FUTURE TRENDS IN HEAVY VEHICLE BRAKING

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1 INTRODUCTION

When looking at Commercial Vehicles with regard to the technology of brakes one will notice that for many years there has been a more or less constant technology used. Both S-Cam as well as wedge brakes have been only limited developed further in order to achieve better quality and more service friendliness. As distinct from passenger vehicles, the requirement for braking performance between truck-trailer harmonisation limit the scope for development.

Until today this brake law requires permanent brake qualities of the trailer brakes to be the same as that provided by the truck, which may incorporate the use of a retarder. Therefore the fade performance of trailer drum brakes requires a brake lining quality substantially different than that of the quality which may be required for the truck. As a consequence of these basic design differences it is therefore nearly impossible to achieve a good brake force distribution in the truck-trailer combination for all operating situations.

Right now the ECE has a new brake testing procedure in preparation. The current type II test in future is to be replaced by a type III interval testing. The type III test aligns the requirements for truck and trailer performance. The technical discussion has finished and the proposal has been agreed to by the ECE GRRF expert group during the 34th session in February 1994. Concurrent with the development of this rule, there has also been a significant development by some truck manufacturers to introduce disc brakes; this additional aspect compounds the issue of incompatibility.

There is an inherent imbalance between trucks using disc brakes and towing trailers using S-cam brakes and for this reason BPW has not only further developed a new generation of S-Cam brakes but has also developed a disc brake for non-driven trailer axles.

From the usage in cars and buses and in recent years also in trucks, it is known that the disc brake due to its design has the following advantages compared with a drum brake:

- high brake moment with very little sensitiveness towards fluctuation in the friction value.
- a nearly equal brake moment with excellent thermal performance; nearly no heat fading.
- sensitive reaction and linear performance which gives good modulation and control. This provides excellent conditions for application of ABS.
- additional safety due to high temperature resistance.
- additional safety due to the reduction of brake chamber stroke when the brake is operated at high temperatures; S-cam brakes inherently suffer from increased stroke under high temperatures.

The requirements for the operation in towed vehicles is especially weight, high reliability, long life expectancy and little maintenance should all be achieved.

The pneumatic disc brake and the adaption to towed vehicles which has been developed by engineers from BPW and Knorr Bremse AG already fulfill these expectations to a major extent, which justifies a limited series introduction. In the course of the current development there are further advantages and improvements to be expected.

II STRUCTURE AND OPERATION OF THE DISC BRAKE

The disc brake SB 4345 is a floating caliper brake with a brake disc diameter 430 x 45 mm thickness to suit axles with 11.5 tonnes capacity in combination with either single or dual tyres 22.5" and larger.

The floating caliper with a pneumatic operated single operating lever can slide axially on a support frame. The support frame is bolted to a flange on the axle beam. The frame surrounds the lining pads so that the brake forces are supported directly by the caliper. Due to this functional separation it is possible to design the caliper and its alignment for the disc pad forces only. (fig. 1 and 2).

The brake application force is transferred through a single arm lever which is supported in a needle roller bearing to a beam. The arrangement of the lever gives a ratio of 1:13,5. The beam presses the brake pad onto the disc by means of two push rods. The floating design of the brake caliper enable the both pads to be applied with the same force. (fig. 3).

The brake assembly is completely encapsulated and has been designed to a very low and constant hysteresis. Measurements show an application hysteresis of less than 10 % under brake actuator pressures of up to 7 bars.

The push rods of the brake assembly incorporate threaded pistons and are designed to synchronise the movement of the pad to provide even adjustment between the pads and ensure that the pad wear is parallel with the disc. The automatic adjustment device is integrated in one of the push rods and is, therefore, due to encapsulation, protected against any outside influences. The automatic adjustment depends on the amount of stroke and acts during the free-play of brake application.

Due to the pressing of even pads on an even disc, a disc brake shows no self-energization. The brake co-efficient C' as a quotient from the circumferencial force F_c and brake application force F_a is proportional to the frictional value pad/disc μ:

$$C' = F_c/F_a = 2\,\mu$$

The proportionality factor 2 results from the quantity of friction surfaces. This linear relationship minimises the sensitivity of the brake performance to fluctuate in the friction values. The performance is not affected by the direction of wheel rotation or variations in the geometry of the brake pads.

A special feature is the constantly good brake performance at high temperatures above 700°C. The reason for the temperature level being much higher than with brake drums results from the low weight of the disc and the small degree of the friction surface covered. Of decisive importance is the high temperature stability.

