UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Distr.
LIMITED

E/CN.14/TRANS/38
9 January 1970

Original: ENGLISH

ECONOMIC COMMISSION FOR AFRICA

TECHNICAL AND ECONOMIC STUDY OF RAILWAY LINKAGES

The Effect of Gauge Adjustable Wheelsets and Bogie Changes on the Traffic between Railways of Different Gauges

M69-3223

CONTENTS

TECHNICAL AND ECONOMIC STUDY OF RAILWAY LINKAGES

A. General

African railway systems south of the Sahara operate mainly on a variety of gauge widths.

The total trackline is 78,811 kms, of which 62,018 kms (79 per cent) are of 1067 mm gauge, and 13,627 kms, (17 per cent) are of 1000 mm gauge. The rest of the rail lines have a gauge width of 1435 mm or less than 1000 mm, and constitute only 4 per cent of the whole trackline.

The growing demand for transport for accelerating the intra-African trade and the need to foster the economic and social co-operation between the countries of the region will be greatly facilitated if the present railway systems are inter-connected.

The secretariat, in its search for economic methods to overcome the difficulties in linking these diverse systems, wish to recommend three methods which will facilitate the smooth frontier crossing of rail traffic and the mutual utilization of rail cars, thus saving the excessive cost and time spent for trans-shipment of cargoes and passengers, and will go a long way to make the handling of containers an easy task, particularly for the land-locked countries.

The three known methods referred to above are:

(1) Standardization of gauges;

(2) Changing of bogies or wheelsets at the border;

(3) The use of gauge adjustable wheelsets.

B. Standardization of gauges

This method requires the expansion of the gauge width from 1000 mm to 1067 mm 1/. This will entail the replacement of the sleepers and wheelsets if these are not convertible, and, if they are, it will only need the change of the sleeper fastenings and the expansion of the wheelsets, and, in both cases, the standardization of the braking and coupling systems. A detailed study was made on this method in the secretariat documents entitled:

"Technical and Economic Study of Railway Linkages in the African Region" (E/CN.14/TRANS/WP.25),

"Technical and Economic Study of Railway Linkages in the West African Region" (M69-781), and

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1/ Since the 1000 mm gauge constitutes 17 per cent of the railway systems south of the Sahara, it is recommended that these should be converted to 1067 mm where this is economically desirable for the flow of traffic to neighbouring countries.

"Technical and Economic Study of Railway Linkages in the East African Region" (E/CN.14/TRANS/36).

C. Changing of bogies or wheelsets at the border

This method is currently in use between France and Spain. The French railway systems operate on a gauge width of 1435 mm, whereas in Spain the railway systems operate on 1668 mm gauge, and the movement of trains between the two countries is made possible by means of changing wheelsets or bogies.

The freight cars running over the border are standardized. In other words, the cars are of one type; they have only 2 axles (four-wheelers), which are the cars mostly used in Europe.

The changing of wheelsets is done very rapidly and smoothly. The wheelsets changing shed is in Hendaya (see Picture 1) and is equipped with 8 electric-driven jacks which can lift up simultaneously 2 freight cars (see Picture 2). The following procedure is applied:

(a) Two cars are pushed into the shed. They are stopped in the right position on the jacks by stop blocks;

(b) Unskilled labourers - 4 per car - unscrew the pedestal binders and jack up the body of the car while 2 other labourers lift the required wheelsets on the changing line (see Picture 3). During the lifting time of the car bodies, the labourers change the seats of the brake-shoes into the required position;

(c) As soon as the jacks have reached the final position, the wheelsets are rolled to the exit of the shed, where 2 other labourers are stocking the wheelsets by lifting them on stock rails (see Picture 4). Meanwhile, the required wheelsets are rolled underneath the cars. The jacks let down the bodies of the cars, the pedestral binders are assembled again;

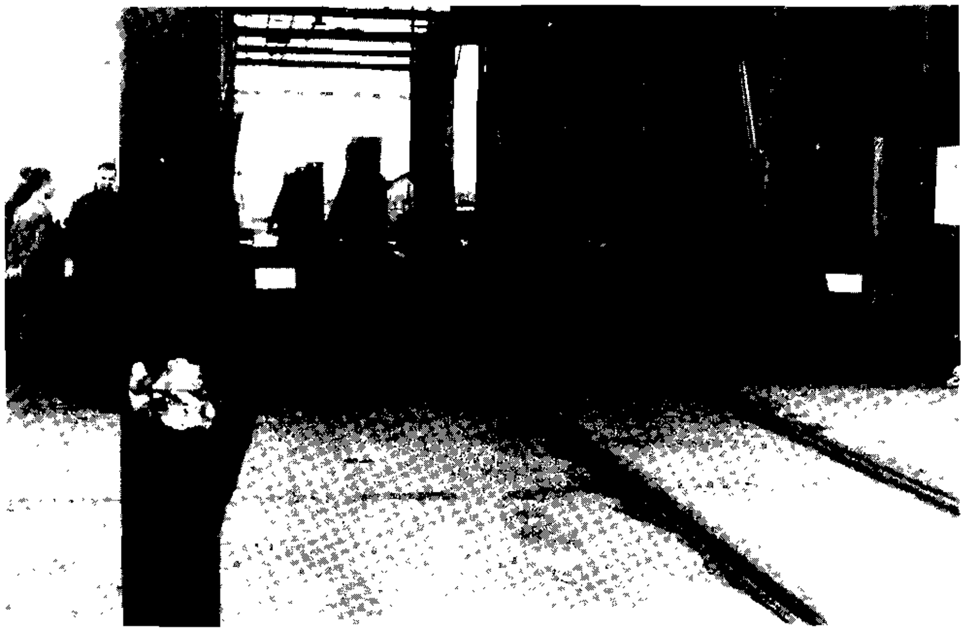
(d) The cars with the changed wheelsets are pushed out of the shed by the new cars arriving for the same process.

The time for changing the wheelsets amounts to 5 minutes per car and labour force of:

2 workers per wheelset

4 workers for handling the spare wheelsets

Considering some delays on the feeding line, rest of the labourers during the shift, other work, e.g., changing of broken springs, etc., it may be



Picture 1

Axle changing shed in Hendaya

Figure 1

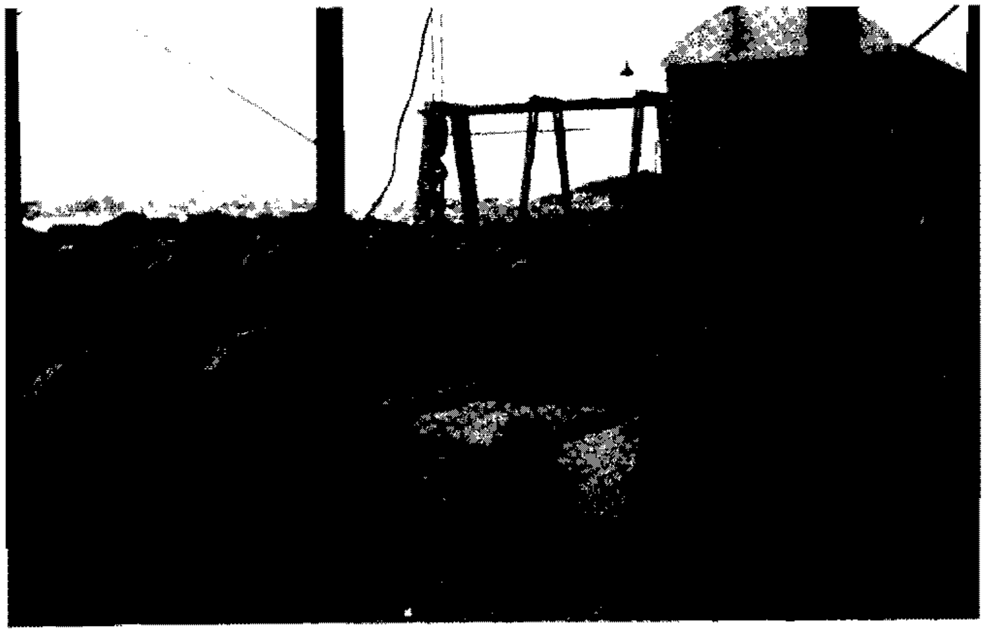
Atelier de changement d'essieux à Hendaye

Picture 2

Changing of axles in Hendaya: two workers per each wheelset

Figure 2

Changement d'essieux à Hendaye: Deux ouvriers par essieu monté

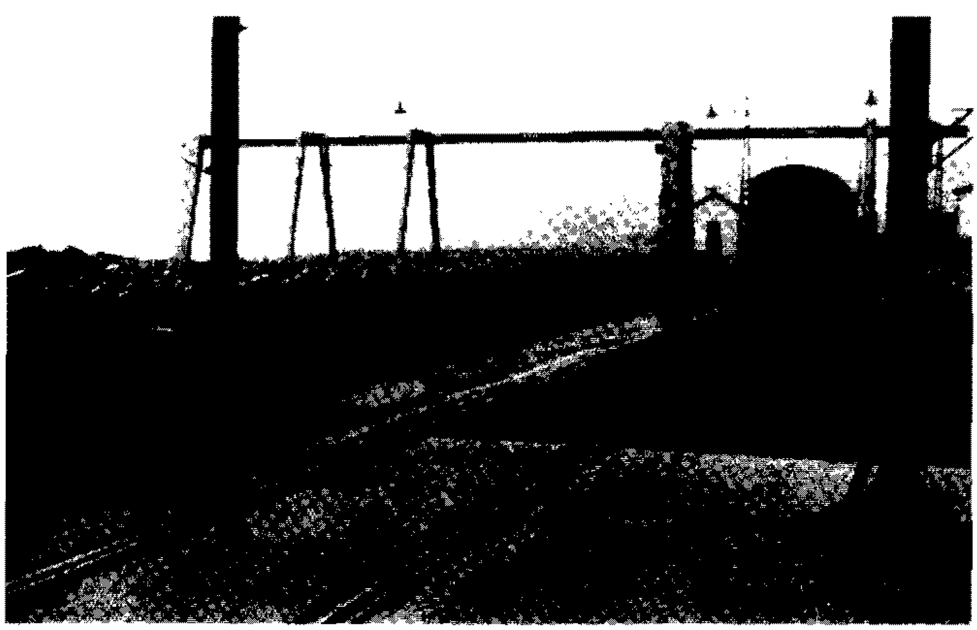


Picture 3

Handling of "Standard-gauge-wheelsets" in Hendaya which must be changed against "broad gauge wheelsets"

Figure 3

Manutention à Hendaye des "essieux à écartement normal" à remplacer par des "essieux à grand écartement"



Picture 4

Hendaya: Stock of wheelsets of same type and same gauge width

Figure 4

Hendaye: Stock d'essieux montés de même type et même écartement

assumed that the efficiency of such a converting shed is approximately 4,300 cars per month, when working in 1 shift (1 shift ≙ 200 working hours/month).

The converting depot in Port Bou changes three cars simultaneously in five minutes. The labourers involved are:

16 workers/3 cars

4 workers for handling the wheelsets out and into the stock.

The efficiency of this shed is similar to that of Hendaya:

approximately 6,000-6,400 cars/month and 1 shift/day or
" 72,000-76,800 cars/year " " " ".

If we assume that:

- 80 per cent of these cars are loaded (57,600 freight cars per year) with a loading factor of 80 per cent and that
- the carrying capacity amounts to maximum 40t/car (payload 32t/car),

the yearly handled tonnages in this one shed over the border in both directions is approximately 1,840,000 net tons/year.

The bogies of passenger cars (sleeping cars) are changed only in Hendaya.

A secondary line next to the station is equipped with 10 electrically-driven jacks and with a dismantling pit (see Picture 5). Five bogie passenger cars are jacked up simultaneously.

The procedures of changing the bogies are as follows:

(a) Different fastenings are opened by 2 labourers per bogie;

(b) Jack up of all 5 bodies of the coaches. In the meantime couplings are adapted into pockets on the bogie frames (see Pictures 6 and 7) in order to move the bogies out later on;

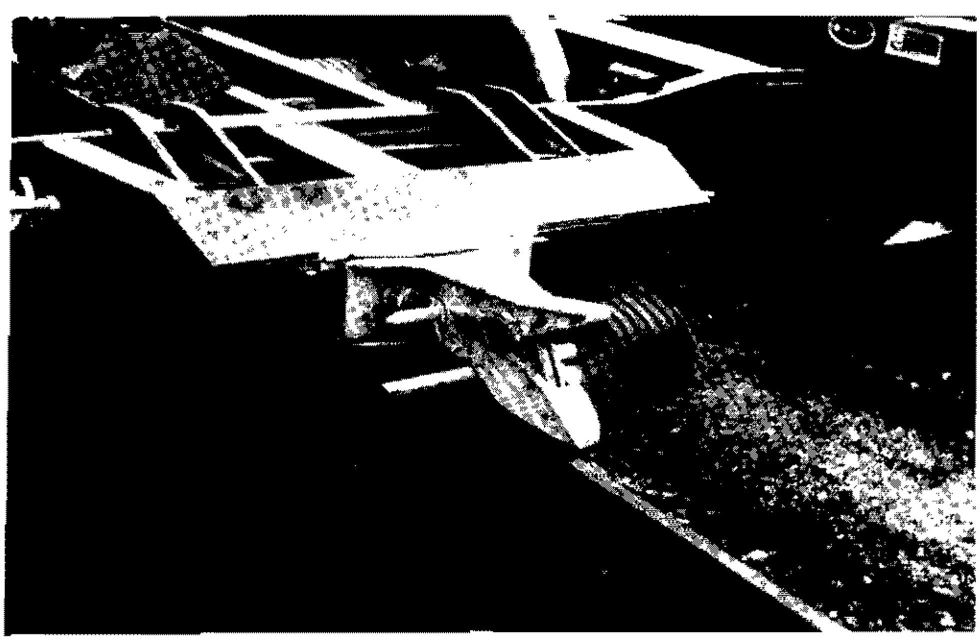
(c) After reaching the jack end-position, an electric driven auxiliary engine (see Picture 8) pulls the required bogies underneath the passenger cars for exchanging and rolls out the changed bogies to the stock line;

Picture 5

Bogie exchange siding
in Hendaya: five bogie
cars same type may be
bogie-changed at same
time

Figure 5

Voie de changement de bogies
à Hendaye: Le changement des
bogies peut être effectué
simultanémént sur cinq voitures
de même type



Picture 6
"Female" adapter coupling attached on bogie frames in order to couple interchangeable bogies for hauling

Figure 6
Partie femelle de l'attelage amovible monté sur les châssis de bogie en vue de l'accouplement des bogies interchangeables pour le halage

(d) The bodies of the coaches are lowered on the bogies and fastened again.

