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THE DISC BRAKE AXLE



- The Disc braked axle – Its experience, evolution and future IRTenZ Conference 11. –13. July 2000 -

*Die scheibengebremste Achse – Erfahrung, Weiterentwicklung und Zukunft
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1. Introduction

The history

As far back as in the 70's and 80's there have been some activities with disc brakes for buses, trucks and trailers. Also BPW has tested some of their own developments. Prototypes have been tested and developments have been patented (*picture 1*). However the time was yet to come.

The new period of the disc brake started at the beginning of the 90's. The air-pressure-operated brake with floating caliper gained popularity. In the first period of getting familiar with the new product, basic tests and restricted in-field tests were conducted.

The market meanwhile has certain expectations in regard to increased safety and more comfortable braking. The users have their own specific demands regarding the new braking technology.

Demands of the transport operators:

- easy maintenance and repair
- low tare weight (high payload)
- economical operation
- long service life of all braking components
- smooth operation with all operating conditions
- more safety (minimum fading, short stopping distance)
- sensitive actuating and appropriate proportioning

Demands of the trailer builders:

- flexible integration in existing running gear
- suitable for standard track widths
- possibility of integration in existing chassis designs
- availability for all product lines of all full trailers and semi trailers
- easy assembly of axle and suspension system

The investigations revealed that the disc brakes developed by the brake manufacturers did suit the requirements of the trucks quite well, whereas they hardly considered the special demands for the trailer running gear. In particular, the design of the disc brake incorporates brake boosters mounted parallel to the axle beam in a position where they are not "compatible" to existing air suspension systems. Therefore, during the testing of the disc brake itself, evaluations of adapting the disc brakes to the trailer suspensions were carried out.

The way to series production

Further steps to the introduction of the BPW disc brake followed:

- Adaptation of the disc brake (in cooperation with the manufacturer of the brake caliper) for the use on rigid and steerable trailer axles in towed vehicles (this is a continuing process).
- In-field test with approx. 100 vehicles (full trailers and semi trailers) in 1993.
- In-field experience of about 10 Million km's prior to series production.
- Recognizing and eliminating of weak points.

- September 1996: Series production of 9-ton disc brake axle for 22,5"-tyres, with BPW disc brakes SB 4345, released at the Motor Show in Hanover.
- May 1997: Series production of 9-ton disc brake axle with new disc brakes SB 3745 (disc-diameter 370 mm) for tyres 19,5" and 22,5" (single tyres as well as dual tyres) to be the standard brake (*picture 2*).
- Since 1997: Use of the disc brakes on a wide variety of products (this is a continuing process).

2. Experience with disc braked axles

Coverage in the market

The introduction of the first truck being completely equipped with disc brakes (DaimlerChrysler's ACTROS) at the Hanover Motor Show in 1996 created vivid enquiries for disc brakes on trailers.

Since the start of series production in 1996 a quantity of around 120,000 BPW trailer axles for tyres 19,5" and 22,5" with disc brakes are operating basically all over Europe. Even outside Europe, e. g. New Zealand, Australia, Arabic Countries, Japan, Kenya, Russia and South Africa a large number of disc brake trailer axles are in operation.

Presently further testing on additional configurations is being carried out by trailer builders who are specialized on certain trailer designs. There is also a solution available for trailers which up to now did not allow a fitting of a standard disc brake because of lack of space in the center of the trailer. A recently designed deviation adapter allows the space-saving positioning of the brake chamber in a horizontal direction (*picture 3*). This design achieves a substantially reduced overall width of the disc brake offering advantages in regard to assembly. Such brakes are used in trailers where the wheels are fitted to single-suspended stub axles and the center area of the trailer can be used for the storing of goods. An example for such a trailer is a glass transporter (*picture 4*).

BPW offers a wide range of axles with disc brakes: rigid axles for tyres 19,5" and 22,5" (single and dual tyres), axle capacity 6,5 tons to 14 tons; self-steering axles for tyres 19,5" and 22,5", axle capacity 9 tons and 10 tons; air suspension systems for ride heights of 235 mm to 600 mm; hub-systems for single-tyres, wheels with and without offset; the disc brake axles are designed for almost the same operating conditions like drum braked axles; for the time being dedicated heavy-duty "off-road-operation" is still excluded due to the possibility of potential damage.

The integration of the disc brake for European standard trailers and semi-trailers is now considered to be completed. Further market penetration now depends on the economical and technical acceptance of the product.

Experience

Generally all users consider their experiences with disc brakes to be "good or even better" when compared to drum brakes, and they would decide to go for disc brakes for future trailer orders. However not all expectations could be fulfilled. They even differ between truck and trailer. The technical aspects which are stated in the introduction to this report have been confirmed in general and these expectations



have been fulfilled. It does look somewhat different with the economical expectations of the disc brake. In this aspect it has to be a differentiation between truck and trailer. These aspects read at the beginning of series production in **1996** as follows:

| | Trailer | Truck |
|-----------------------------------|---------|-------|
| • Maintenance friendly | 0 | + |
| • Change of brake pads | 0 | + |
| • Change of discs | -- | - |
| • Servicing of the wheel bearings | -- | 0 |
| • Weight | - | 0 |
| • Cost | -- | 0 |
| • Service life pad / disc | + | + |

Legend: trailer disc brake compared to truck disc brake

| |
|------------------|
| ++ = much better |
| + = better |
| 0 = neutral |
| - = worse |
| -- = much worse |

With the ratings listed above, one should keep in mind the fact that the disc brake had to compete against a continuously evolving drum brake which almost reached its climax in regard to economical efficiency. Under this aspect the drum brake on the truck was comparatively complicated and old fashioned.

The chart highlights that the disc brake for trailers in regard to change of the brake pads, servicing of the wheel bearings, weight and cost showed disadvantages in comparison to the drum brake. It was the aim to improve in these aspects in the following years.

Service life of brake pad and disc

Based on the huge experiences of the in-field tests, BPW has decided to include two different disc brake sizes into its trailer axle program. Disc brake SB 3745 is designed specially for an axle capacity of 9 tons and has provided excellent performance. The larger disc brake SB 4345 is meant for higher axle capacities and special requirements. At 9 tons capacity only it would be overrated - depending on the operating conditions. This could lead to a glazing of the brake pads.

Now, what is the service life of brake pad and disc? Did the optimistic expectations turn out to be correct or have the skeptics been right?