With regards to cooling, the rotor is of special importance. The both open and simple geometry of the rotor provides good cooling (fig. 4). There are, however, principly two decisive aspects of heat loss:

1. At high temperatures cooling is achieved mostly by heat radiation, which temperatures increases proportionally in relation to the fourth power.

2. Convection by inner ventilation is of main importance in the lower temperature range. Because of its design the revolving double discs achieve a radial external directed ventilation between the frictional surfaces.

This design is at the moment being further optimized through tests and calculations by means of finite element analysis by BPW engineers. It is our aim to improve the thermal balance with a low weight, high stability and cost-optimized production of the rotor.

During February 1992, BPW obtained an EEC-test report approved in accordance with EEC directive 71/320 Appendix VII (Identical to ECE-R 13 Appendix Eleven). This report shows that brake SB4345 is approved for an axle load of 11,500 kg. At an end temperature of approx. 650°C after a type II-test the residual brake performance value at 47 % is most convincing. By this the low fading of the brake is proven which highlights its safety.

III APPLICATION IN TOWED VEHICLES

When considering possible applications for disc brakes in towed vehicles, of special importance is the technical data as per Table 1, in particular the space requirements, low maintenance characteristics, weight, and life expectancy of pads and discs.

A. Installation requirements

Figure 5 shows the adaption of SB 4345 to a BPW axle SHSF 9100 (120 mm square beam) with 22.5" single or dual tyres. The brake chamber or spring-actuated brake for the parking brake flanged onto the brake applicator should be seen parallel to the axle and in front, underneath the trailing arm (fig. 6). At a track of 2040 mm spring centre of 1300 mm is possible. When utilising axle beam 150 mm a maximum combination of 2040/1100 mm is possible.

The brake chamber is to be found in front, above the trailing arm with underslung air-suspensions. The area between the trailing arms is completely available for containers, such as tanks or bulk-powder units according to the constructor's requirements. Type of brake chambers necessary for disc brakes, when seen in comparison with brake SN 4218, are much smaller. (see table 2).

B Low maintenance characteristics

Periodic lubrication or maintenance work to the caliper are not necessary due to all moving parts of the brake applicator including the automatic adjustment are completely encapsulated. Maintenance is reduced to simple visual and function tests when exchanging the brake pads.

The replacement of pads in the caliper can be carried out very easily with very few manual operations and almost completely without tools. It is however, necessary to dismount the wheel and rim from the hub as today's design stands.

C Weight

Both brakes SB 4345 and drum brake SN 4218 (brake load according to approval 10,200 kg) fitted to the axle and including linings, but without brake cylinders weigh in at almost 100 kg. Given that the SB 4218 disc brake has a higher approved axle load, then by comparison the disc brake potentially offers a better weight. Additionally it may be noted that further development of the flange for caliper and rotor, thanks to the help of tests and FEM-analysis, a saving potential of minimum 5 kg per brake will surely be possible.

Looking at the whole vehicle a further weight saving can be achieved because of smaller brake chambers and substantially smaller air tanks which, taking legal requirements into consideration, can be used because of a lower consumption of air.

D Life expectancy

In accordance with our own tests and experience, accumulated with practical operations detailed further on in this presentation, an increase of lining / pad life can be expected by approx. 50 % in comparison with brake SN4218 with identical usage. Life expectance of discs is three times that of pads.

IV EXPERIENCE IN TESTS AND IN THE FIELD

The features of the disc brake have been determined in substantial test series using the BPW brake testing rig and through driving tests with BPW R+D - trailers. The tests with the brake testing rig were necessary in order to optimize the brake and to be awarded the EEC brake approval. The brakes were subjected to extreme thermal loads in alpine driving tests. Downhill tests in high mountainous regions with a difference in altitude of approx. 1000 m and a route of 11 km (an average decent of 9,4 %) rotors and pads were tested up to and above 900°C without defect. The test trailer used was demonstrated at the Truck Show in Hannover in 1992.

A triaxle semi-trailer together with a disc braked tractor unit has been undergoing permanent field tests for over 2 years on mountainous motorways and country roads. Every 15,000 km regular inspections are carried out in order to check the compatibility of the combination, the brake forces and hysteresis and the deceleration from 60 kp/h as well as the wear of pads and rotors. After more than 300,000 km the brake pads and rotors are in a very good condition. Considering the type of application and the realistic operation, the results of the road testing have confirmed the previously mentioned statement concerning the comparison of the life expectancies.

