
The principle of generating mechanical force by means of pressure is also used in controlling and regulating components.

The function of controlling components is best described as a balance of forces being achieved on two opposing piston and diaphragm surfaces in certain conditions.

A simple principle used in many components, the force of a spring, is counteracted by the force of a piston or a diaphgram under pressure. This function is easy to see in a charging valve.

The compressed air arriving at 1 builds up pressure beneath the spring-loaded diaphragm which acts as a force (F = A × p) against the force of the spring. When the force of the spring beneath the diaphragm has been reached or slightly exceeded, the diaphragm is raised from the seat of the valve and the compressed air can flow over to 2. On many valves of this kind the force of the spring and thus the corresponding opening pressure can be adjusted by means of a screw.

Another principle for controlling and regulating a component is to achieve a balance of forces by increasing the pressure on both sides of a piston. This principle is very easy to see on a relay valve:



(1) supply pressure p_1
(air reservoir)

(2) output pressure p_2
(Brake cylinder)

(3) venting port
(Atmosphere)

(4) Control port p_4
(Foot brake valve)

E = inlet valve
A = outlet valve
R = relay piston

If at control port 4 a pressure of, for example, 3 bar is applied, force F_4 will move the relay piston downwards, closing outlet valve A and opening inlet valve E. Compressed air can now flow from supply 1 towards cylinder 2. At the same time, this pressure also builds up beneath the piston, thus acting as force F_2 against force F_4. When the pressure at port 2 reaches the pilot pressure of 3 bar, a balance of forces is achieved ($F_4 = F_2$) at identical pressures ($p_4 = p_2$) since the piston surfaces are of identical size ($A_o = A_u$). The piston is raised, closing the inlet valve, and the pressure at port 2 cannot rise any further. This is the **“final braking position”**.

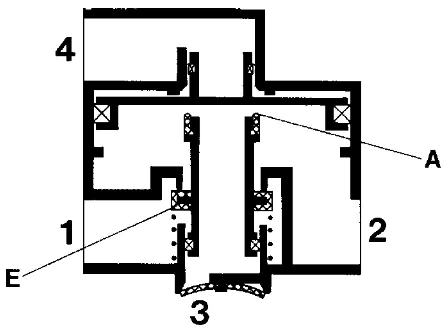
$$\mathbf{F_4 = F_2}$$

$$\mathbf{A_o \times p_4 = A_u \times p_2}$$

$$\mathbf{\frac{20cm^2 \times 30N}{cm^2} = \frac{20cm^2 \times 30N}{cm^2}}$$

$$\mathbf{600N = 600N}$$

The fact that a balance of forces at the control piston does not necessarily mean that the input and output pressures are identical becomes clear when we modify the relay valve slightly by reducing the upper piston surface.



(1) supply pressure p_1
(air reservoir)

(2) Control Port p_2
(Brake cylinder)

(3) venting port
(Atmosphere)

(4) Control port p_4
(Foot Brake Valve)

E = inlet valve
A = outlet valve

If again we apply a pressure of 3 bar at port 4, the inlet valve will open, similar to the example above, releasing pressure at port 2. This output pressure in turns builds up beneath the relay piston. If F_2 thus becomes similar to F_4, the inlet valve closes.

In this case this happens at an output pressure p_2 of 1.5 bar. The reason for this is that the lower piston surface is twice the size of the upper surface ($A_u = 2 \times A_o$). Thus half the pressure per cm² is sufficient to achieve the balance of forces $F_4 = F_2$.

$$\mathbf{F_4 = F_2}$$

$$\mathbf{A_o \times p_4 = A_u \times p_2}$$

$$\mathbf{p_2 = \frac{A_o \times p_4}{A_2} = \frac{10\ cm^2 \times 3\ bar}{20\ cm^2} = 1.5\ bar}$$

This means that different surfaces (A_o and A_u) on piston diaphragms or valve bodies achieve a balance of forces ($F_4 = F_2$) at different pressures ($p_4 \neq p_2$).

In this principle, the force/surface ratio is inversely proportional.

double the piston surface ↔ half the pressure

half the piston surface ↔ double the pressure

This applies to all other piston surfaces at the corresponding inverse ratio.

Arrangement

Braking systems can be arranged according to their features:

- Purpose
- type of energy used
- type of transmission
- number of connecting lines in vehicle combinations

Braking Systems by Purpose

Service Braking System: (SBS)
The service brake (foot brake) can be used to both reduce the speed of the vehicle, and to stop it.

Its actuation (with the foot) is continuously variable and acts on all wheels.

Parking Braking System: (PBS)
The purpose of the parking brake (hand brake) is to keep the vehicle stationary, even when parked on a gradient, and even when the driver is absent.

It must be fully effective even if the pneumatic or hydraulic energy fails. For this reason it must act mechanically on the wheel brake. This can be achieved by means of cables, linkages, or loaded springs.