The time used for changing the bogies of five coaches varies between 16 to 25 minutes.

If it is assumed that the last-described technique would be used for the frontier crossing traffic between African railways with 1067 mm and 1000 mm gauge width, because these are mainly bogie freight cars, the following practice should apply:

Assumption

(a) All freight cars crossing the border are equipped with standard bogies or with interchangeable bogies;

(b) Carrying capacity of a bogie freight car, minimum 36 tons;

(c) Loading factor 80 per cent, payload minimum 29 tons;

(d) 80 per cent of all cars crossing the border in both directions are loaded; 20 per cent are empty;

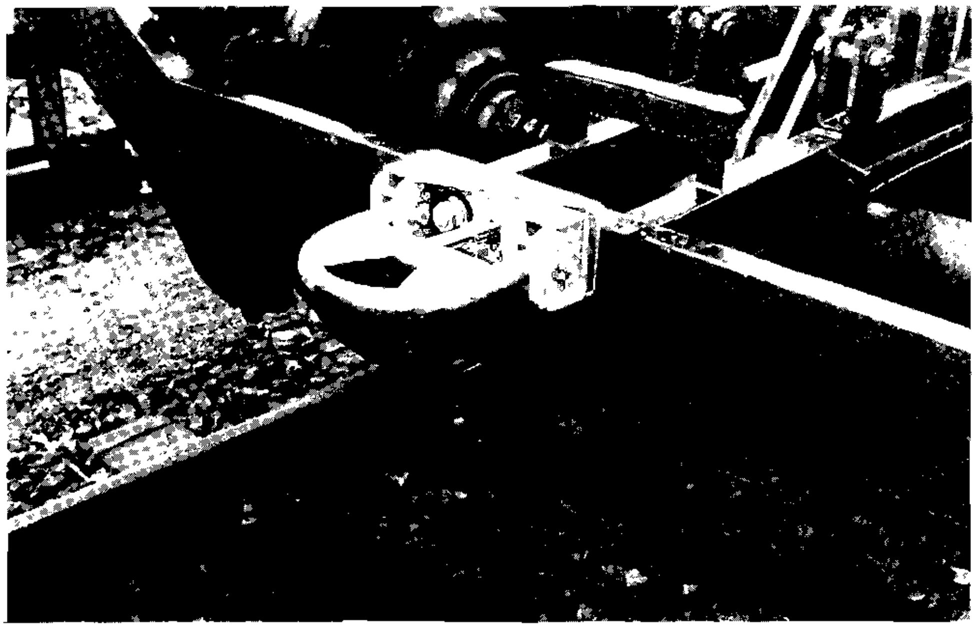
(e) Actual working hours of 1 shift = 6.5 hours, 22 shifts/month;

(f) Number of freight cars which are handled at any one time = 3 pcs.

Time required to change bogies = 25 min/3 cars.

Under these assumptions the following calculations are made to show the number of cars that can be handled every year:

	1 shift/day	2 shifts/day
1. Maximum number of bogie freight cars able to cross the border per year	13,200	26,400
2. Maximum border-crossing traffic-flow in net tons/year		
36 x 0.8 x 0.8 x 13,200 or 26,400 . .	304,128	608,256
say:	300,000	600,000

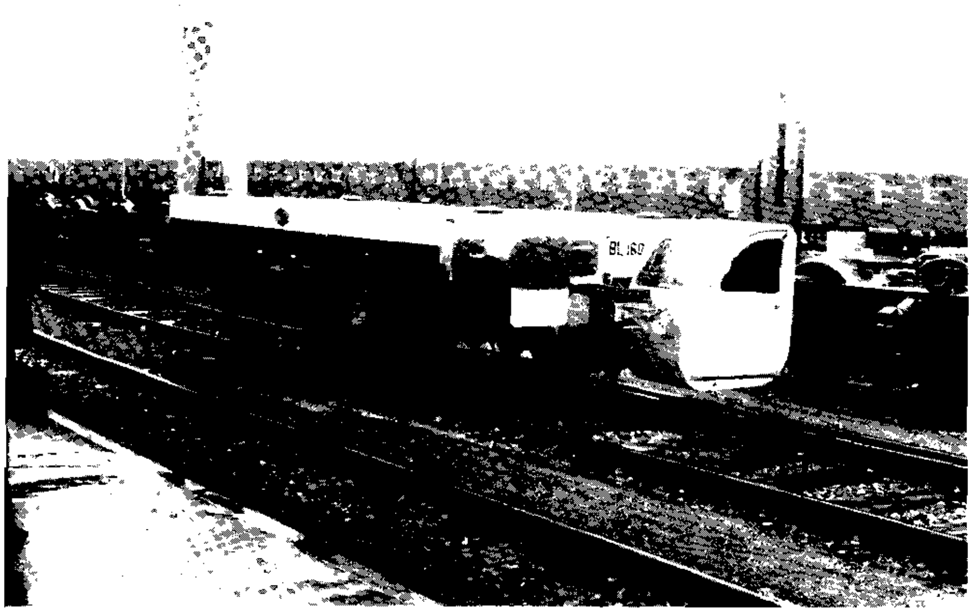


Picture 7

"Male" adapter coupling attached on bogie frames in order to couple interchangeable bogies for hauling

Figure 7

Partie mâle de l'attelage amovible monté sur les châssis de bogie en vue de l'accouplement des bogies interchangeables pour le halage



Picture 8

Electric driven auxiliary unit for hauling bogies underneath the jacked up coach bodies (Hendaya)

Figure 8

Machine auxiliaire à moteur électrique pour le halage des bogies en position sous les voitures levées par vérin (Hendaye)

If it is assumed that the necessary time for customs formalities and the technical check-in and check-out of trains at the border is in the range of 2 hours per train, and that these formalities can be done whilst the bogies are being changed, and the total travelling time of a freight train between the destination points is 24 hours, including the time for the border formalities, but without the time for changing the bogies, the following hours should be added to the time-tables:

No. of freight cars per train	Time for changing bogies in 1 shed 2/ in hours	Hours added to travelling time 3/ if bogies are changed (hours)	Prolongations of travelling time 3/ in %
10	1.39	0	0
15	2.08	0.08	0
20	2.78	0.78	3.25
25	3.47	1.47	6.13
30	4.17	2.17	9.05
35	4.86	2.86	11.90
40	5.56	3.56	14.80

It can be seen that this method will increase the travel time by approximately 6 per cent for a train of 25 cars (train load: approximately 900 to 1000 Brt. payload 576 net t). With more than 25 vehicles per train, the increase of the travelling time appears somewhat high.

Because of the necessity for the fast changing of bogies at the border and for the maintaining of the vehicles and especially the running gears on the lines of other railway systems in case of extraordinary wear (skidded wheels, hot boxes) or accidents, the standardization of the rolling stock becomes necessary, particularly on the following:

(a) Interchangeable bogies;

(b) Uniform underframes of freight cars to avoid the shifting of the jacks in the converting depots to meet the lift-up markings at the cars always on the same point;

(c) Interchangeable wheelsets with bearings.

2/ 3 cars in 25 minutes.

3/ Travelling time between the destination points without changing bogies = 24 hours including 2 hours for formalities at the border.

Further on it is recommended to increase the axle-loads, which are at present between 14 and 16 tons, in order to increase payloads without enlarging the number of cars per train and thereforè to avoid excessive conversion-times in the depots at the border.

D The use of gauge adjustable wheelsets

The Spanish Railways (RENFE) opened a competition to obtain solutions for gauge adjustable wheelsets for coaches to avoid changing of bogies at the border. These wheelsets must be able to run on the Spanish gauge 1668 mm and the standard gauge 1435 mm (gap = 233 mm). The technical conditions for this competition are mentioned in Appendix 1.

The winners according to this competition are:

(i) Ateliers de constructions mécaniques de Vevey, Villeneuve (Vaud), Switzerland, who are designing a type of wheelset called "Vevey-wheelset";

(ii) Oficina General de Ingenieria (O.G.I.), Sevilla, Spain, who are designing a type of wheelset called "OGI-wheelset".

Besides this competition, the Company Talgo S.A., Madrid, offered a special gauge adjustable wheelset 4/ for the "Talgo-trains" which are indivisible train-units equipped with special running gears.

Whilst the Vevey - and OGI-wheelsets have not been produced up to now, the Talgo wheelset is already being built, and the Talgo trains running between Barcelona and Geneva are equipped with these adjustable wheelsets.

All these solutions, either Vevey, or OGI or Talgo, are aimed to fit into coaches running with a maximum speed of 160 km/h (see Appendix 1). But this does not mean that these solutions are not applicable to African-bogie freight cars.

Another type of a gauge adjustable wheelset for bogie freight cars was developed by Deutsche Reichsbahn, Berlin, German Democratic Republic. This type was designed to avoid bogie changes at the Polish-Russian border.

The gap between these two gauges is 89 mm (USSR-gauge = 1524 mm, Poland = 1435 mm). The first train equipped with these gauge adjustable wheelsets crossed the border on 20 May 1961. Since that time, Deutsche Reichsbahn gained extensive experience, and today approximately 300 bogie freight cars are equipped with the so-called DR-IV - gauge adjustable wheelsets. The technical conditions for the development of this DR-IV wheelset (see Picture 9) may be seen in Appendix 2.

4/ In the following, called "Talgo wheelset".

The DR-IV wheelsets are the most proved ones and their advantage is that they were developed for a gauge-gap of 89 mm (Spain-France = 233 mm) which is nearly equal to the African gauge-gap 1067 - 1000 = 67 mm.

All solutions will be described in the following sub-chapters.

D 1. Gauge adjustable wheelset type DR-IV

The drawing of the DR-IV wheelset can be seen in Appendix 3 (see also Picture 9).

The DR-IV wheelset, including the brake elements, can be automatically adjusted to the requested gauge width in a 15 m long transition-rail.