Unrealistic claims of optimistic service life periods are not of assistance. The wear of brake pads and discs depends on many issues: Frequency of braking, long distance or short distance operation, operation in hilly countryside, use of retarders and EBS-systems, brake adjustment of truck / trailer etc.. More reliable are the experiences on disc braked trailers which have been gathered by numerous transport operators. Field-test data on service life in trailer operation has been compiled.

The corresponding diagram (*pictures 5 and 6*) on service life periods in mixed operation shows that the disc brake SB 3745 is the correct choice for 9 tons axle capacity.

Further explanation on the data as per chart, see examples 1 and 2:

- In more than 90 % of all cases BPW disc brakes SB 3745 exceed service lives of min. 200.000 km (brake pads) and min. 600.000 km (discs).
- In 50 % of all cases BPW disc brakes SB 3745 exceed service lives of min. 500.000 km (brake pads) and min. 900.000 km (discs).

All other approximate service lives can be taken from the chart as described above.

Result: The expectations in regard to service life have been fulfilled and in some cases exceeded.

Change of brake pads

In regard to the European standard design (22,5" single tyres without offset) the disc brake SB 3745 offers the advantage that brake pads can be changed without having to remove the wheels (picture 7).

Result: For the majority of operations the brake pads on a disc braked axle can be changed quicker than on a drum braked axle.

Servicing of the wheel bearings

After the series introduction of the disc brake in 1996 BPW launched in Europe a new hub/bearing system "ECO^{PLUS}", which is service-free for a period of 5 years. Service work on the bearing in between the change of the pads and the disc is no longer needed.

Result: The new BPW - ECO^{Plus} bearing system is custom made for the disc brake and saves additional servicing in between the regular service intervals.

Weight

The use of disc brake SB 3745 (in place of SB 4345) for 9 tons axle capacity led to a weight saving of approx. 8 kg in comparison to a drum braked axle. This advantage was highly appreciated by weight-orientated users, such as e. g. transport operators with tank or container trailers. As the disc brake for commercial vehicles is just at the beginning of an optimizing process, further weight reductions can be expected for the future.

Result: The disc brake already now exceeds the demands in regard to weight and offers further weight reduction potential for the future.

Temperature

In view of red hot discs observed during initial testing the question of the effect of temperature stress on the surrounding areas came up. The brake pads have been designed right from the beginning with an eye on these temperature conditions. Specific attention should be paid to all other components which are close to the disc brake, e. g. hub bearing and tyres. Does the temperature during operation rise to such an extent that the life expectancy is negatively influenced?

Recently conducted comprehensive tests on temperature-data with disc brakes have proven that the tyres - with steel rims as well as with alloy rims - are not facing higher stress as with drum brakes. The average temperatures for bearings, grease and seals are within an uncritical range as well, so that the working life of these components is not decreased.

Result: The temperature stress caused by the disc brake is within an uncritical range for tyres, rims and hub bearings.

Realization of the market demands - present status

In order to check on how far the demands of the market for the trailer are met, we have updated the basic requirements of the chapter "experience" again with status **May 2000** (without the comparison to the truck):

| | Rating | Remark |
|---------------------------------|--------|---|
| • service life brake pad / disc | + | Unchanged, positive tendency confirmed |
| • change of disc | -- | Unchanged |
| • change of brake pads | + | Improvement: change of pads with 22,5" single tyres to be done without dismantling of the wheel |
| • servicing of wheel bearings | -- | Conventional hub system |
| • servicing of wheel bearings | + | Improvement: Achieved by new ECO ^{PLUS} – hub system (5 years service-free) |
| • weight | ++ | Improvement: Advantage of weight in comparison to drum braked axles |
| • cost | 0 | Improvement: OEM and spare parts supply with reduced prices |

Changing of the brake pads, servicing of the wheel bearings, weight and costs have been improved. What still needs some improvement is the change of the disc which at present, does need some more work compared to the drum brake.

All demands of the trailer builders - which are mentioned in the introduction - have now been fulfilled.

Wheels with and without offset for single tyres (picture 8)

There are two options being offered in Europe, which is basically for single tyres (super singles). On the one hand disc brakes with wheels without offset and on the other hand wheels with 120 mm offset.

Disc braked trailer axle for wheels without offset (picture 9) :

The load transmission from the tyre over the hub straight into the bearing is linear. The disc is positioned to the inside of the bearings at the bead of the rim in the air current.

This leads to the following advantages:

- minimized weight
- optimized cooling of the brakes
- minimized wear of the brake pads
- with tyres 22,5" the brake pads can be changed without dismantling of the wheel

Disadvantage:

- Brakes are positioned closer to the center of the axle, thus less space for the assembly of the suspension components (only disadvantageous for underslung trailing arms).

Disc braked axle for wheels with offset (picture 10) :

The force transmission from the tyre into the hub is done indirectly. The disc is positioned in the base of the rim and is positioned exactly in line with the bearings.

Advantages:

- The brake is positioned far to the outer edge of the wheel which allows more space for the assembly of the suspension components (is used for underslung trailing arms only)
- Protected position of the brake inside the base of the rim

Disadvantages

- increased weight
- increased temperature of the brake
- increased wear of the brake pads
- increased temperature of the tyres
- increased temperature of the bearings

Result: The problem of using wheels with or without offset is not a question of philosophy; advantages and disadvantages of both options need to be considered carefully prior to deciding the optimum solution.

3. View to the future

Extension of the operating range

Presently work has commenced on the development of a disc brake for tyres 17,5" for trailer axles to suit low loaders. The capacity range being targeted for this brake is between 5 tons to 9 tons per axle.

Further reduction of weight

Due to improved research and production-technologies as well as increasing experience with new developments, savings on weight will be achieved within a short period of time.

Cost

Already it can be noted that the smaller disc brake SB 3745 in most cases achieves lower operating costs than the larger disc brake SB 4345 (*picture 11*). Increasing quantities in series production for OEM as well as spare parts use will have a positive influence on the costing situation.

BPW, as a manufacturer of complete running gear, is aiming to offer the transport operators fixed costs in the future - based on service cost per km - to support them in their service cost calculations.

Innovations

The electronic age for the commercial vehicle has already begun. Out of the vast range of new opportunities those will be chosen which give economical and safety-related technical progress and which offer additional features to the user. Some examples of innovations which may be applied to disc brakes:

- Sensoring - for electronic recording - and control of brake pad- and disc-wear
- Electronic recording and control of conditions of brakes in self-steering axles and in lift axles
- Information on the condition of brakes displayed in the truck and via satellite to the service center of the transport company

4. Summary

The disc brake in the commercial vehicle has passed its test.