After achieving the positive experience from long-term tests a number of vehicles were fitted with disc braked axles in 1993, among others, long distance and fleet vehicles. All drivers have agreed that a constant and fine response behaviour and a very precise brake performance have been achieved.

V STATE OF DEVELOPMENT AND PROJECTION

It was decided at the end of 1993 to run the first pilot production series enabling our customers to gather their own experience in normal haulage operations. The first vehicles are at the moment being fitted with disc braked axles for in field experience.

At the same time, work is being carried out on the optimization with the firm target of additional weight reductions and any added benefits for assembly and service savings. Furthermore, the adaption of disc brakes to the BPW self-steering axle is being prepared.

Further targets are the adaption of the smaller brake series to BPW-axles for 19.5" and 17.5" wheels.

It is to be expected that at the truck show 1994 in Hannover more prime movers equipped with disc brakes - not only on steering axles - will be on display. The latest development of BPW allows to start the operation of disc braked axles in towed vehicles at the same time as the series introduction of disc braked trucks.

Therefore operators of combination vehicles can make maximum use of the advantages

- excellent brake performance
- high temperature resistance
- fine response behaviour
- compatability
- long life expectancy
- simple service
- beneficial weight.

Disc Brake	SB 4345
Manufacturer	Bergische Achsenfabrik Fr. Kotz & Soehne, Germany
Type	Floating Caliper Brake
Actuation	Pneumatic
Slack Adjuster	Automatic, integrated
Permissible Axle Load P_e	11,550 kg
Brake Factor $n_a C^*$	0.70
Nominal Transmission Ratio i	13.5
Mean Friction Radius R_m	171.5 mm
Disc Diameter	430 mm
Disc Width	45 mm
Permissible Disc Wear	7 mm
Pad Area	2 x 206 cm²
Pad Width / Lining Width	30 mm / 23 mm
Permissible Lining Wear	21 mm
Tyre Size	≥ 22.5"

Table 1: Technical Specification of Disc Brake SB 4345

DISC BRAKE SB 4345		DRUM BRAKE SN 4218	
Brake torque at 6.5 bar in Nm	Installed cylinder type	Brake torque at 6.5 bar in Nm	Installed cylinder type and lever length
20,700	16"	20,200 21,300	20" / 150 mm 24" / 135 mm
24,100	20"	23,700	24" / 150 mm
26,000	22"	25,900 26,100	30" / 120 mm 24" / 165 mm
28,200	24"	28,600 29,200	24" / 180 mm 30" / 135 mm
33,000	27"	32,500	30" / 150 mm
38,500	30"	39,100	30" / 180 mm