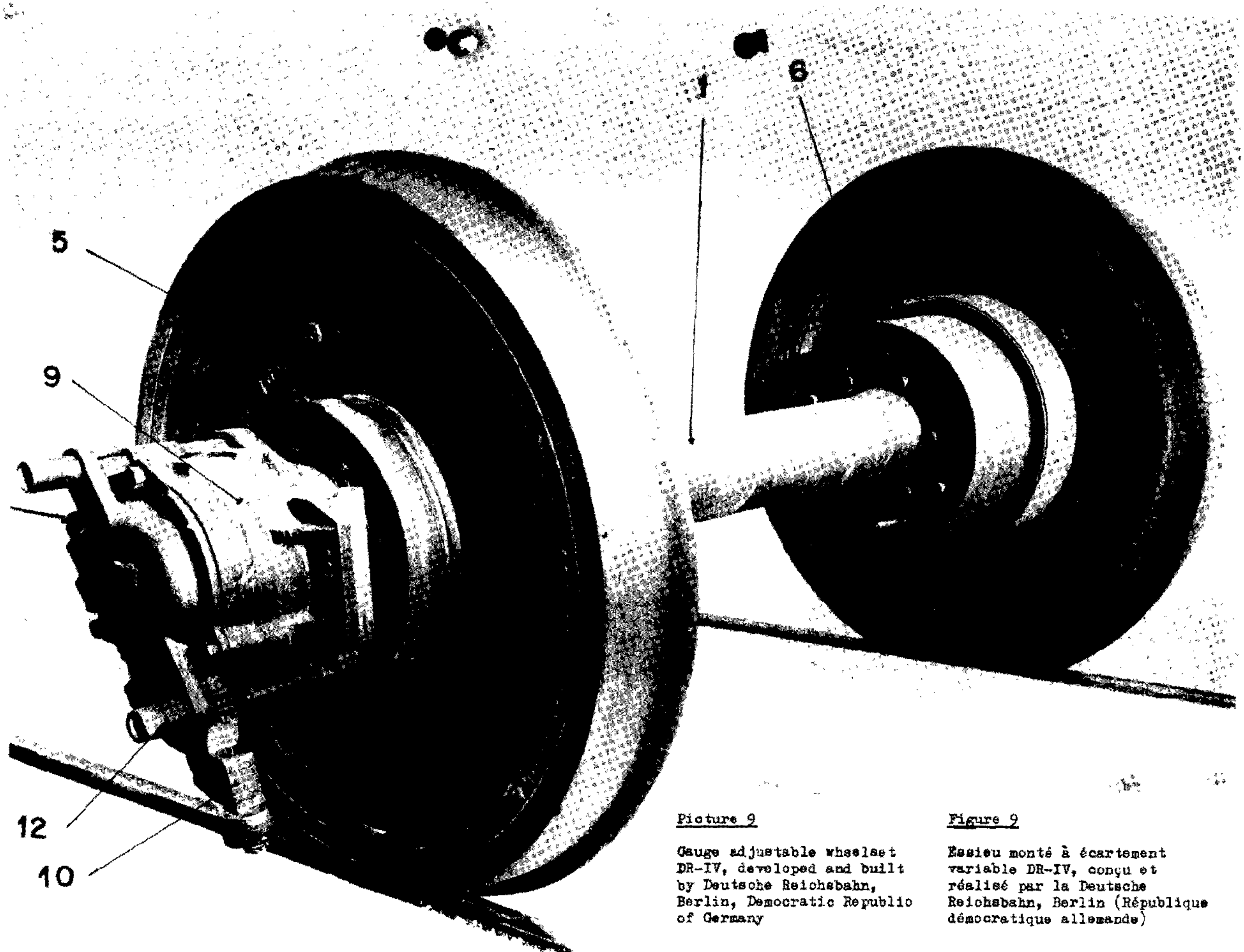
Description of the function (see drawing, Appendix 3)

1. Construction

A clutch-star (2) is press-fitted on the axle (1). Three rocker arms (3) are pivoted on the clutch-star (2). Trapezoidal grooves are machined into the wheel hub (4) of the wheel disc (5) into which the rocker arms (3) snap. By this, a rigid axial connexion is produced between the axle (1) and the axial shifting wheel disc (5). The sleeve (6) is put under stress by compression springs (7) and therefore is shifted over the rocker arms (3). A slope (8) is to be found on the top of the rocker arm (3). The inner surfaces of the sleeve (6) are conically tapped in the same slope like the slope (8). Therefore the rocker arms (3) are pressed into the locking position by the sleeve (6). The horizontally-acting forces on the flange of the wheel are trying to shift the wheel disc (5) in axial direction and to force through the groove slope to unlock rocker arm (3) and sleeve (6). A plane surface is worked out behind the slope (8) to prevent unlocking. The sleeve (6) can only be axially shifted within a small tolerance, because afterwards the plane surfaces of the sleeve and the rocker arms are clashed. Unlocking is impossible. The horizontally-acting forces on the flange of the wheel are transformed by the slopes (8) on the rocker arms (3) into radial acting forces. These radial acting forces effect an expansion of the sleeve. Therefore the sleeve is reinforced with two bracing rings (19) connected by a circular flange (20) to avoid this expansion. A second sleeve (21) seals the whole locking device against dirt in connexion with the reinforcement (19 and 20) of the sleeve (6).

2. Unlocking device

A crank (10), pivoted in collars (18), is fitted on the axle-box case (9). The crank (10) is connected with two levers (11). In the case of unlocking, the crank (10), with the levers (11), are moved axially towards the wheel disc by unlocking rails (not to be seen in the drawing; (see Picture 10). The unlocking rails are fixed on the sleepers. The levers (11)



Picture 9

Gauge adjustable wheelset DR-IV, developed and built by Deutsche Reichsbahn, Berlin, Democratic Republic of Germany

Figure 9

Essieu monté à écartement variable DR-IV, conçu et réalisé par la Deutsche Reichsbahn, Berlin (République démocratique allemande)

are swingable, pivoted into axial-movable push-rods (12), guided in guide holes (17). The levers (11) by means of push-rods (12), trigger the pilot disc (13) which is connected with the sleeve (6) by rods (14). Stop pins (15) on the inner surface of the sleeve (6) are moving on cams (16) of the rocker arms (3), and pivot the rocker arms (3) out of the locking position. The springs (7) will be more-compressed and will shift the sleeve backwards in the locking position after the wheels are adjusted by guiding rails in the required position.

The slide fitting of the wheel on the axle is performed by a hard-chromium-plated steel bushing (23), pressed into the wheel-hub, and a hard-tissue bushing (22) shrunk on the axle. The joint hard-chromium-plating and hard-tissue bushing eliminate fretting corrosion.

3. Shifting of brake blocs

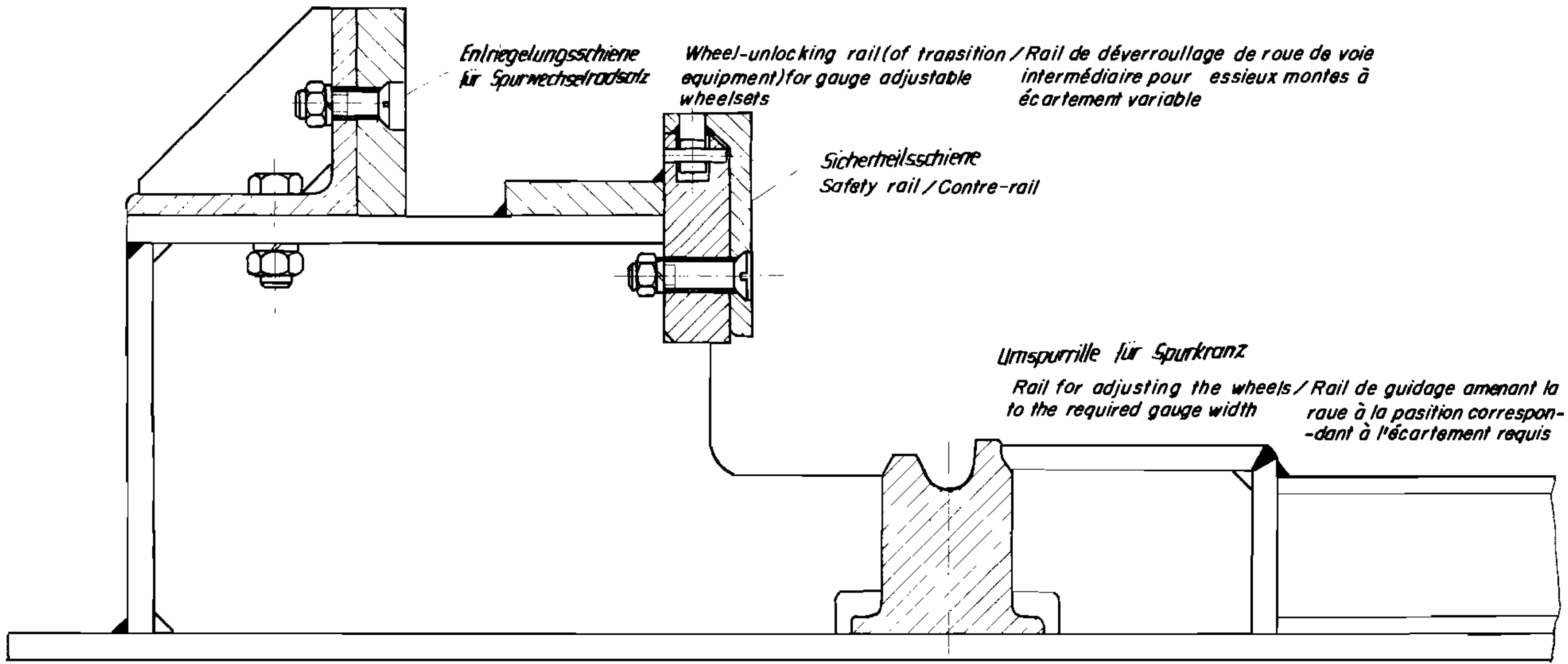
The device of gauge adjustable brake shoes may be seen in Picture 11. The two positions of the brake blocs, according to the gauge width, are locked by a quill-gear (1) which is pivoted on a bushing (2). The bushing (2) is connected to the brake shoe (3). A pin (4) is pressed into a groove on the brake beam (5) and adjusts the brake shoe in the shown position. As soon as the wheel is shifted to a smaller gauge width, lever (6) shifts bushing (2) with brake shoe (3) towards the middle of the axle. Pin (4) remains in the groove, but the quill gear will be pivoted by 90 degrees and will lock the new brake bloc position again.

The maximum permissible axle-load of the DR-IV wheelsets is 21 t. The weight (1,700 kg) of the DR-IV wheelset with bearings and 1000 mm ∅ wheels is 19 per cent higher than a normal UIC wheelset (1,430 kg). It can be said that the weight of the gauge adjustable device of a bogie car is therefore in the range of 1,080 kg. If we assume that the future maximum speed in Africa is less than 160 km/h, it might be possible to reduce the weight of the gauge adjustable device to about 1000 kg per bogie car. If these DR-IV wheelsets could be assembled into normal bogie freight cars with a maximum payload of 40 t, only 2.5 per cent of the payload are lost in favour of the gauge adjustable wheelsets.

It was learned that the costs of bogie freight cars with gauge adjustable wheelsets are 7 per cent higher than normal ones.

Trains equipped with gauge adjustable wheelsets type DR-IV accomplish the passage to a different-gauge track in 3 minutes (passenger train of up to 250 m length) and 9 minutes (goods-train of up to 600 m length) only under supervision of the shunting personnel, excluding any shunt work.

During strictly controlled runs between Poland and USSR (with numerous gauge width changing operations) a reduction in operating costs was observed, - apart from the remarkably lower investment cost (in comparison with the reloading and running-gear interchanging systems).



Länge der Umspuranlage ~ 15 m
Length of the transition equipment
Longueur de la voie intermediare

Picture 10

Diagrammatic drawing of the transition equipment for gauge adjustable wheelsets type Deutsche Reichsbahn DR-IV

Figure 10

Schéma de voie intermédiaire pour changement d'écartement d'essieux montés Deutsche Reichsbahn type DR-IV à écartement variable