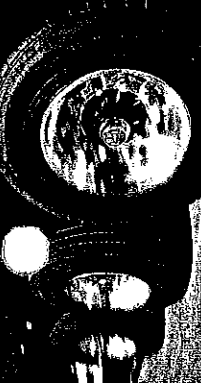
The technical and economical expectations have been fulfilled to a high extent.

In Europe the disc brake is on its way to supersede the drum brake.

The disc brake is becoming the standard brake on truck and trailer.

The penetration into applications not yet using disc brakes and the rate of market acceptance outside of Europe depends primarily on the technical and economical acceptance of the disc brake.

The disc brake offers a lot more potential for evolutionary improvements and innovation.

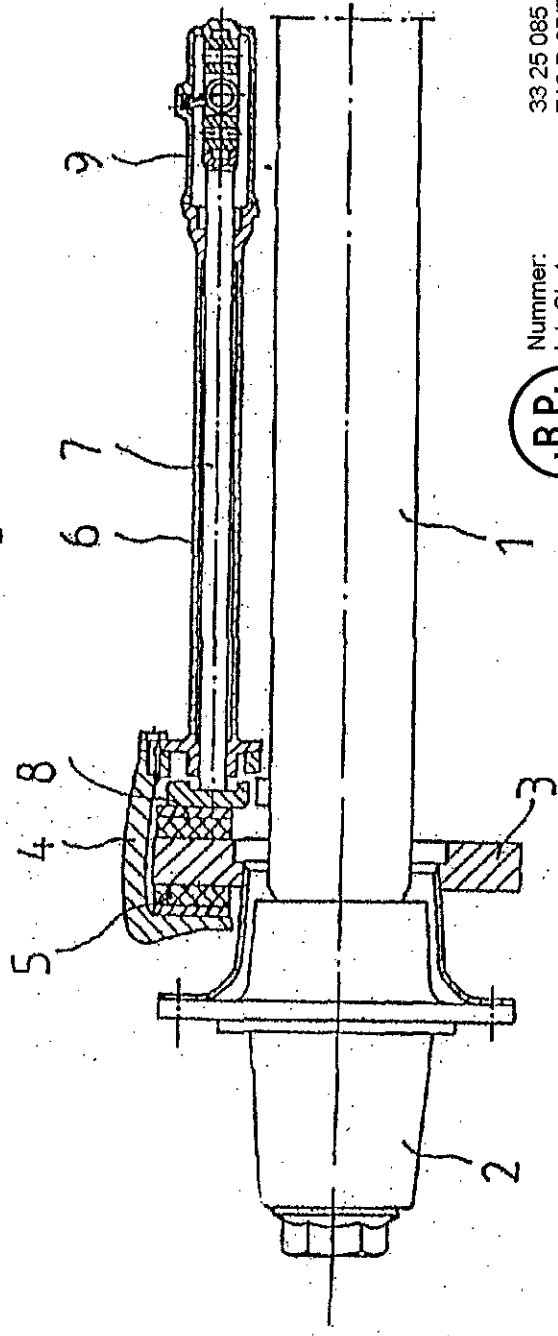


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History

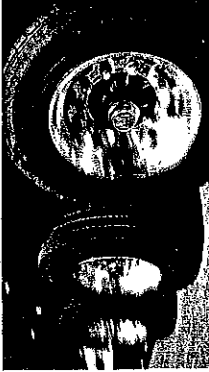
Fig. 2



Nummer: 33 25 085
Int. Cl. 4: F16 D 65/52
Veröffentlichungstag: 15. Januar 1987

Patent release of a BPW disc brake with floating caliper with spindle application

Picture 1



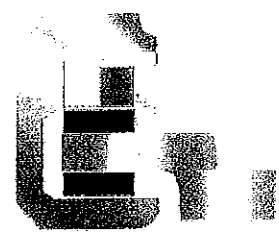
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Two different sizes of disc brakes available in the BPW-trailer axle program

SB 3745: Tailor-made for 9 t axles

- approx. 25 % lighter than SB 4345

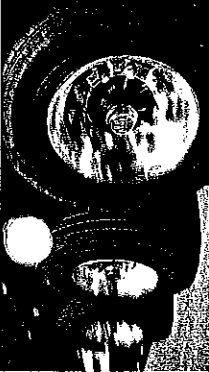


Disc diameter: 370 mm
 Especially for 9 t-rigid axles and self-steering axles. With 19.5" or 22.5" tyres.
 Disc thickness: 45 mm

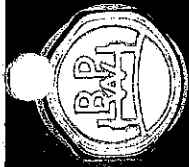
SB 4345: made for 10 t and 12 t axles



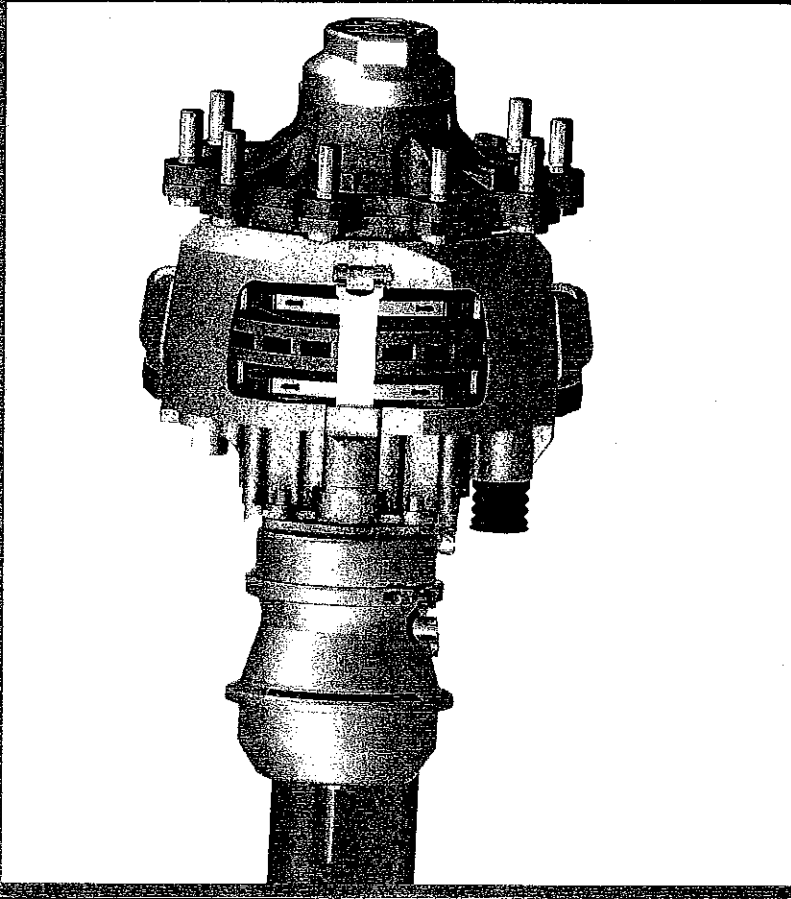
Disc diameter: 430 mm
 Especially for 10 t and 12 t axle load ranges. With 22.5" tyres.
 Disc thickness: 45 mm