Table 2: Comparison of Brake Installation

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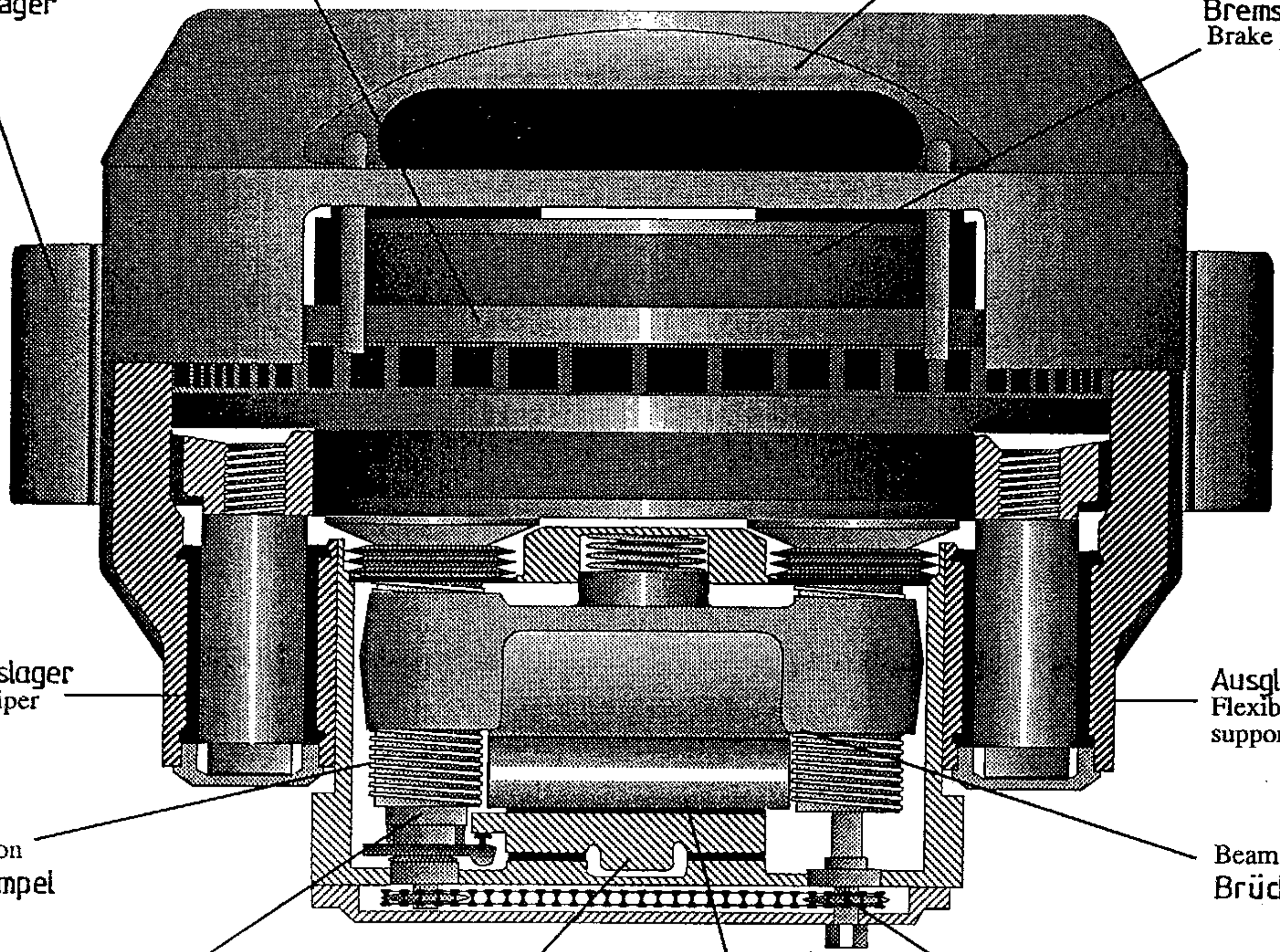
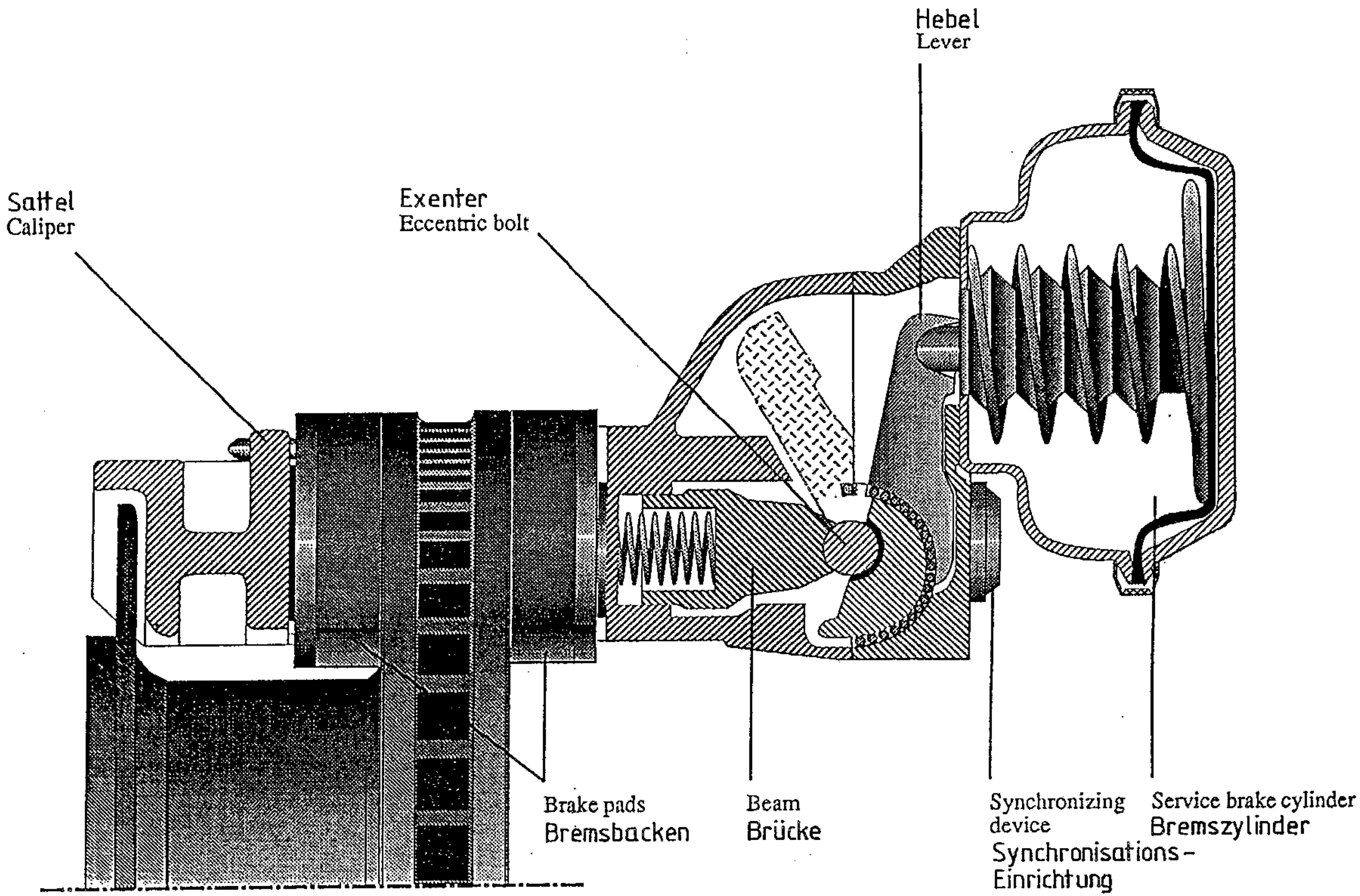