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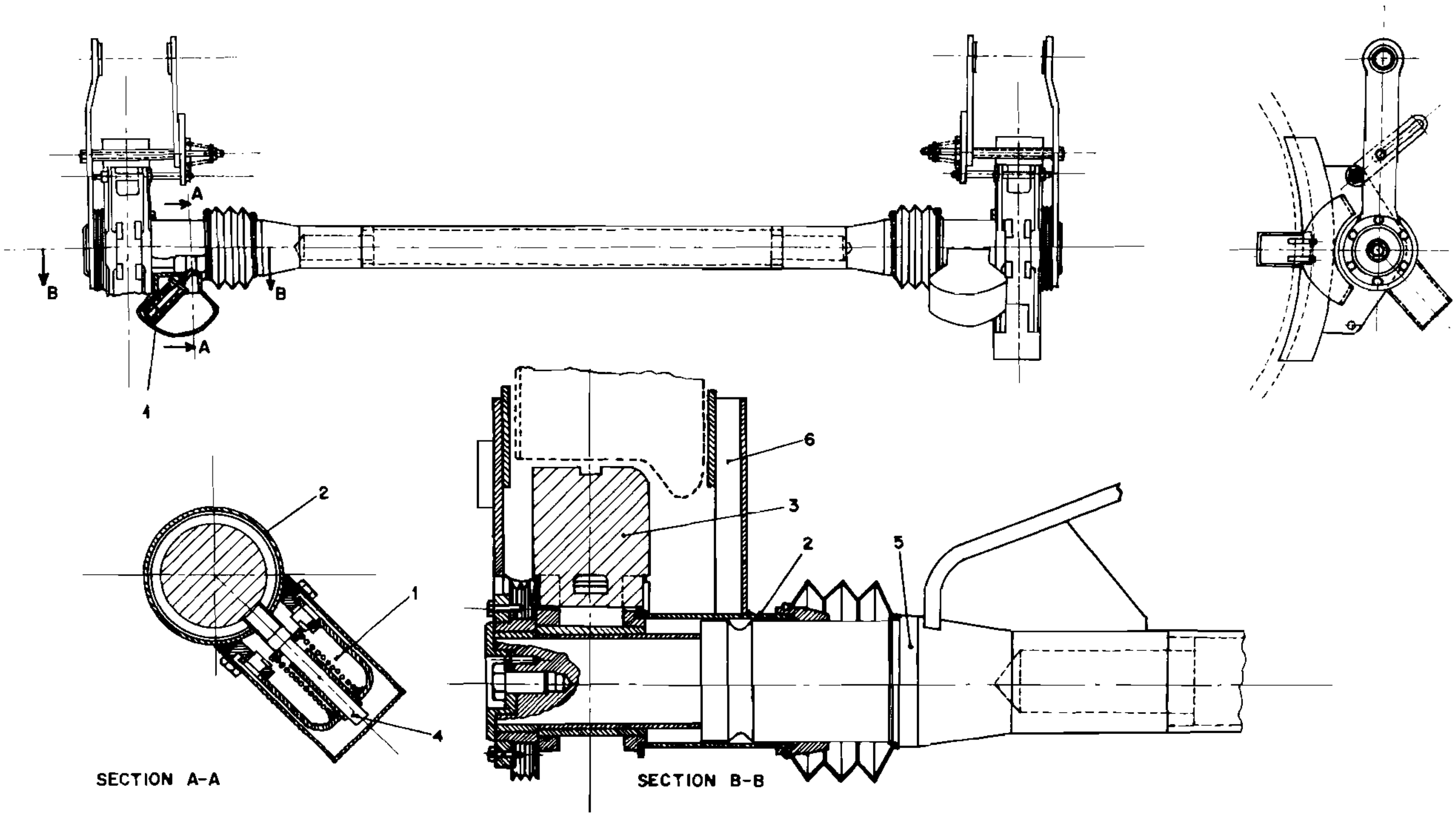
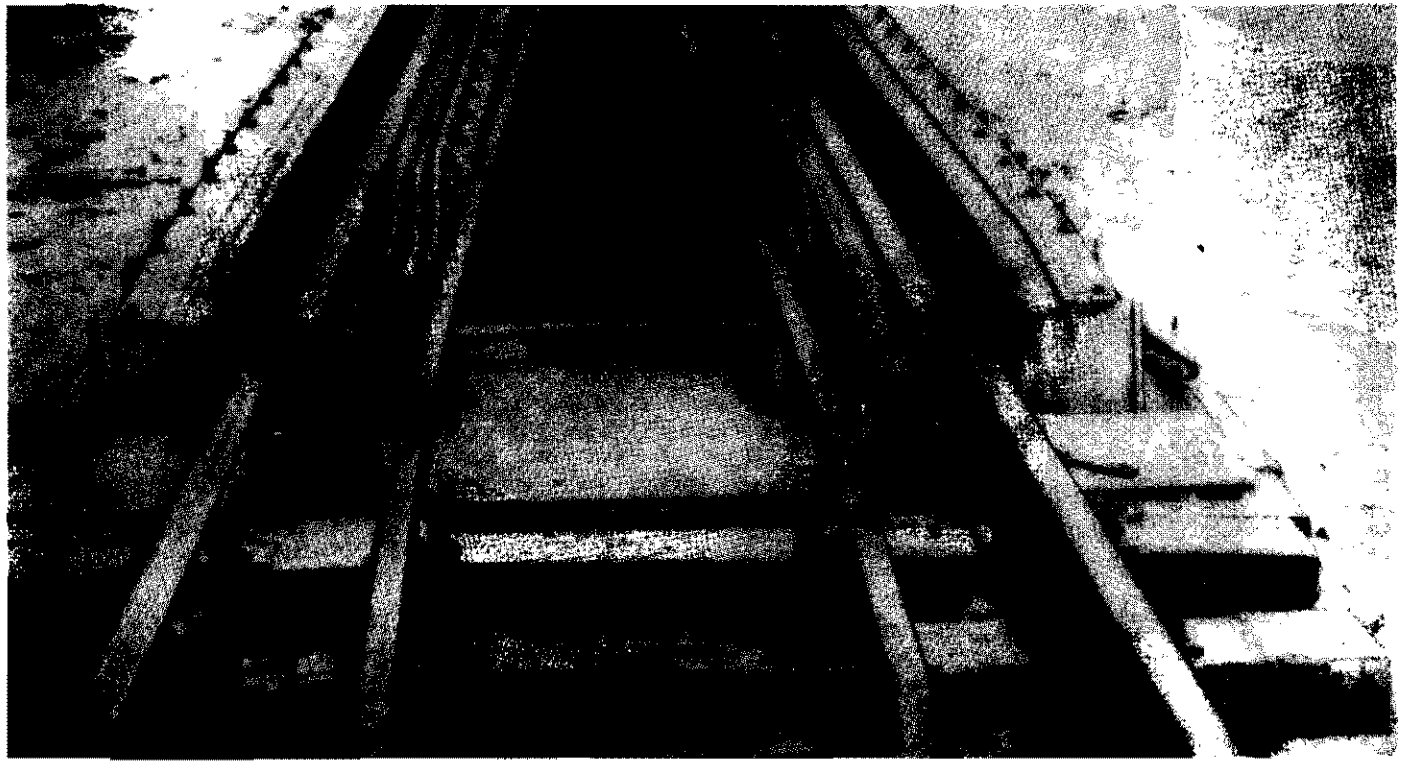


Picture 11

Gauge adjustable brake shoe shifting device used for gauge adjustable wheelsets type Deutsche Reichsbahn DR-IV

Figure 11

Dispositif de changement d'écartement des sabots de frein, accompagnant les essieux montés Deutsche Reichsbahn type DR-IV à écartement variable



Picture 12

Transition equipment
for gauge adjustable
wheelsets type Deutsche
Reichsbahn DR-IV

Figure 12

Voie intermédiaire pour change-
ment d'écartement d'essieux
montés Deutsche Reichsbahn type
DR-IV à écartement variable

The Deutsche Reichsbahn pointed out that the wheel tyre wear is about 30 per cent lower than with usual wheelsets - thanks to the higher elasticity of the DR-IV type. Maintenance work is, besides the routine checks, restricted to semi-annual lubrications of the locking device.

The DR-IV wheelsets were developed in 1956 by Deutsche Reichsbahn, and have been tested over several years in bench tests and practical use (approximately 500,000 km).

The transition equipment (see Picture 12) is of welded construction, mounted on wooden sleepers, and can be fitted on any point of a straight track. Investment costs are negligible.

D 2. Gauge adjustable wheelset type Vevey

Appendix 4 shows the diagrammatic drawing of the Vevey gauge adjustable wheelset. As already mentioned, this type is not yet proved in practical use. But all single parts of the construction are not newly developed, they are examined already in other railway equipments or rolling stock and may be regarded as to be proved. Like the DR-IV wheelset, the Vevey one is designed for locomotive-handled vehicles and not for vehicles with driven axles. It involves the use of a fixed axle (1) and free-turning wheels (2). The complete wheelset can be installed in conventional bogies without excessive modifications.

Description of the function

1. Construction

On the fixed axle (1), the axially-shiftable wheels (2) are pivoted. Each wheel centre contains two cylindrical, axially shiftable roller-bearings (9) - transmitting radial forces - and one ball-bearing (10) - transmitting axial forces. The ball-bearing (10) is acting on a cylinder (4), which forms a hollow half shaft concentric on the fixed axle. The ball-bearing (10) allows the wheel to rotate on the cylinder and avoids lateral movements because the cylinder (4) is connected with a single locking device fixed on the axle (1), and which is able to move vertically only. The connexion between the two cylinders (4) and the locking device - consisting of the helmet (5), roll (11) and a cross (6) of four compressed springs (12) /in the drawing, only one spring is shown/- is done by trapezoidal pins (8) engaged in cut-outs of the helmet (5). Only vertical surfaces on the pins (8) and the cut-outs are transmitting axially acting forces. The compressed springs (12) keep the helmet (5) in the locking position.

2. Unlocking device

A conductor rail ramp (7) is fixed between the transition rails on which the roll (11) runs as soon as the wheelset is entering the transition rails. The helmet (5) is moved upwards and the fixed connexion is interrupted between the two cylinders (4) as soon as the pins (8) leave the

cut-outs of the helmet. The four springs (12) are more compressed. Rail guides (not shown in the drawing) are shifting the wheels - under load - into the required gauge. After the shifting of the wheels, the roll (11) runs down the conductor rail ramp (7) and the springs (12) are pressing the cut-outs of the helmet (5) on the trapezoidal pins (8) and are locking the connexion between the cylinders (4) again. Contrary to the technical conditions for gauge adjustable wheelsets of the Deutsche Reichsbahn (see Appendices 2 and 3), which requires torsional-strengthened connexions between the two wheels, the Vevey solution is characterised by free-turning wheels. Wheelsets with free-turning wheels of another layout are already assembled into the Spanish Talgo trains with special running gear equipment. It is, however, not known in which manner these Vevey wheelsets, assembled into a conventional bogie, should manage the auto-centering effect which is the base for good running qualities and low wear on the flanges of the wheels.

The Vevey wheelset may be braked either with normal brake-shoes or with disc-brakes. Space for both possibilities is available. A special gauge adjustable brake shoe device was not designed by Vevey because Vevey and RENFE also did not see any problems in the construction of these devices. As far as brakes with brake shoes are concerned, it may be suggested that the Vevey gauge adjustable brake-shoe device might be similar to the one used on the DR-IV. As far as disc-brakes are concerned a similar construction may be choosen like the Talgo gauge adjustable disc-brake device (see Appendix 6).

The advantage of the Vevey wheelset is doubtlessly the low weight in comparison with other solutions and the very rigid and simple locking device which does not need nearly so much maintenance and lubrication of e.g., the DR-IV locking device. A certain disadvantage might be seen in the fact that the locking device is not mechanical double locked like e.g., the DR-IV or the OGI wheelset. At present, RENFE, in connexion with Vevey, is working out a mechanical double locking device to eliminate this "disadvantage".

It was learned that no price has been calculated up to now the time of this study.

D 3. Gauge adjustable wheelset type OGI

Appendix 5 shows the diagramatic drawing of the "OGI" gauge adjustable wheelset. This wheelset has not been built at the time of the preparation of this study either. The locking device is similar to the one used on the DR-IV.

Description of the function

1. Construction

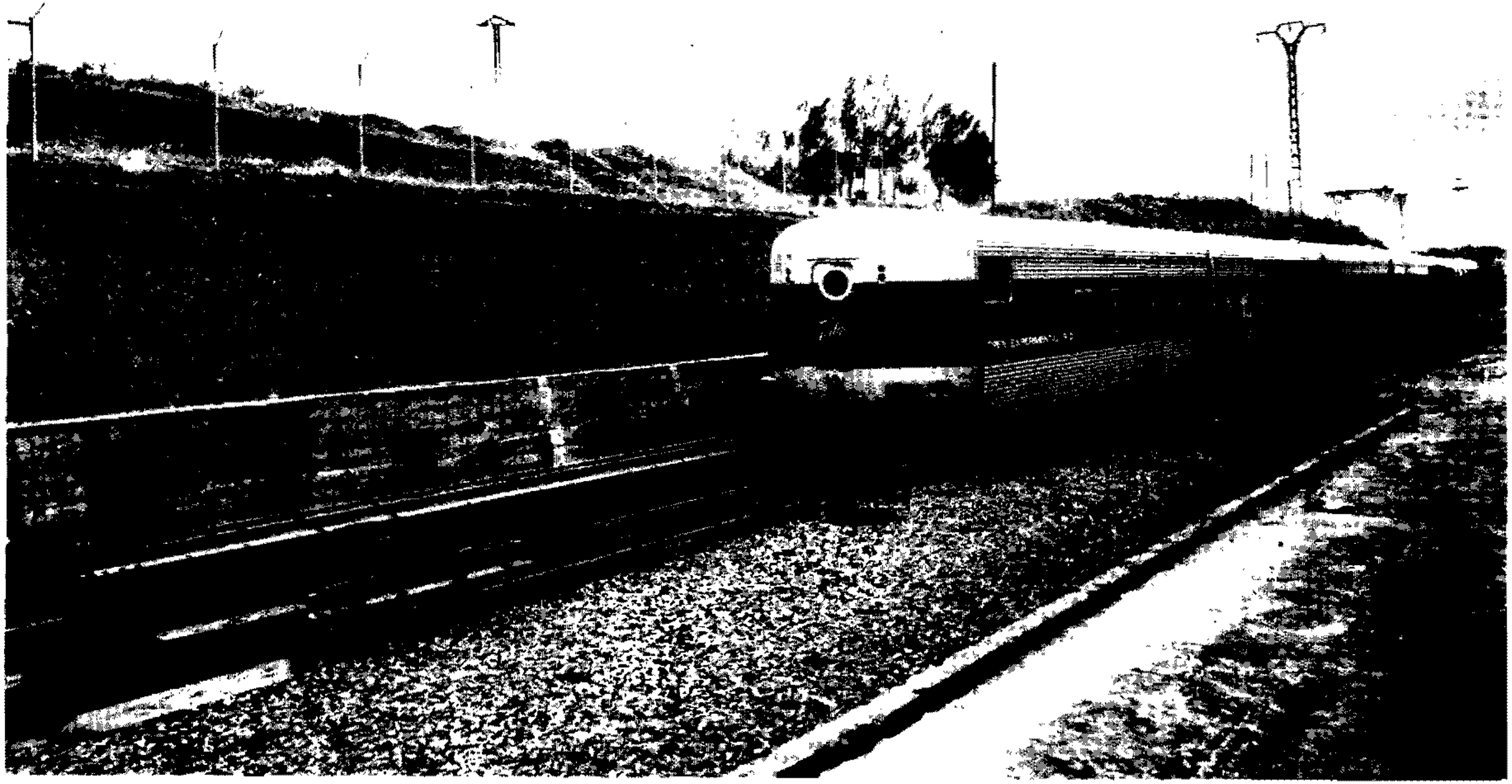
On the axle (1) the wheels are axially-shiftable. Three pairs of levers (3) are transmitting all torsion momenti to each of the two wheels (2). The levers (3) are pivoted on a splined bushing (4), which is fixed on the axle stub. Two sockets (10) are shrunk on the axle (1). Split bushings (11) are fixed on the sockets (10). The split bushing (11) consists of elastic fingers (8) which have trapezoidal forms on the ends. The fingers (8) are snapping into trapezoidal grooves tapped into the hubs of the wheels (2). An axially shifting and rotating sleeve (6) is pressed on top of the fingers (8) of the split bushing (11) by compressed springs (7). Therefore a mechanical double-lock is obtained, like that of the DR-IV model.