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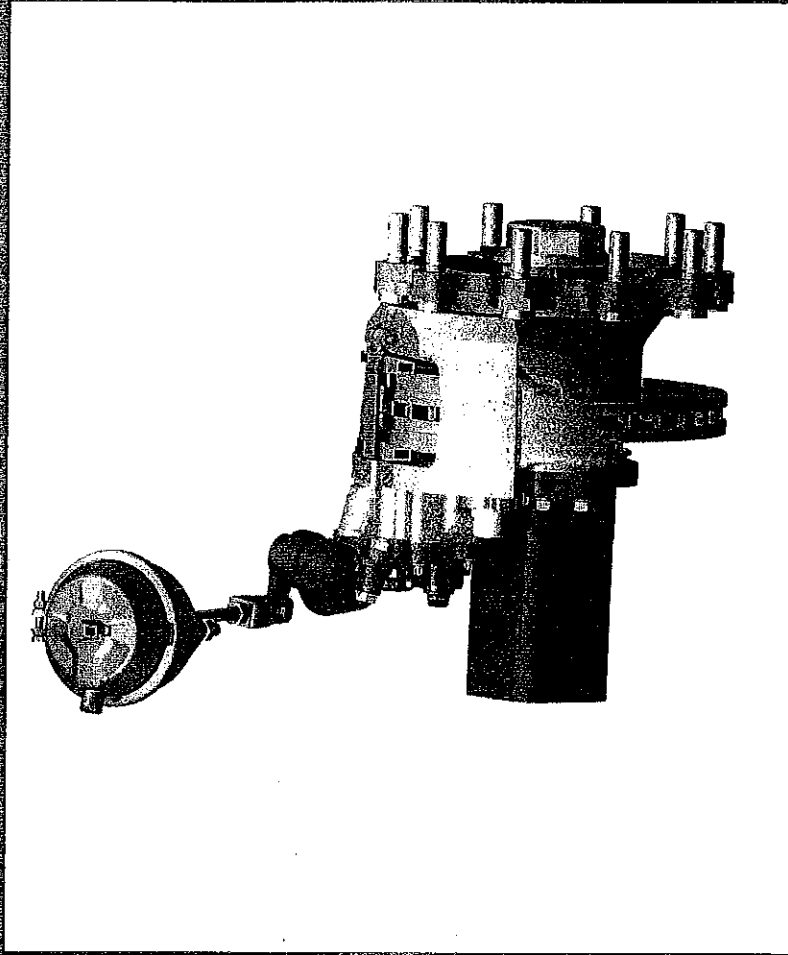


Disc brakes with axial brake application



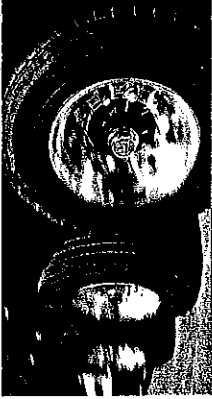
- o Standard disc brake with spring brake boosters

Disc brakes with radial brake application



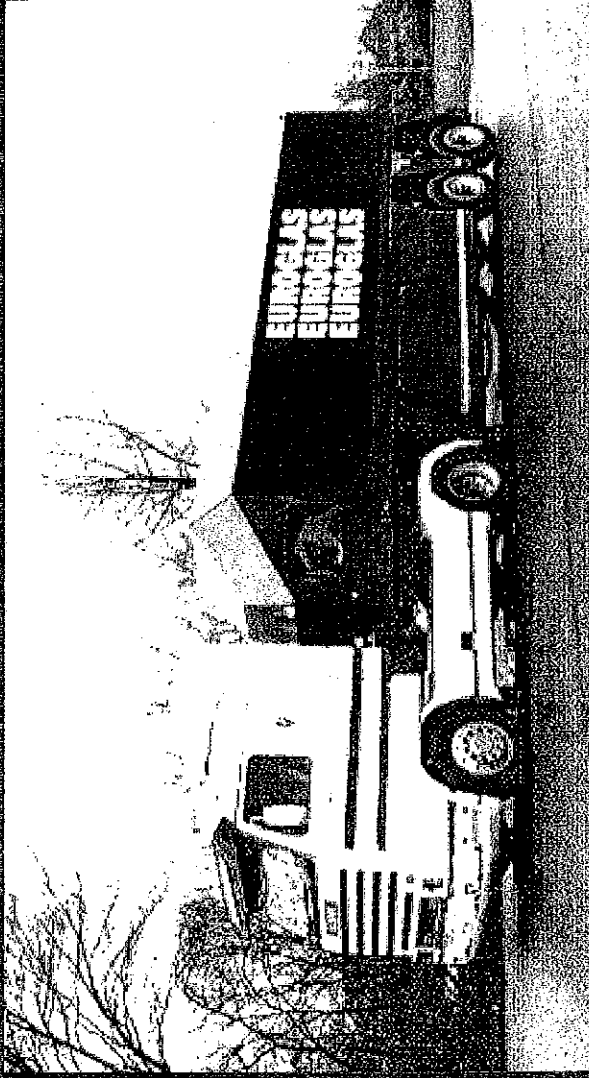
- o Small overall width of the complete brake unit
- o Brake booster can be positioned outside of the shape of the tyre