Emergency Braking System: (EmBS)
The secondary or emergency braking system must take over the task of the service brake if that fails, albeit with reduced performance.

This does not need to be a third independent braking system with separate actuation. Either the still operable braking circuit of a dual circuit service brake or the parking brake can be used as a secondary braking system. In the latter case, however, this requires the parking brake to be gradable.

Retarder:
The retarder allows the driver to adjust his speed without using the service or the emergency braking systems.

Braking Systems by Type of used energy

Manual Braking System:
This type of system is mainly used in passenger cars and motorcycles. It uses muscular power which is hydraulically or mechanically transmitted to the wheel brake.

Power-Assisted Braking System:
These systems are used in passenger cars and light-duty commercial vehicles. A brake servo unit boosts the muscular power by means of an auxiliary power generated by compressed air, a vacuum, or hydraulic fluid.

In the event of a failure of the auxiliary power source, the vehicle can still be braked using muscular force only. This, however, requires much greater force.

Power Braking System:
In this type of system, which is mainly used in medium and heavy-duty commercial vehicles, the vehicle is braked exclusively from an external source.

This external source is either compressed air, or a vacuum, or hydraulic fluid, and the driver’s muscular power only controls the braking system.

For this reason, no braking force can be generated in the event of a total failure of energy.

Braking Systems by Type of Transmission

Single-Circuit Braking System
This system has a single-circuit transmission.

The failure of a single portion renders the whole of the braking system ineffective.

Dual Circuit Braking Systems
For reasons of enhanced safety in operation, the transmission of the service brake is today designed as a dual-circuit system.

In the event of the failure of one braking circuit, the vehicle can still be braked. However, the braking performance is significantly reduced, and the vehicle must be taken to nearest authorized workshop immediately.

Braking Systems for Vehicle Combinations

The energy supply and the actuation of the trailer braking system are initiated in the towing vehicle.

The transmission between the two vehicles is achieved, as the name makes clear, by **one** connecting line in a single-line braking system, and by **two** connecting lines in a dual-line braking system.

Single-Line Braking System
Filling of the air reservoirs and control of the trailer’s brakes are achieved via **one** line (“pilot line“).

Since the brakes are actuated when the pressure in the pilot line falls, no air supply can flow to the trailer during the process of the brakes being actuated. For this reason there is a hazard of a continuous application of the brakes on long downhill gradients exhausting the trailer’s pressure supply.

For this reason, dual-line braking systems are today required by law.

Dual-Line Braking System
In this type of system the towing vehicle and its trailers are connected by **two** lines: the supply line and the control line achieving the control process by means of an increase in pressure.

Since compressed air can flow to the trailer via the supply line even whilst the brakes are being actuated, the braking system cannot be exhausted.

The hose couplings for both lines nowadays usually make it impossible to confuse them when connecting them.

Introduction

The legal requirements of brake systems are described in national (like German StVZO) and international regulations (EG / ECE)

The national (German) directives for brake systems are contained in **§ 41 STVZO ("Brakes and brake wedges")**.

As international legislations must be indicated the **Brake Directive 71/320/EWG** issued from the Committee or the Council of the European Community in Brussels, lately changed by 98/12/EG, as well as the **Brake Directive ECE-R13** issued from the Economic Committee for Europe in Geneve, actualized with the update **Series 09**. The Directives 71/320/EWG and ECE-R13 are nearly all conforming.

§ 41 StVZO

In § 41StVZO contains the national directives for design and efffectivity of brake systems in motor vehicles and trailers. However, these are becoming less important, since § 18 of this directive demands that the brake system of motor vehicles and trucks with initial registration **from Jan. 1, 1991** (except some special vehicles) must be conform to EG Directive 71/230.

Brake Directive 71/230/EWG

The EG Directive "Brake system" (71/320/EWG) was released from the Council of the European Community in 1971. The intention was the adaption and harmonization of the various national member legislations for brake systems of certain motor vehicles and trailers and contains design and installation speicifications for the brake systems and also specifications for their effectivity and test.

Vehicles concerned are motor vehicles and trailers with 4 wheels as minimum and a design dependent speed limit above 25 kmh.

Meanwhile the basic directive 71/230/EWG was repeatedly changed and by completions adapted to the technical progress. Last time (7. adjustment) on Jan. 27, 1998, by the directive **98/12 EG** of the Committee of the European Community

Brake directive ECE-R13

While the EG directives are obligatory only for the EG member states, the ECE directives are applied at present in 30 countries of the United Nations (UN), thereof 22 European countries. For brake systems the ECE directive No. 13 is effective, lastly changed through adjustment of series 09.

At the time being the brake directive ECE R13 with regard to the already issued and future adjustments is even more actual than the othrerwise nearly conform Brussels EG directive "Brake systems".