2. Unlocking device

An unlocking rail of the transition equipment - fitted between the running rails (not to be seen in the drawing) - moves the two levers (5) towards the wheels (2), whereby the sleeves (6) are axially shifted. As soon as the sleeves (6) unlock the split bushings (11), guidance rails of the transition equipment (not to be seen in the drawing) are shifting the wheels (2) under load into the required gauge width. The fingers (8) are spread and are sliding on the hubs of the wheels (2) and snap in the second trapezoidal grooves. As soon as the wheelset leaves the zone of contact of the unlocking rail of the transition equipment, the springs (7) are pressing the sleeves (6) on the fingers (8) and double-lock the device.

As far as the device of gauge adjustable brake-shoes is concerned, the same can be used like the DR-IV one. Disc-brakes cannot be fitted on the wheels. The only possibility to assemble brake discs on the OGI-wheelset is in the middle of the axle. But it is doubtful whether sufficient space between the two levers (5) is available. It seems that there is only 260 mm space between the two levers (5), which is not sufficient for mounting even one brake-disc. The same or probably worse conditions will be found for 1067 mm and 1000 mm gauge adjustable wheelsets if the levers (5) remain in the shown positions.

The most remarkable construction part of this wheelset seems to be the split bushing (11). It was learned that split bushings are mainly used in aircrafts for similar purposes, e.g., in the main landing-gear actuators of Boeing jets. The advantage of the split bushing against the three rocker-arms (locking device of the DR-IV wheelset) is that the axial forces which are transmitted into radial ones by the trapezoidal flanks of the three rocker-arms must not be absorbed at only three points on the periphery of the sleeve (6) (see Appendix 3), but are distributed symmetrically over the whole periphery and minimize expansions of the sleeve (6).



<u>Picture 13</u>
Talgo train (Research train) enters transition equipment

<u>Figure 13</u>
Train Talgo (train expérimental) s'engageant sur la voie intermédiaire

A further advantage of the whole locking device of the OGI wheelset over the DR-IV one seems to be that the construction volume is smaller. However, the visual examination of the actual locking after changing the gauge-width from outside the transition equipment is more difficult.

It was learned that prices of the OGI wheelset have not been calculated up to the time of this study. The weight of this wheelset seems to be greater than that of the Vevey-wheelset.

D 4. Gauge adjustable wheelset type Talgo

As already mentioned in Chapter D, Talgo, Madrid, has developed gauge adjustable wheelsets, and equipped them into their indivisible train units.

The Talgo trains normally consist of 13 short bodies, articulated to one another. An example of these units may be seen in Picture 13 (actually this is a research unit).

The drawing and the picture of the Talgo gauge adjustable wheelset can be seen in Appendix 6, and in Picture 14. The two wheels are not connected by one axle. Each wheel is pivoted in a cast steel frame. The wheels are turning freely. The advantage of this running gear is that the height of the passenger floor above rail level was reduced to 625 mm. The diameter of the wheels is 862 mm, and is 58 mm smaller than normal UIC 5/wheel-diameters (920 mm ∅).

Description of the function

1. Construction (see Appendix 6)

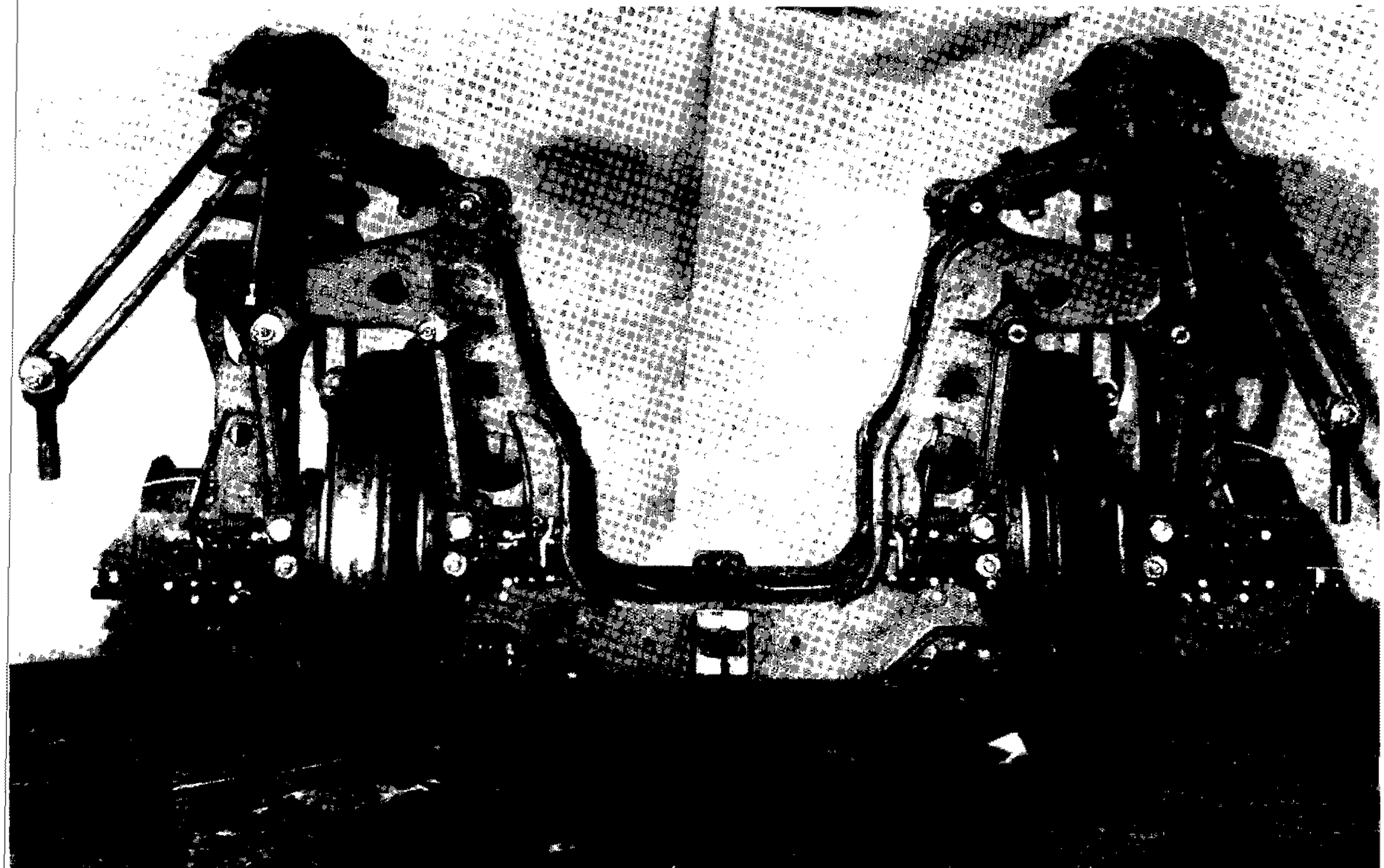
The free-turning wheels (1), shrunk on small axles, are pivoted into pairs of bearings (2).

The four bearnings (2) per running gear are not axially shiftable on the axles. The axle box case of the bearing has two rectangular opposed blocs (3). The exact distance between the wheels is secured by two pins (4) per each bearing, connected by a yoke (5), which are vertically guided in guide holes of the cast steel frame (10). Therefore, an axial shifting of the wheels (1) is not possible. Yoke (5) with pins (4) are kept in the shown position by four coil springs (9) (see also Picture 15).

2. Unlocking device

Contrary to the other systems of gauge adjustable wheelsets, the horizontal shifting of the wheels is not done under load.

5/ UIC : Union internationale des chemins de fer.

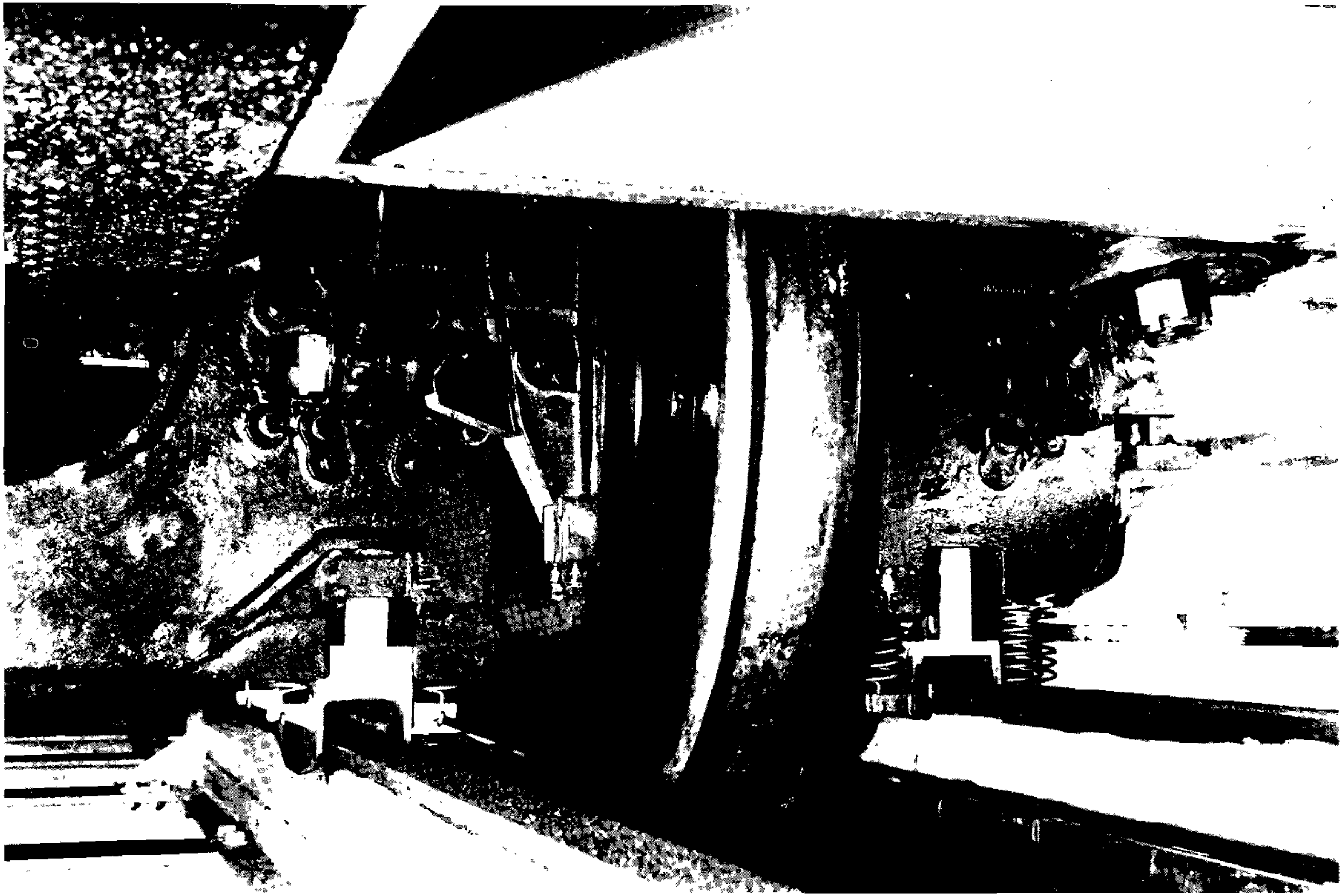


Picture 14

Gauge adjustable wheelset type Talgo with free running wheels and disc-brakes fitted in Talgo TRANS-EUROPE-EXPRESS-trains

Figure 14

Essieu monté à écartement variable type Talgo, à rouses libres et freins à disques, équipant les trains Talgo TRANS-EUROPE-EXPRESS



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<u>Picture 15</u>
Gauge adjustable wheelset type Talgo moving through the transition equipment. The wheel is unlocked at this moment

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<u>Figure 15</u>
Essieu monté à écartement variable type Talgo passant sur la voie intermédiaire. La roue est déverrouillée à l'instant représents par la cliché