Picture 3

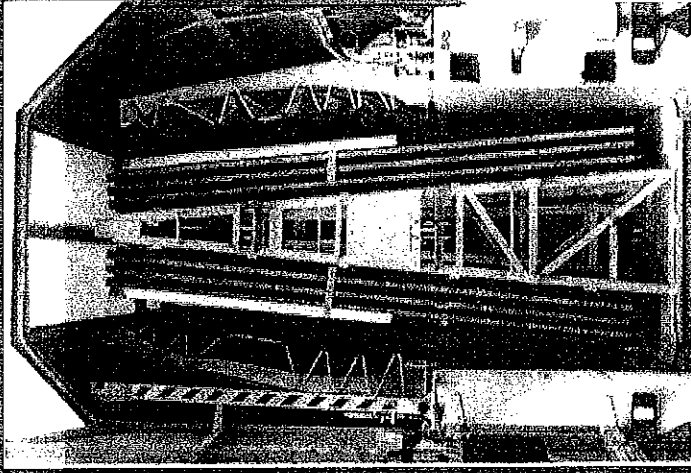


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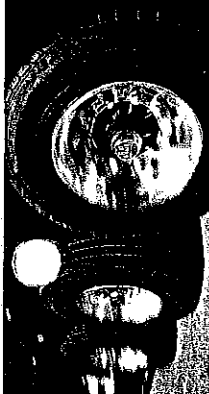
Disc brakes with radial brake application Example for an operation



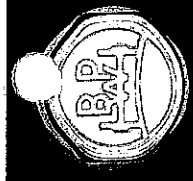
Glass transporter - Semi trailer



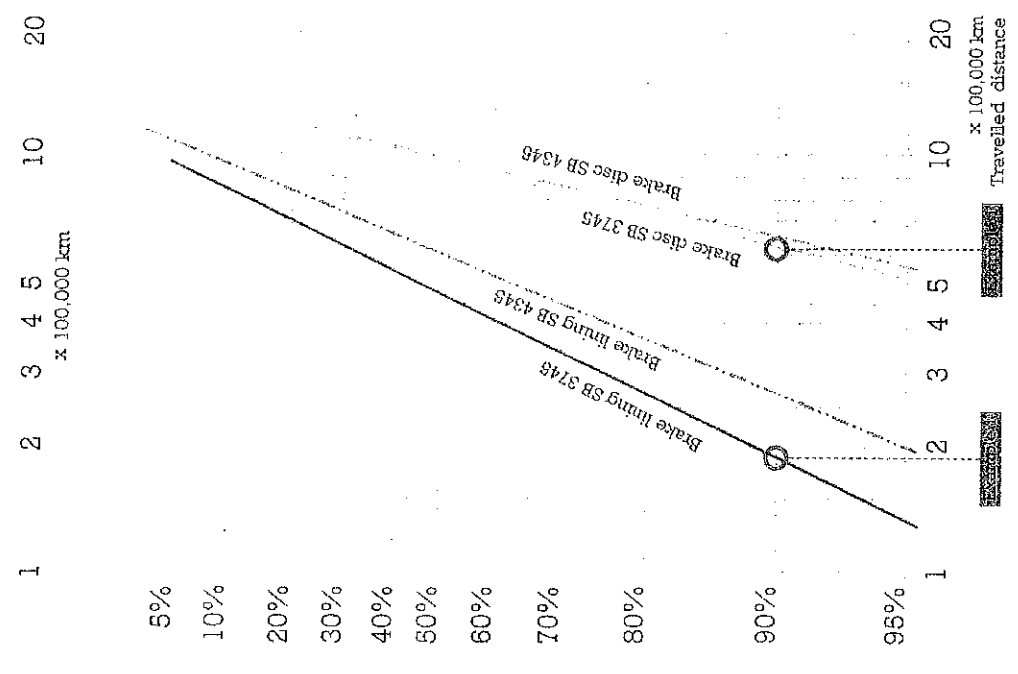
Rear view: Window panes are stored in between the stub axles



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**Anticipated service life
for pads and brake discs in mixed transport**



**Anticipated service life for pads and discs
in mixed transport**

In 90% of all cases, pad service life of min. 200,000 km and disc service life of min. 200,000 km are exceeded with the BPW 3745 disc brake (relation 1:3).

Other service life probabilities can be read off in the same way, e.g.:

In 50% of all cases, pad service life of about 500,000 km and disc service life of about 500,000 km are achieved with the BPW 3745 disc brake.

In 10% of all cases, pad service life of about 850,000 km and disc service life of more than 850,000 km are achieved with the BPW 3745 disc brake.

Figure 5

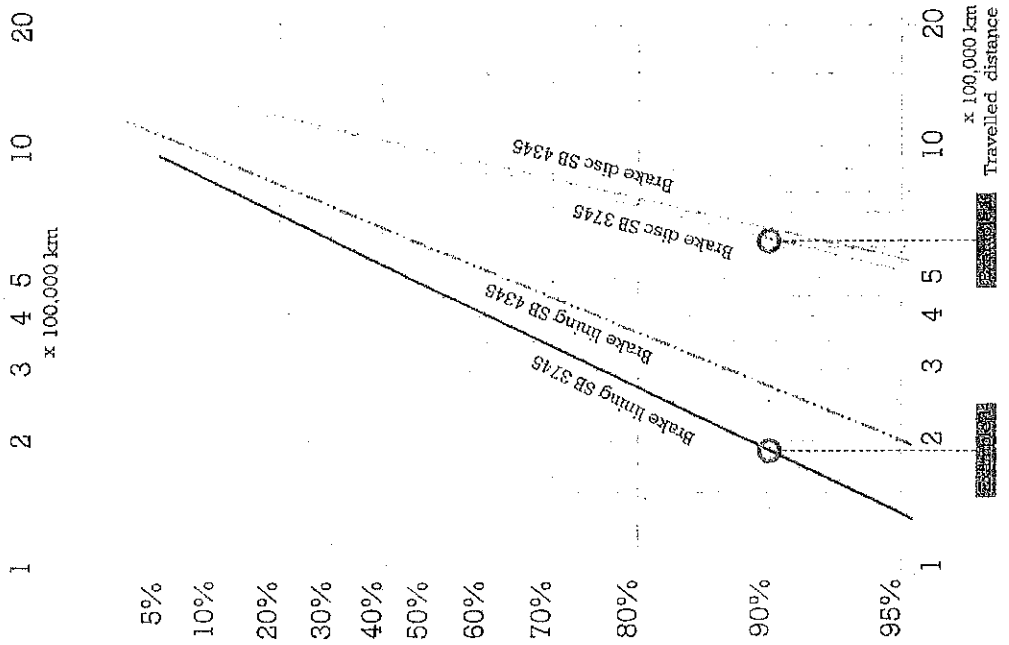


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Anticipated service life

for pads and brake discs in mixed transport



Life expectancy of SB 3745 compared to SB 4345:

SB 3745

In 90% of all cases, pad service life of min. 200,000 km and

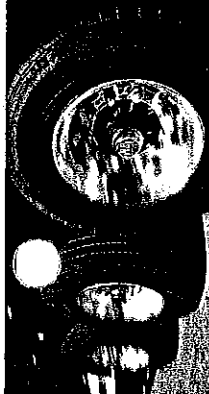
are exceeded (Relation 1:3)

SB 4345

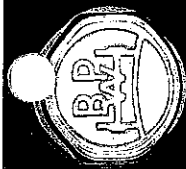
In 90% of all cases, pad service life of min. 250,000 km and

are exceeded (Relation 1:2,5)

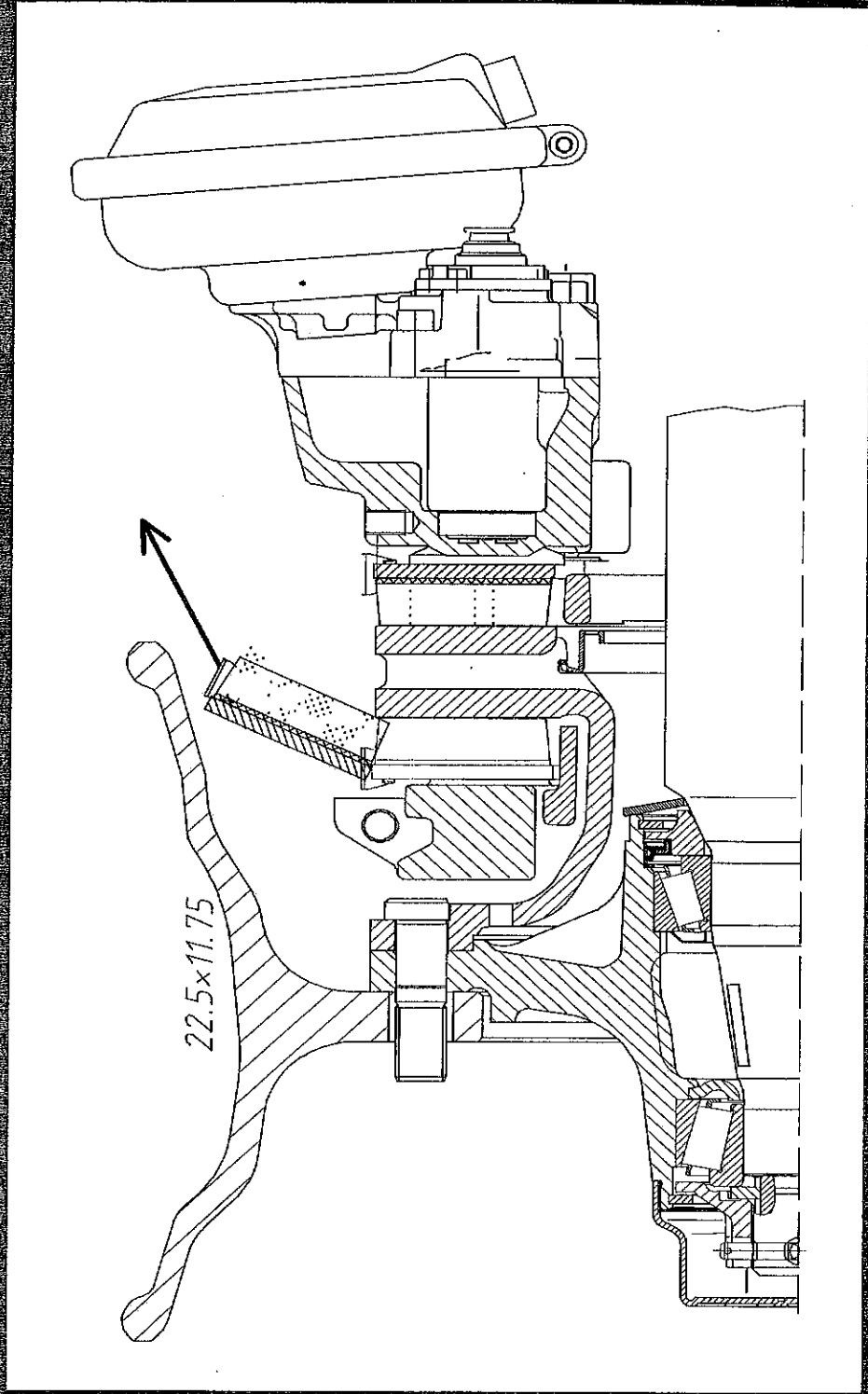
This is a typical value for highly stressed brakes, prevailing in short distance service



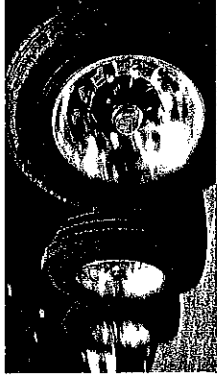
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Changing of brake pads with single tyres 22.5 and disc brake SB 3745 without dismanding of the wheels