Disc brake SB4345

Schematic view from top

Fig.1

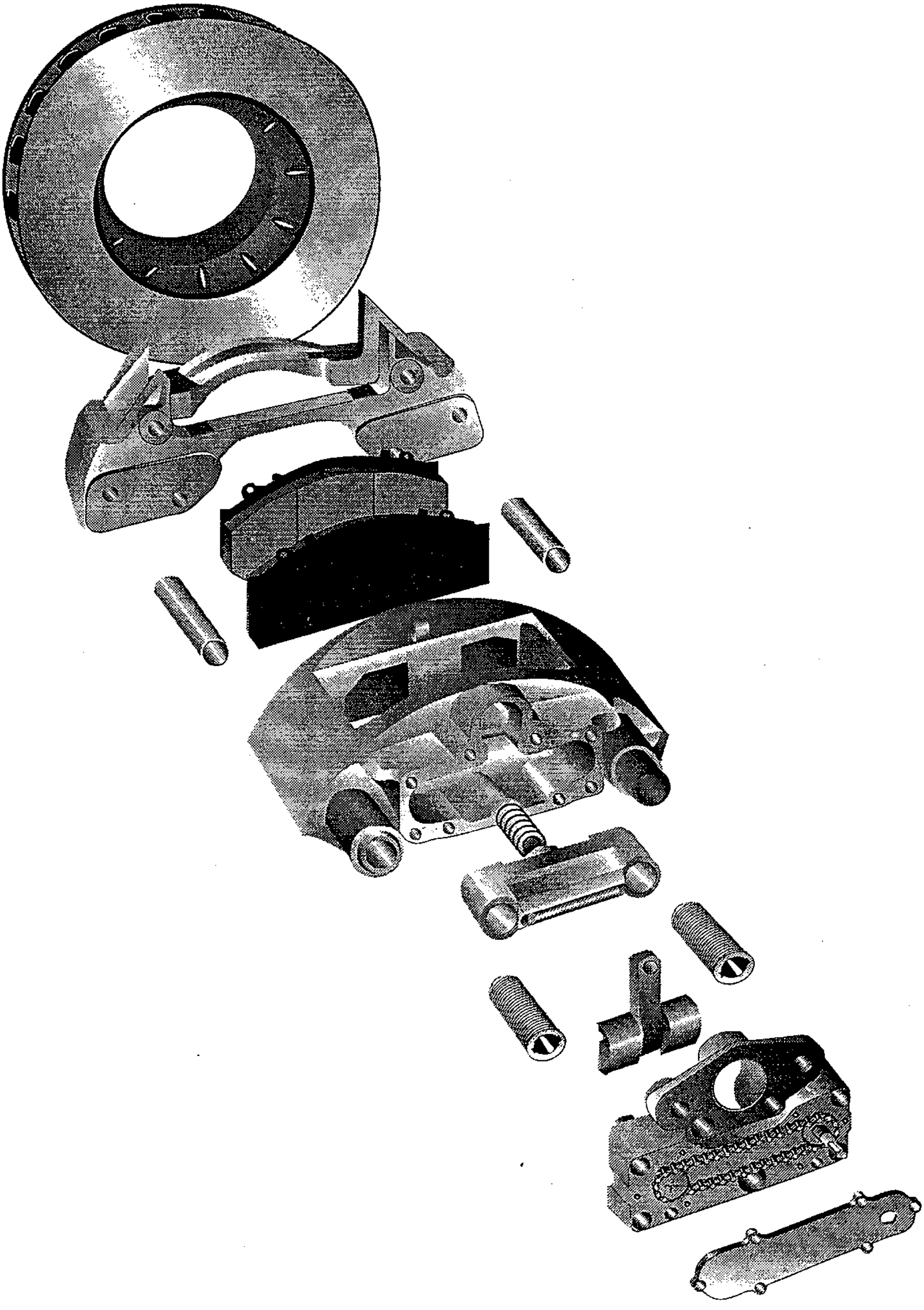
1994



Disc brake SB4345

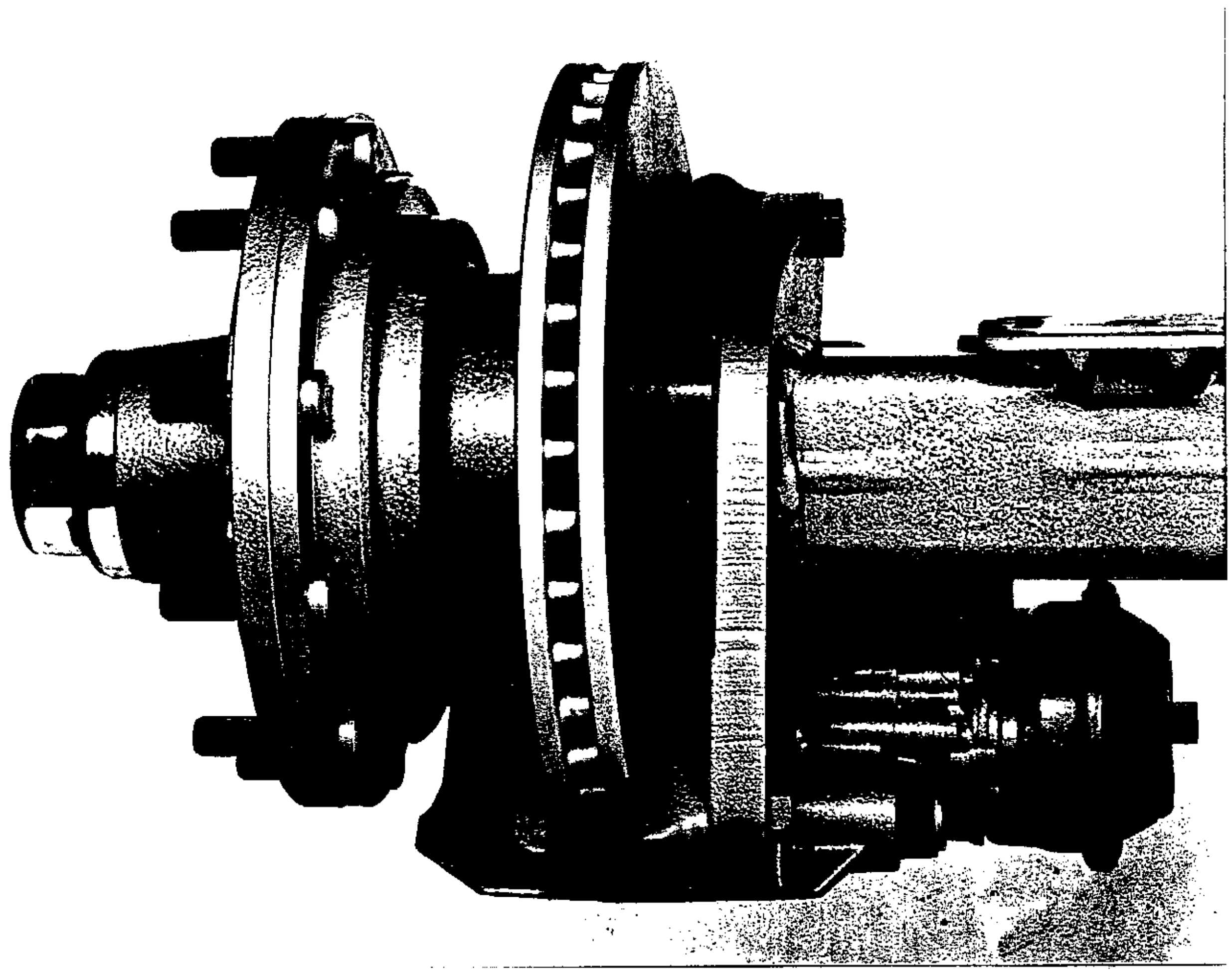
Schematic vi[illegible] from the side