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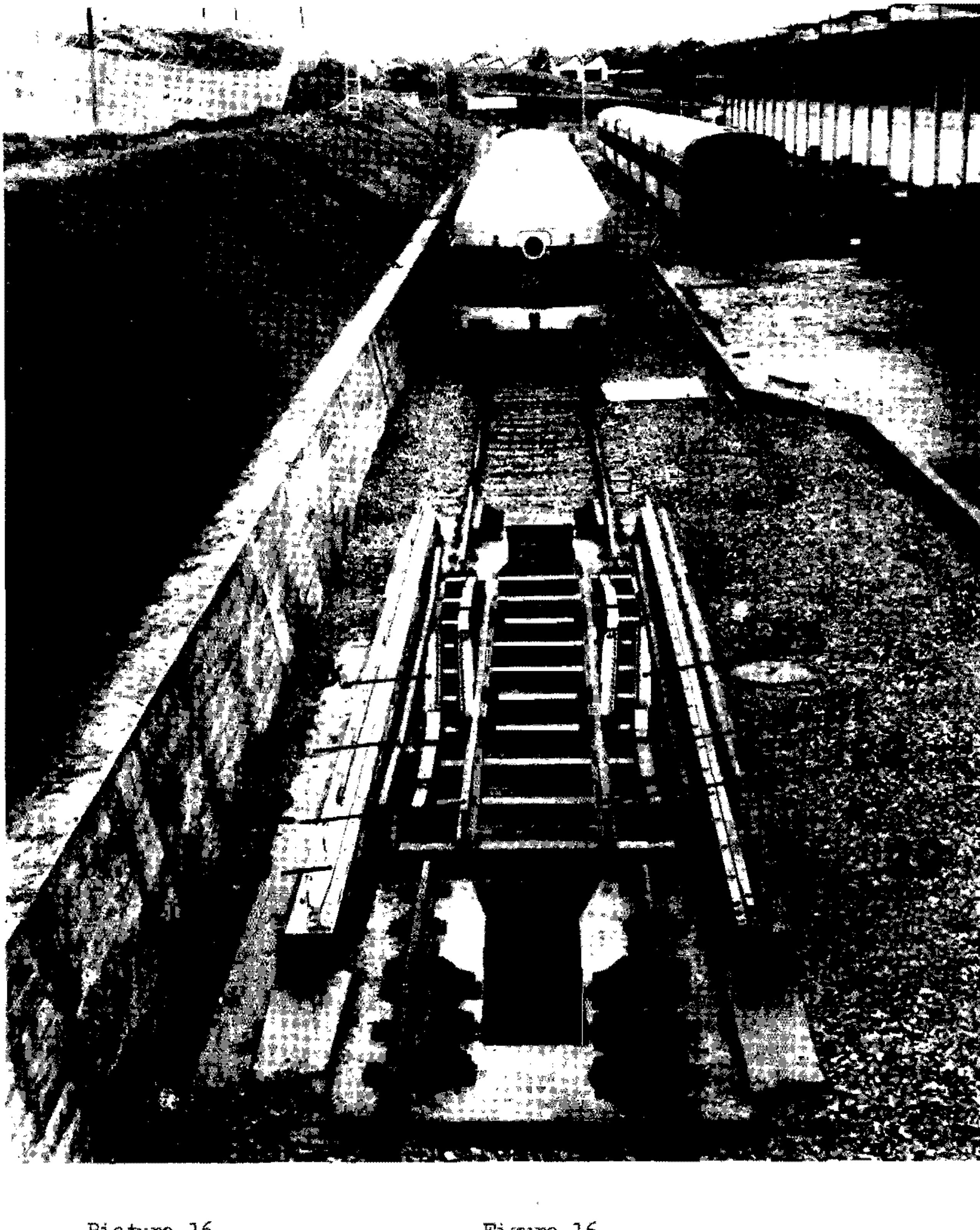


Picture 16

Transition equipment for gauge adjustable wheelsets type Talgo

Figure 16

Voie intermédiaire pour changement d'écartement d'essieux montés type Talgo à écartement variable

The transition equipment consists of 3 pairs of straight rails and 2 pairs of guidance rails (see Pictures 13 and 16). As soon as the train reaches the transition equipment and the wheels are leaving the running rails, the cast steel frame (10) (see Appendix 6), with support blocs (7), are supported by the rails (20). Nylon plates on the support blocs (7) facilitate a smooth sliding on the water-lubricated rails. After supporting the cast steel frame (10), two pairs of rails,(21 and 22), are inserted into cut-out of the yokes (5). The slopes of the rails (21 and 22) (see Picture 13) cause the pins (4) connected with the yoke (5) to be pulled down vertically (see also Picture 15) until the rectangular opposed blocs (3) on the axle box case of the bearing (2) are not blocked up any more. All parts of the cut-outs of the yoke (5), which slip on rails, are fitted with nylon plates (6) to enable also a smooth sliding on the water-lubricated rails.

Then guidance rails (23) (see Picture 16) shift the wheel (1) into the required position. The slope of the rail (21 and 22) presses each yoke (5) with its two pins (4) upwards and locks the axle box cases in the new position. After reaching the running rails again, the wheels lift up the cast steel frame (10) and unload the support rails (20).

An adjustment of the brakes (18) to the required gauge is not necessary because the wheels are equipped with disc-brakes which are fixed on the axle box case. Axle box cases, axle and wheel are one unit.

The total conversion time for a whole train, consisting of 13 coaches, including time for changing locomotives; which are not adjusted to the new gauge, does not exceed 5 minutes.

The Talgo wheelset is constructed for a speed of 160 km/h. Running tests of up to 170 km/h were fully satisfactory.

Two pairs of passenger trains, equipped with these gauge adjustable wheelsets, are running daily between Barcelona and Geneva since 1 June 1968. The time-saving accounts to approximately 10-15 per cent.

The additional weight of the gauge adjustable device and the additional costs are insignificant.

D 5. Applicability of gauge adjustable wheelsets to African railways

The gaps of the mainly used gauge widths in Africa are:

mm	mm	mm	mm
1067 - 1000 =	67	1435 - 1067 =	368
1067 - 950 =	117	1435 - 1000 =	435
1000 - 950 =	50		

The gauge adjustable wheelsets described were designed to overcome the following gaps:

Wheelset type

Vevey) OGI)- Talgo)	1668 mm 233 mm	- 1435 mm = (Spain - France)	
DR-IV - -	1524 mm 89 mm	- 1435 mm = (Poland - USSR)	

An examination of whether these gauge adjustable wheelsets are applicable to African railways, considering their present layout, shows the following result:

Gap = 67 mm

(a) Vevey wheelset

It appears that the Vevey wheelset is not applicable because the design of the helmet (5), with the cut-outs and the tapezoidal pins (8) (see Appendix 4), do not permit a further attenuation of the material, due to the resistance against axial forces;

(b) OGI wheelset

It appears that the OGI wheelset is only just applicable if the gradient of the trapezoidal fingers (8), which snap into the tapped groove, would be steeped up (see Appendix 5). But there is a certain limitation in doing so, because in case of a very steep gradient the fingers (8) could block the shifting of the wheels;

(c) DR-IV wheelset

This wheelset appears to be the most suitable one of those described. However, the two tapped grooves in the wheel hub (4) (see Appendix 3) are located extremely close to each other, which demands careful recalculations of the maximum tensions in the material between the grooves.

Gap = 117 mm

(a) Vevey wheelset

The same comments regarding "Gap = 67 mm" apply for this gap of 117 mm;

(b) OGI and DR-IV wheelsets

No difficulties are to be expected.

Gap = 50 mm

None of the described gauge adjustable wheelsets are applicable for overcoming this gap.

Gap = 368 mm and 435 mm

Modifications on the OGI and the DR-IV gauge adjustable wheelsets to overcome these gaps are theoretically possible. However difficulties are to be expected concerning the loading gauges of railways with gauge widths to 1067 mm and 1000 mm, which shall probably be exceeded by these wheelsets. It appears that the Vevey gauge adjustable wheelset is not applicable to these gauge gaps, due to the limited space between the wheels.

The construction of the Talgo gauge adjustable wheelset appears to be only applicable for gauge gaps wider than 117 mm up to a certain limit.

E. Economic comparison between gauge adjustable wheelsets and bogie exchanges

In this chapter we are going to calculate - under certain assumptions - the increase of operation costs due to the higher investments necessary for gauge adjustable wheelsets and for facilities of changing bogies.

Gauge adjustable wheelsets

It was pointed out in chapter D 1 that the investments for high-sided bogie cars with gauge adjustable wheelsets type DR-IV are approximately 7 per cent higher than for normal ones. That means that one gauge adjustable wheelset costs approximately 160-175 US$ more than a normal one.

Further on, it was stated that the wear of the wheel tyre is approximately 30 per cent less than normal.

Assumed basis for the cost calculation:

(a) Average length of haul per ton . . . 600 km

(b) Trips per car and year . . . 40 trips/year and car

(c) Maximum load . . . . . 40 t/car

(d) Load factor . . . . . 80 per cent

(e) Empty run of a car . . . 300 km

(f) Additional investments for gauge adjustable wheelsets (160 ÷ 700) x 4 = 640 ÷ 700 say 700 US$/car

(g) The maintenance cost - savings out of reduced tyre-wear of gauge-adjustable wheelsets are balancing the arising costs necessary for the lubrication of the locking device - semi-annually - and the few additional maintenance costs for the locking device only.

(h) Lifetime of a gauge adjustable locking device: 10 years

(i) Interest: 6.5 per cent/year

Under these assumptions, only capital costs have to be considered and calculated. Additional capital costs:

$$\frac{700}{10} + \frac{0.065 \times 11 \times 700}{20} = 70 + 25 = 95 \text{ US\$/year and car}$$

Additional cost/trip $= \frac{95}{40} = 2.38$ US$/trip and car

Length of a trip (600 + 300) = 900 km

Additional cost per tkm $= \frac{238}{900} = 0.264$ US ct/km

Total tkm 600 x 0.8 x 40 = 19,200 tkm

Additional cost per tkm - payload: $\frac{238}{19,200} = 0,0124$ US ct/tkm payload

If we assume that the tariff rates for long hauls are in the range of 1.5 - 2.0 US ct/tkm, the additional costs per tkm payload amounts to approximately 1 - 2 per cent of the tariff rates.

Changing of bogies

A cost calculation is made up in Appendix 7. On the basis of 13,200 frontier crossing cars per year of which bogies must be changed the following costs were worked out:

Investments	US$
Buildings	31,600
Track-lines (bogie stock-line), switches	61,500
Mechanical equipment (jacks, lighting, bogies, etc.)	250,050
	343,150
Say:	340,000

Running costs	US$/year
Maintenance	5,400
Capital	26,800
Labor	9,000
Operation (shunting)	8,000
Total:	49,200

The biggest factors in these items are the investments and capital costs for the bogies in stock at the converting depot. It was assumed in Appendix 7 that approximately 44 bogie cars (13,200 cars per year) must be bogie-changed daily. That means 88 bogies of different gauges must be kept in stock in order to avoid train delays. The cost for changing bogies therefore is very high, i.e.:

3.73 US$/bogie changed car (assumption: 13,200 cars per year)

If, however, the number of border crossing cars increases, for example, up to 26,400 cars per year, no further investments are necessary either on the construction or on the mechanical equipment part. Considering only higher maintenance, labour and operating costs, the cost per bogie changed car can be expected to be:

2.51 US$/bogie changed car (assumption: 26,400 cars per year)

The additional cost per tkm payload (600 km average haul per ton, 40 t maximum capacity, load factor 80 per cent) is:

0.0194 US ct/tkm (13,200 bogie changed cars per year)
0.0131 US ct/tkm (26,400 " " " " ")

Both calculations, either for gauge adjustable wheelsets or bogie-changed cars, have been worked out under the estimation that the number of changed loaded cars between railways with different gauges is balanced and that no empty runs of cars over the border must be handled. As soon as this balance is disturbed, and empty runs of cars over the border have to be considered - especially when bogies must be changed - the cost calculation is to be revised.

Of course, the comparison of costs may change whenever other conditions occur. But it seems that the dimension of the costs is fairly good. It is, however, very delicate to recommend the one or the other solution because the decision depends highly on the various operation conditions.

The changing of bogies of standardized cars has the advantage in that these cars can still run in free movements on different railways systems and in the most economic manner; they can be sent, after being unloaded, to the next nearest loading-point, while cars with gauge adjustable wheelsets have to be sent back loaded or empty to the originating railway company because the pool of these cars is limited. There is no doubt that cars with gauge adjustable wheelsets have unbeatable advantages where time delays cannot be admitted and where heavy traffic on single lines exists.

Both systems are applicable for African railways, if the present gauge adjustable wheelsets type DR-IV and OGI can be modified to overcome the difference of the mainly used gauge widths of 1067 mm and 1000 mm. Standardizations of bogies and wheelsets, however, are necessary to secure an interchangeability of the running gears in cases of extraordinary wear (hot boxes, skidded wheels, breakages of springs) or accidents.

F. Conclusion

The presented study tried to describe different possibilities of handling railway traffic between connected railway systems with different gauges by changing bogies on the railway joints and by using gauge adjustable wheelsets. The experiences of the Spanish Railways (RENFE) and the Deutsche Reichsbahn (DR) with both systems were reported and the techniques - especially those of gauge adjustable wheelsets - were examined as to whether they are applicable for African railways. The gauge adjustable wheelset type Deutsche Reichsbahn DR-IV is the most examined and proved one. Since 1961, iron-ore trains - consisting of bogie cars with these gauge adjustable wheelsets - have been operating between USSR and Poland.

Other types of gauge adjustable wheelsets developed under the auspices of RENFE show remarkable constructions. But most of them are not examined yet. It may be stated that out of all constructions only the gauge adjustable wheelset type Deutsche Reichsbahn DR-IV and possibly also the OGI wheelset might be suitable to overcome African gauge gaps of 67 mm (1067 mm - 1000 mm) or larger. However, careful recalculations of the admissible tensions in the material have to be done. None of the described constructions is capable of overcoming gauge gaps smaller than 67 mm.