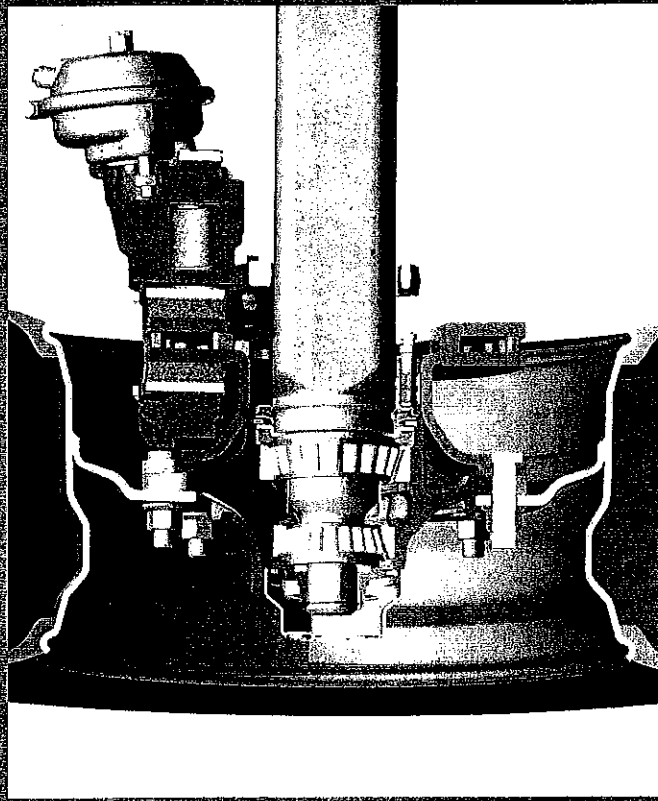
Picture 7



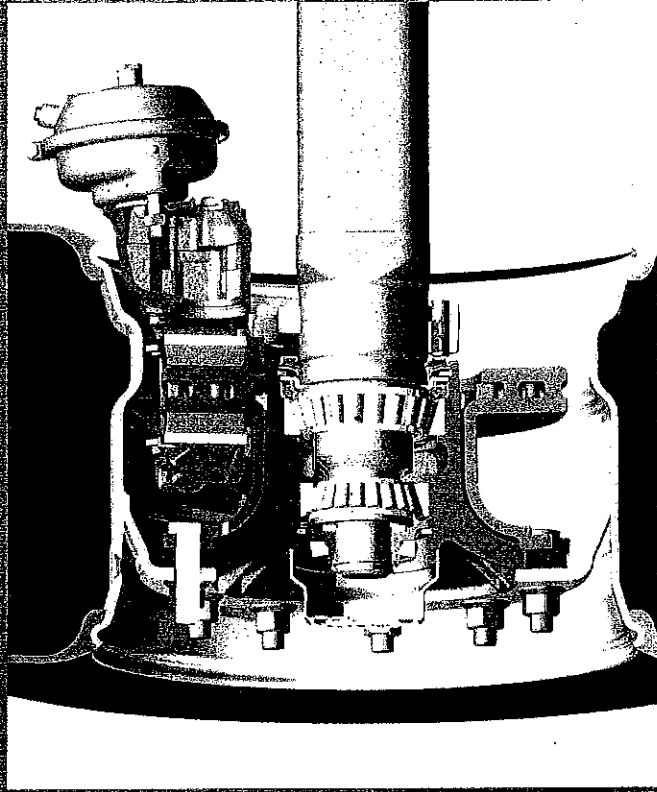
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Disc braked axles
without offset



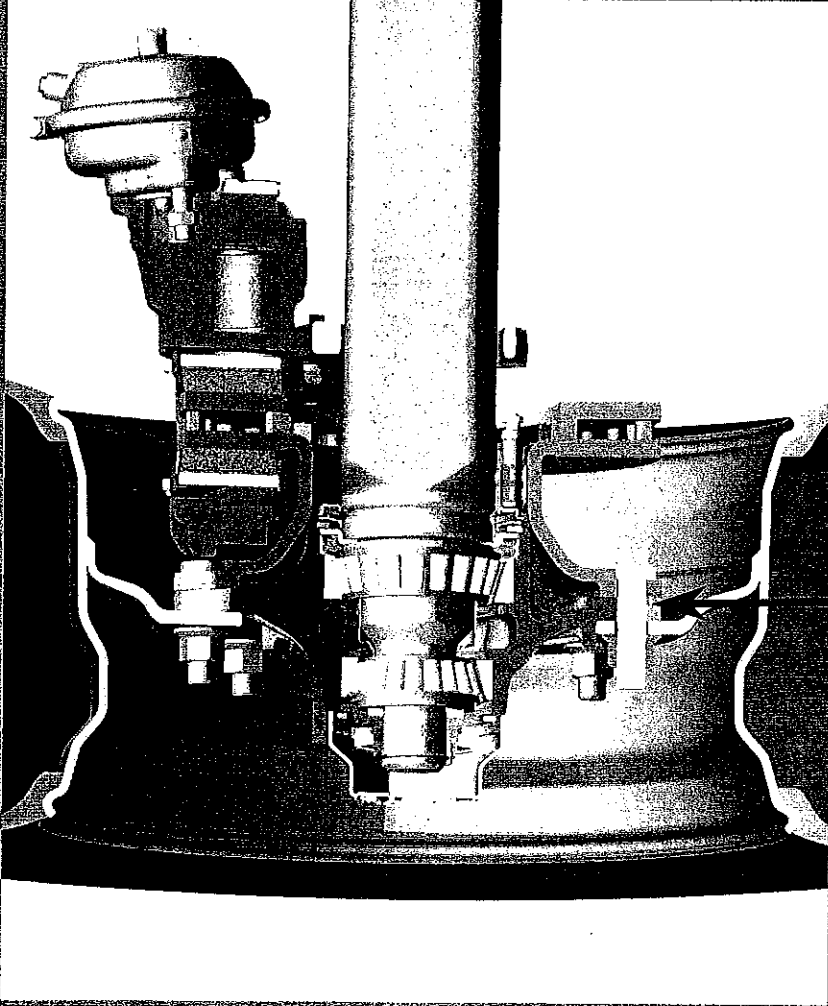
with offset



This is not a question of philosophy!
Advantages and disadvantages of both options will have
to be considered carefully to find an optimum solution for
the operating conditions in question.