Fig.2
1994



Exploded view SB4345

Fig.3
1994



BPW axle SHSF 9010 with disc brake

Fig.4
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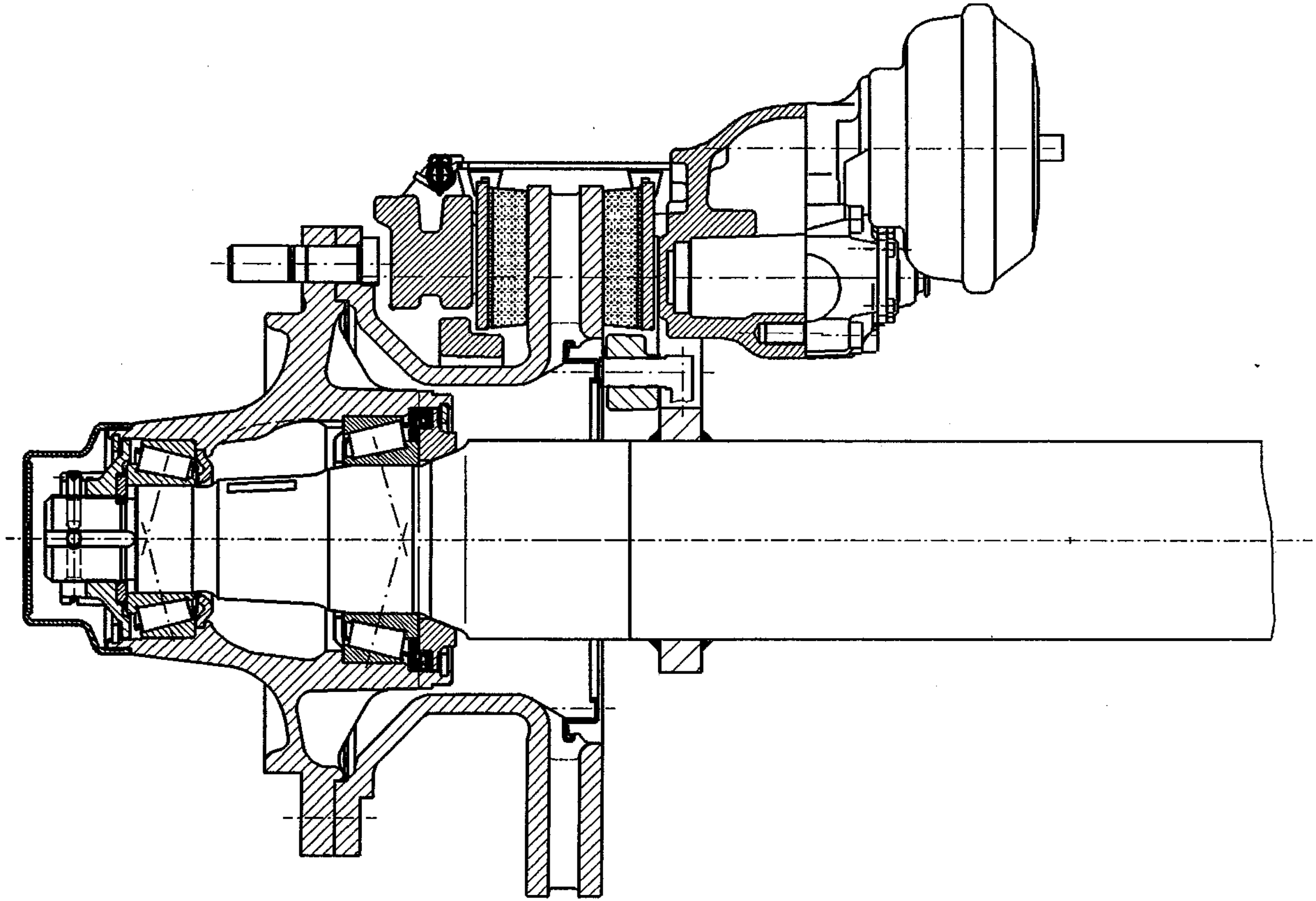