Gauge gaps up to 117 mm (1067 - 950 mm) and over 368 mm (1435 - 1067 mm) cannot be overcome by the Vevey wheelset. The other gauge adjustable wheelsets can be adjusted to 1435 mm and 1067 mm, or 1000 mm gauge width. Difficulties have to be expected, however, by exceeding the limits of the loading gauges on the tracklines with 1067 mm and 1000 mm gauge width.

Additional costs were calculated under certain assumptions which would arise when changing bogies on the frontier or when using gauge adjustable wheelsets. The cost of a bogie change can be anticipated with approximately 2.51 US$/car if the depot changes approximately 26,400 cars per year. It appears that the maximum number of bogie changed cars per one depot comes to approximately 30,000 cars/year.

The additional investment costs for bogie cars with gauge adjustable wheelsets are approximately 700 US$/car. Under certain assumptions, it was calculated that the additional cost per car trip can be expected with 2.38 US$/trip. However, the savings were not taken into account if train delays are avoided when changing bogies.

APPENDICES

Appendix	Title
1	Competition for the design of a bogie with wheelsets of adjustable gauge for passenger coaches - Technical conditions
2	Technical conditions for gauge adjustable wheelsets, type DR-IV, transition-rails and brake blocs developed by Deutsche Reichsbahn (DR)
3	Gauge adjustable wheelset, type: Deutsche Reichsbahn DR-IV, Democratic Republic of Germany
4	Gauge adjustable wheelset, type: Ateliers de Constructions Mecaniques de Vevey, Villeneuve (Vaud) Switzerland
5	Gauge adjustable wheelset, type: Oficina General de Ingenieria O.G.I., Spain
6	Gauge adjustable wheelset, type: Talgo, Madrid, Spain
7	Cost per bogie-exchanged car - assumed figures: 13,200 border crossing cars per year

APPENDIX 1

COMPETITION FOR THE DESIGN OF A BOGIE WITH WHEELSETS OF ADJUSTABLE GAUGE FOR PASSENGER COACHES

TECHNICAL CONDITIONS

General constructional conditions

All component parts of the bogie shall be manufactured in accordance with the regulations of the Technical Unity of Railways (UT), International Carriage Regulations, and all UIC 1/ leaflets concerning passenger vehicles on international services.

The system envisaged in the following Articles assumes, in particular, that the wheels are mounted on an axle so that the distance between them can be adjusted. If the principle of the system is different or, more generally, if some of the provisions laid down in these technical conditions are not fulfilled, the necessary justification for this shall be given.

General calculation conditions

The general calculation conditions shall be those laid down in UIC leaflet No. 567 for coaches on international services, the minimum tare weight being 45 metric tons and the seating capacity as stipulated for type X or Y coaches.

The value of 1.45 shall be used for the coefficients intended to make allowance for the dynamic efforts.

Gauge

The component parts of the system proposed may encroach upon the international gauge for the lower parts, or even on that of the RENFE, all along the transition track length, strictly within the limits required for releasing the wheels, owing to the fact that parts of the fixed equipment may enter the vehicle gauge or parts of the vehicle may enter the clearance gauge; however, once this track length is cleared, all parts of the bogie must remain within the gauge of the track for which the wheels have been set.

1/ UIC: Union internationale des chemins de fer.

Wheels

The diameter of the wheels shall be 920 mm, in accordance with UIC regulations for vehicles on international services, and the profile of the running tread shall be as specified by the UIC.

The quality of the wheels shall be that stipulated in the UIC leaflets, unless as a result of the nature of the system, the wheels have to bear heavier stresses than a normal wheelset, in which case the appropriate quality must be stated.

For speeds of 160 km/h, the static out-of-balance of fully machined wheels, before securing on the axle, shall not exceed that of a weight of 100 g, acting at the extremity of a 500 mm radius.

The residual out-of-balance of each wheel shall, after it is secured on the axle, be in the same diametral plan and on the same side of the centre line.

Bearings

The axle boxes must necessarily be on the outside. They are to be fitted with roller-bearings, suitable for speeds up to 160 km/h, the UIC standard types being preferred and, of these, bearings fitted on axle journals with a 130 mm diameter. The roller-bearings must be of an already approved make and their dimensions justified, even in respect of the resistance to the axial efforts they have to bear.

Once the wheels are in place on the axle at the required distance, they must be securely held in position in translation, as well as in rotation, in relation to the axle; if the proposed system makes use of the axle box to achieve translation immobilization, detailed justification must be given of the bearing strengths and the methods of achieving them, by employing safety coefficients similar to those used for ordinary wheelsets.

Axles

If the proposed axles are different from normal axles, in respect of the mechanical characteristics as such, as well as of the variation of the position of the reaction efforts according to the track gauge, their dimensions and the quality of steel must be duly justified, by means of safety coefficients similar to those accepted by the UIC for standard axles. Any grooving or sudden variations in cross-section likely to reduce strength cannot be tolerated.

Running safety

The securing of the wheel on the axle in translation, as well as in rotation, after the bogie has run over the transition track length from one gauge to the other, must be very reliable and unaffected by external or internal influences, so that the proposed system does not give rise to any risk other than that at present inherent in ordinary axles for normal gauges. In order to check that the wheels are securely locked in their extreme positions, the locking device shall be provided with a system showing, in a manner that is plainly visible, that locking has been effected.

The distance between the wheels for each track gauge obtained must conform to the tolerances stipulated for normal wheelsets.

The extent to which the running surface may be out-of-true in relation to the axle shall not in any circumstances exceed the tolerances laid down for normal wheelsets. For speeds of up to 160 km/h, the offset shall not be more than 0.2 mm.

The conditions for securing the wheel, which are of prime importance for running safety, must be effective up to a speed of 160 km/h and without any additional overhauls of the bogie involving its raising before a distance of 100,000 km has been covered.

Brakes

If the brakes proposed are of a current model with cast-iron brake shoes and rigging giving a multiplication of 1:4, UIC types will be employed, giving a braked-weight of approximately 150 per cent, in accordance with the provisions of UIC leaflets No. 546 for speeds of up to 160 km/h and with compressed-air control, and of 90 per cent for vacuum brakes on RENFE lines. As a variant, the possibility is given of using shoes made of composite materials, with a constant friction coefficient, even though the current studies, at the international level, have not as yet resulted in definite conclusions being reached.

The brake rigging on the bogie shall enable the shoes to attain their maximum degree of wear, any play being taken up by means of an automatic adjuster.

If the braking system is not of an ordinary, current railway type, i.e., if, for example, pneumatic or hydraulic disc brakes are proposed the system shall be explained in detail in order to show that the decelerating effort produced by the produced braking system, irrespective of the speed conditions, is similar to that obtained in coaches fitted with ordinary brakes since coaches fitted with the proposed bogies must be suitable for running in trains made up of stock with both types of bogie.

If the system proposed necessitates the modification of the position of the shoes when the distance between the wheels is changed from one gauge to the other, the related device shall not be detrimental to the faultless operation of the brake, in respect of its effectiveness, as well as of its consumption of power and the wear of parts:

Stability

Stability conditions must be excellent over both gauges of track, up to a speed of 160 km/h and, to achieve this, the distance between the bogie axles shall be a minimum of 2,500 mm and a maximum of 2,600 mm, as specified in UIC leaflet No. 567. If the system proposed requires a variation of these limits, this must be justified and it shall be shown that the variation would not prevent the bogie from being fitted to the body of present-type international coaches.

Comfort

The suspension must provide conditions of comfort which are at least equivalent to those obtained with Minden-Deutz 2/, Y-24 or Schlieren 2/ bogies. The flexibility of the suspension shall not produce variations in the height of buffers in excess of those laid down by Technical Unity, the RIC 3/ and the UIC, and shall not make it difficult to couple up coaches fitted with normal buffers.

If a bogie bolster is used with the body of a type X or Y international coach, it must be ensured that its maximum lateral movement on curves, allowance being made for all the dynamic effects of the suspension, does not encroach on the international clearance gauge, as specified by the UIC, Technical Unity and the RIC.

If hydraulic dampers are employed, they must be positioned so they do not constitute an integral part of the bogie structure, and fitted so they can be replaced and maintained easily.

From the standpoint of comfort, it must be ensured that the proportion of the suspended weight is similar to that obtained with normal bogies. The value of the non-suspended weight must also be stated.

Arrangement of the electric lighting generator

The generator for the electric lighting equipment and, if required, for the heating system, shall be fixed to the bogie frame in a position enabling it to be driven, from one of the axles, by means of pulleys or gears. The generator and its transmission must be within limits of both track gauges.

2/ ECA comment: These are names of standardized bogies.

3/ RIC: Regolamento Internazionale Carrozze: Regulations dealing with the mutual utilization of coaches and baggage cars.

Behaviour of bogies in respect of track circuits

The bogie as a whole must be designed so that track circuits can be shunted normally and the return of the heating current (when this is required for electric heating) can be effected without danger of erosion to the different axle bearings and journals of the bogie.

Fitting the system to motor bogies

Although the competition concerns bogies for passenger coaches, it would be of interest to know the possibilities of fitting the system proposed to self-propelled vehicles with adjustable-gauge motor bogies. The jury would give consideration to possible solutions of this problem.

APPENDIX 2

TECHNICAL CONDITIONS FOR GAUGE ADJUSTABLE WHEELSETS, TYPE LR-IV TRANSITION-RAILS AND BRAKE BLOCS DEVELOPED BY DEUTSCHE REICHSBAHN

1. The gauge adjustable wheelset must grant the safe operation on the gauge widths 1435 mm and 1524 mm. The changing of gauges must be possible by leading the cars over a maximum 15 m long transition-rail under load with a speed of 5-10 km/h.

2. All parts of the wheelsets must not exceed the limits of the loading gauges.

3. The wheelset must carry 21 t load, it must withstand all forces which arise during the operation (brakeforces, pushes, momenti, forces due to gravity, etc.).

4. Stability conditions must be excellent over both gauges of track, up to a speed of 120 km/h.

5. Influence of weather, temperatures and wear shall not influence the stability of the wheelset.

6. The wheelset should be used in bogies without axle guides.

7. The weight of the wheelset should not exceed 1.8 t.

8. The wheelset must have sufficient electric conductance (resistance from wheel-to-wheel 0.01 ohm). The wheelset must grant protector ground not exceeding 0.01 Ohm.

9. The space between the wheels must be reserved for parts of brake equipment and energy auxiliaries.

10. The gauge adjustable wheelset must be changeable with normal wheelsets.

11. The securing of the wheel on the axle in translation, as well as in rotation, after the bogie has run over the transition-track length from one gauge to the other, must be very reliable and unaffected by external or internal influences, so that the proposed system does not give rise to any risk other than that at present inherent in ordinary axles for normal gauges. In order to check that the wheels are securely locked in their extreme positions, the locking device shall be provided with a system showing, in a manner that is plainly visible, that locking has been effected.

The distance between the wheels for each track gauge obtained must conform to the tolerances stipulated for normal wheelsets.

12. The axle and the wheels must not show any bores, nuts and grooves.

13. Parts of the transition rail may be located in the loading gauges as long as they are necessary for the unlocking and locking device.

14. Check-rails for shifting the wheels must be constructed in such a way that they withstand horizontal acting forces of min. 5.3 t/wheel.

15. The automatic change of the brake shoes into the required position must be granted.

16. Skid devices, self-adjusting brake gears and cardan shafts must be able to be fitted on the axle box case.

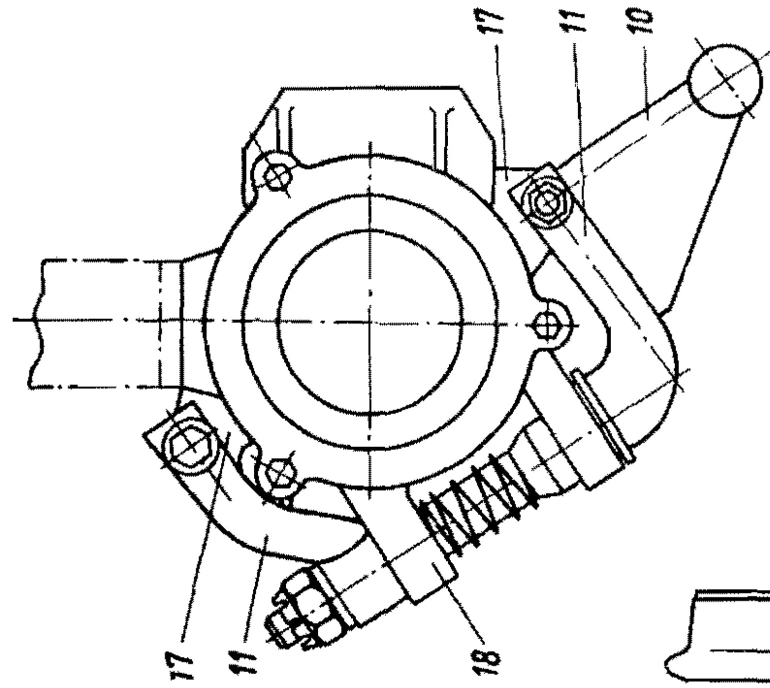
17. The functioning of the locking device must not be influenced neither by brake warming nor by temperature of - 50° C.