Disc braked axles without offset



Wheel force

Linear load transmission from the tyre over the hub into the bearing

- ⇒ Minimum stress of the components
- ⇒ Minimum weight

Disc brake positioned at the bead of the rim in the air current

- ⇒ Optimized cooling of the brake
- ⇒ Minimum wear of the brake pads

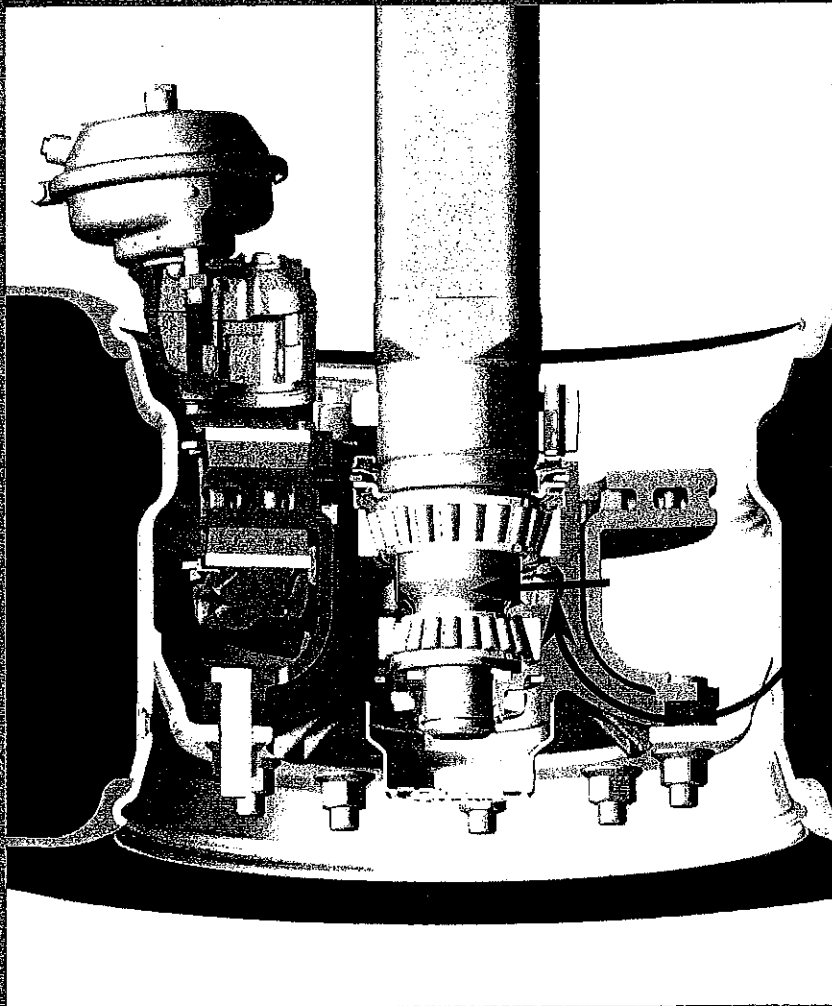
Brake positioned to the inside of the bearings

- ⇒ Low temperature of the bearing
- ⇒ Improved service life

The disc brake SB 3745 with 22.5 single tyres allows the changing of the brake pads without a dismantling of the wheels!



Disc braked axles with offset



Redirecting of the contact force over wheel and hub by 120 mm (offset)

- ⇒ Higher bending loads
- ⇒ Higher weight

Disc brake rotor positioned in the base of the rim

- ⇒ Higher temperature of the brake
- ⇒ Higher temperature of the tyres

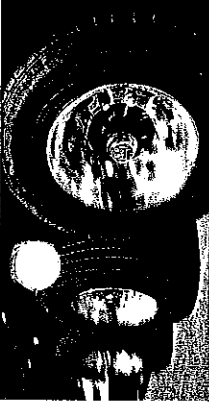
Brake positioned exactly on top of the bearing

- ⇒ Higher temperature of the bearings

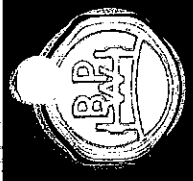
Brake positioned at the outer edge of the base of the rim

- ⇒ Larger space for the suspension components

Wheel force

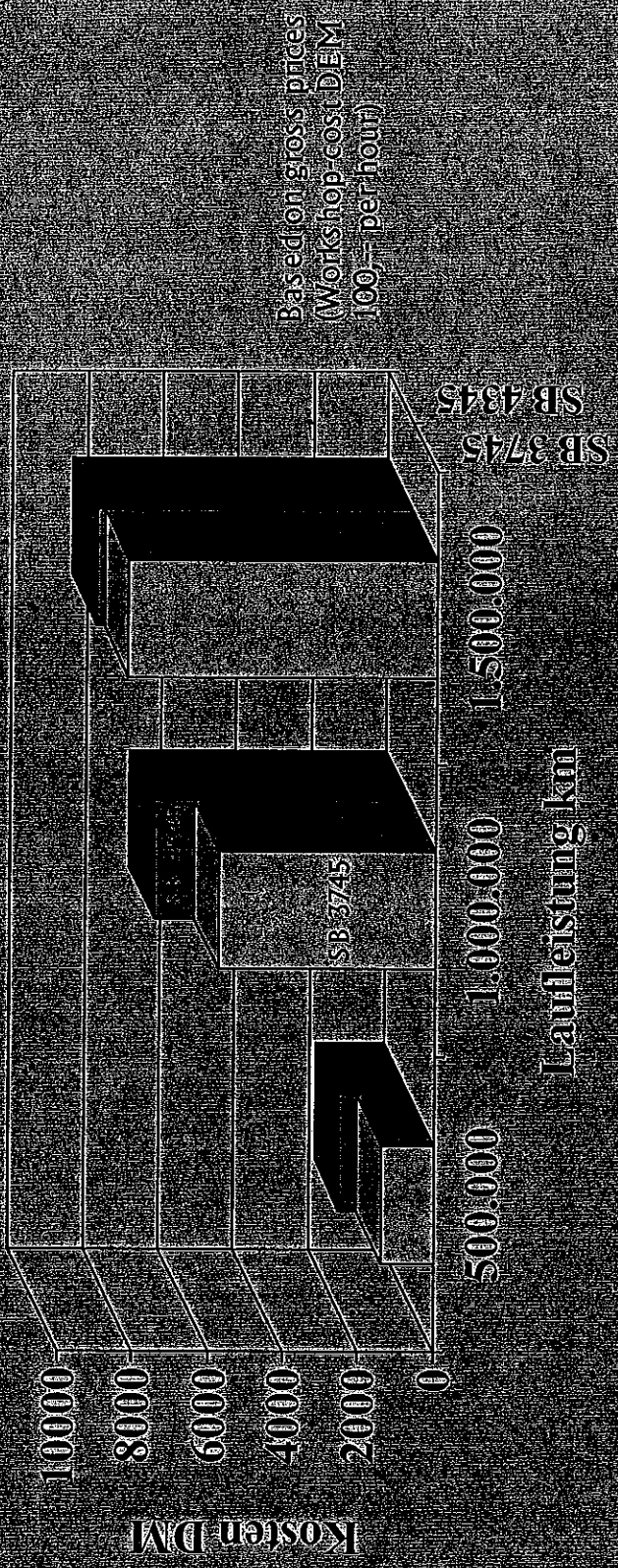


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SB 4345 or SB 3745

It all depends on the correct dimensions
Comparison of servicing costs



The economical advantages of disc brake SB 3745 are the following:

- with single tyres changing of brake pads can be done without dismantling of the wheels
- rotors are designed to exactly match the brake pads
- lower tare weight

Figure 11