Cross section SB4345

Fig.5
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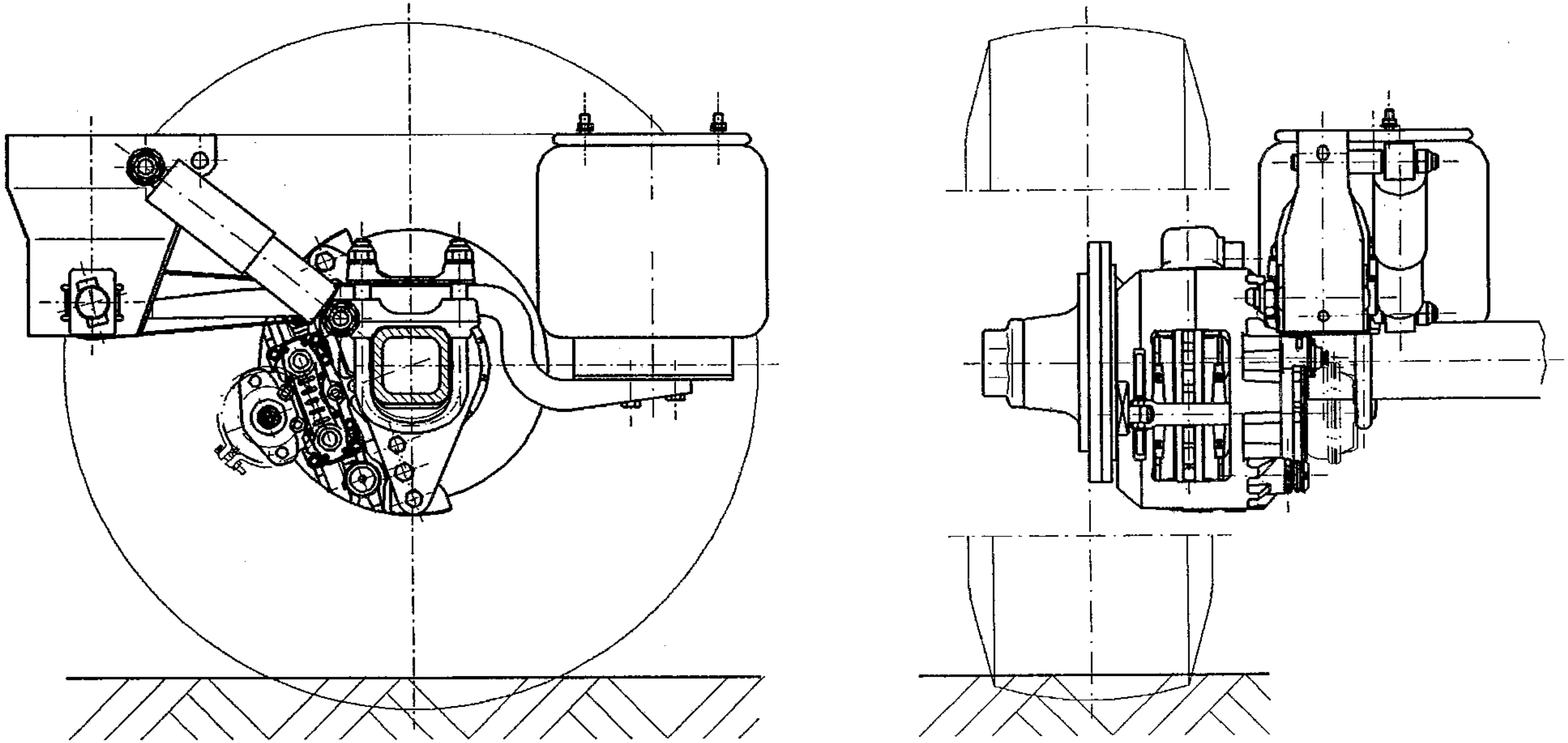

Adaption of disk brake to air-suspended BPW axle

Fig.6
1994