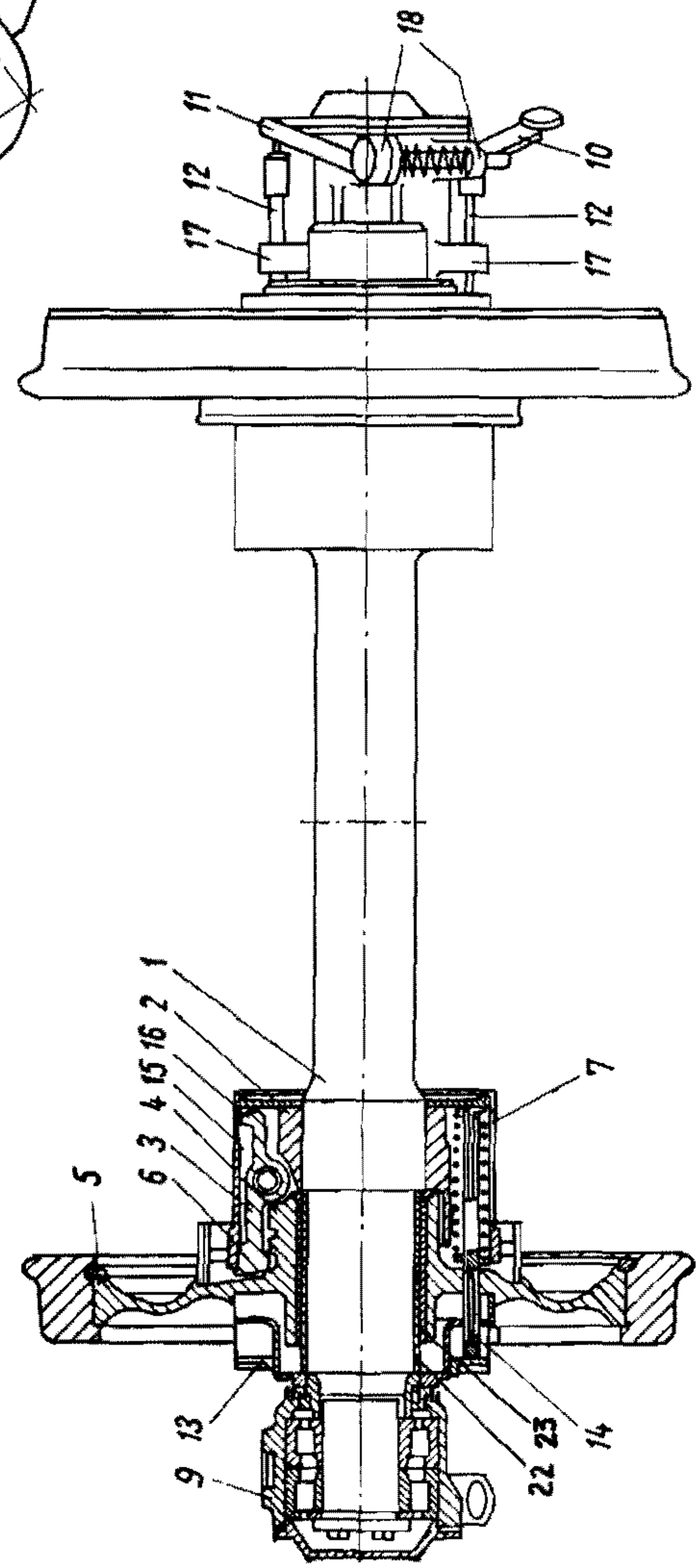
LEGEND/APPENDIX 3

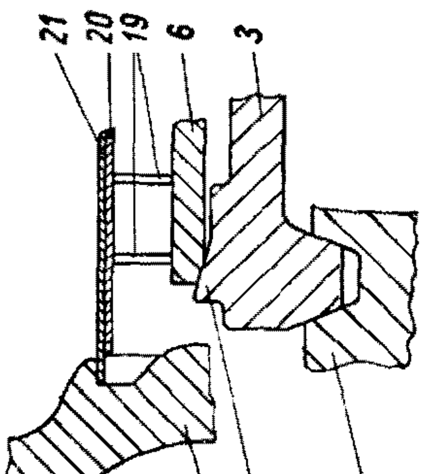
1 - axle
2 - clutch-star
3 - rocker arm
4 - wheel hub
5 - wheel disc
6 - double-lock sleeve
7 - compression spring
8 - slope
9 - axle-box case
10 - crank
11 - lever
12 - axial-movable push-rod
13 - pilot disc
14 - rod
15 - stop pin
16 - cam
17 - guide hole
18 - collar(s)
19 - bracing rings
20 - circular flange
21 - protecting sleeve
22 - bushing, hard-tissue
23 - bushing, chromium-plated steel

LEGENDE/ANNEXE 3

1 - essieu
2 - manchon d'accouplement à griffes
3 - levier basculant
4 - moyeu de roue
5 - corps de roue
6 - manchon de verrouillage
7 - ressort de compression
8 - surface biaise
9 - corps de boîte d'essieu
10 - manivelle
11 - levier
12 - poussoir (coulissant axialement)
13 - disque de commande
14 - tige
15 - saillie
16 - came
17 - trou de guidage
18 - palier(s)
19 - couronnes entretoises
20 - bride circulaire
21 - bride de protection
22 - manchon en matière plastique dure armée de tissu
23 - chemise en acier chrômé







Gauge Adjustable Wheelset
Type: Deutsche Reichsbahn DR-IV
Democratic Republic of Germany.

Essieu à écartement variable
Gauge Adjustable Wheelset
Type: Deutsche Reichsbahn DR-IV
Democratic Republic of Germany.

APPENDIX 7

COST PER BOGIE CHANGED PER YEAR

(ASSUMPTION: 13,200 BORDER-CROSSING CARS)

<u>Assumptions for the cost calculation:</u>

(a) Converting shed (steel construction) without pit:

Length: 36 m
Height: 7.5 m
Width: 7 m
Cost per m^3/shed: 9 US\$/m^3

Shed - - - - - - - - - - -		17,010 US\$
	Lifetime - -	40 years
(b) Pit (see Picture 5)		
75 m^3 concrete cement at 110 US\$/m^3 - - -		8,250 US\$
	Lifetime - -	40 years
(c) Concrete floor 200 m^2 at 32 US\$/m^2 - - -		6,400 US\$
	Lifetime - -	20 years
(d) Lighting of the pit and the shed - - - -		4,800 US\$
	Lifetime - -	10 years
(e) 12 electric driven jacks, 20 t lifting power, including electric installation - -		18,000 US\$
	Lifetime - -	20 years
(f) Stock track for bogies (double-gauge line) 750 m track at 50 US\$/m, including earth-moving ballast, etc. - - - - -		37,500 US\$
6 switches at 4,000 US\$ - - - - - -		24,000 US\$
		61,500 US\$
	Lifetime - -	60 years
(g) Auxiliary diesel unit for hauling bogies (see Picture 8) - - - - - - - -		5,000 US\$
	Lifetime - -	10 years
(h) Adaptable couplings (see Picture 6 and 7). If 13,200 cars are crossing the border there is a need of approximately 88 say 90 couplings. Cost 25 US\$ each - - - - - - - -		2,250 US\$
	Lifetime - -	10 years

(i) Bogie stock. Same assumption as under (item h) 88 bogies at 2,500 US$ each - - 220,000 US$
Lifetime - - 20 years

(j) Interest - - 6.5%

Total investments - - 343,210 US$

Split up into lifetime:

		US$
Lifetime 60 years	- -	61,500
" 40 "	- -	25,260
" 20 "	- -	244,400
" 10 "	- -	12,050

Split up into buildings, trackline, mechanical equipment:

Buildings - - - -	31,660
Trackline, switches - - -	61,500
Mechanical equipment (jacks, lighting, bogies, etc.)	250,050

Maintenance costs/year

		US$
(a)	Buildings 1 per cent of the investment costs (31,660 US$)	316.60
(b)	Trackline 150 US$/km and year - -	112.50
(c)	Mechanical equipment 2 per cent of the investment costs -	5,001.00
	Total maintenance costs	5,430.10
	Say:	5,400.00

Capital costs/year

Investment costs (US$)	Lifetime - years	Capital costs US$/year
12,050	10	1,635
61,500	60	3,055
25,260	40	1,506
244,400	20	20,554
	Total capital costs	26,750
	Say:	26,800

Labour costs/year

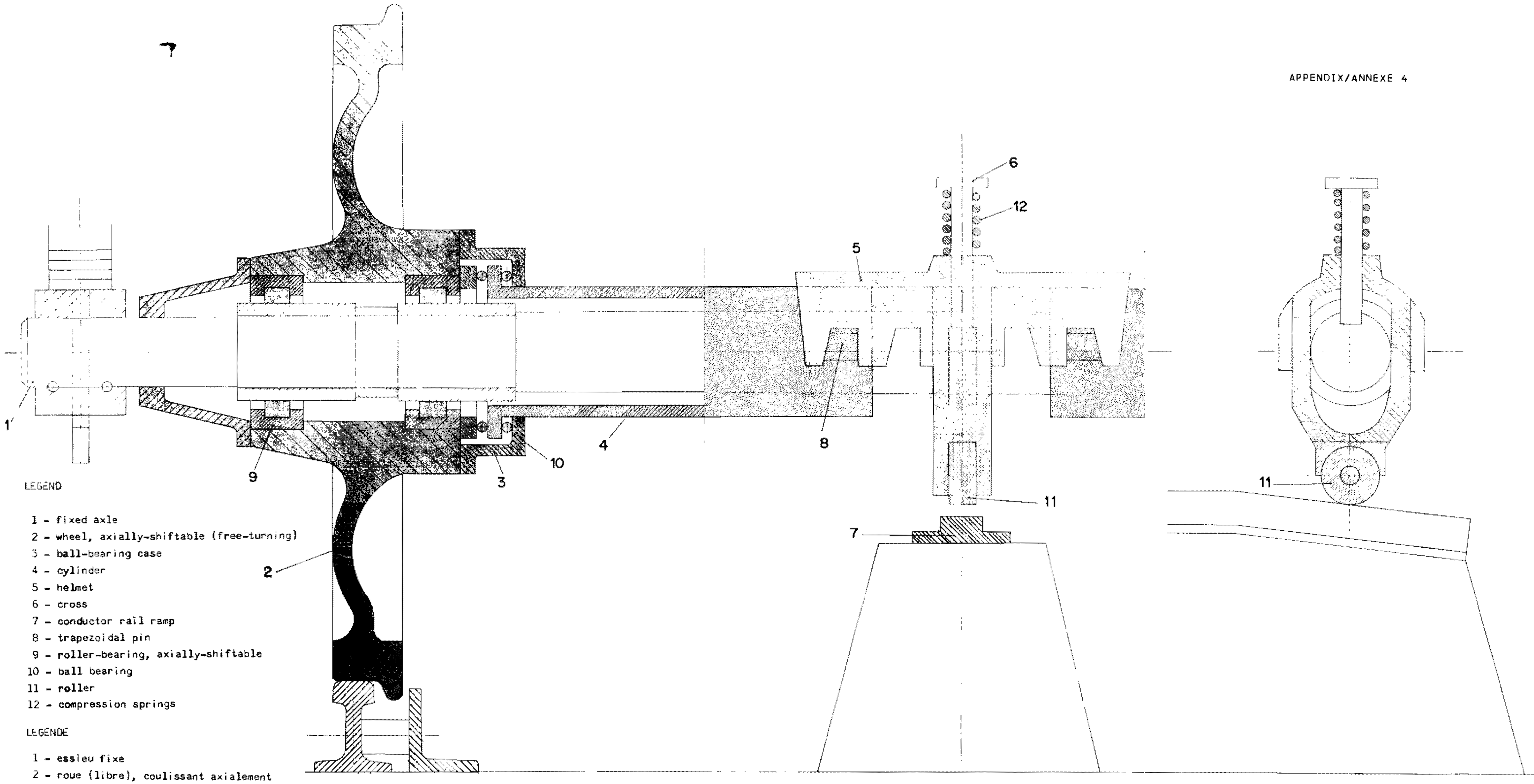
		US$/year
(a)	12 workers on the jacks 12 x 300 shifts/year = 3,600 shifts/year 1 US$/shift - - - - -	3,600
(b)	Two locodrivers (auxiliary unit and shunting loco) 4 US$/shift - - - - -	2,400
(c)	Two shunters: 1.50 US$/shift - -	900
		6,900
	30 per cent overheads, sickness, on leave	2,070
	Total labor costs	8,970
	Say:	9,000

Cost for shunting locomotive per year

$\frac{13,200 \text{ cars/year}}{3 \text{ wagons}}$ x 25 minutes - - - - -	1,833 h/year
Plus going and coming time - - - -	167 h/year
	2,000 h/year
Cost per locomotive-hour - - - -	4 US$/h
Cost shunting locomotive - - - -	8,000 US$/year

Summary of costs

Costs	US$/year
Maintenance - - - - - -	5,400
Capital - - - - - -	26,800
Labour - - - - - -	9,000
Operation (shunting locomotive) - - - - - -	8,000
	49,200
Cost of changing bogies (13,200 cars/year) -	3.73 US$/car



LEGEND

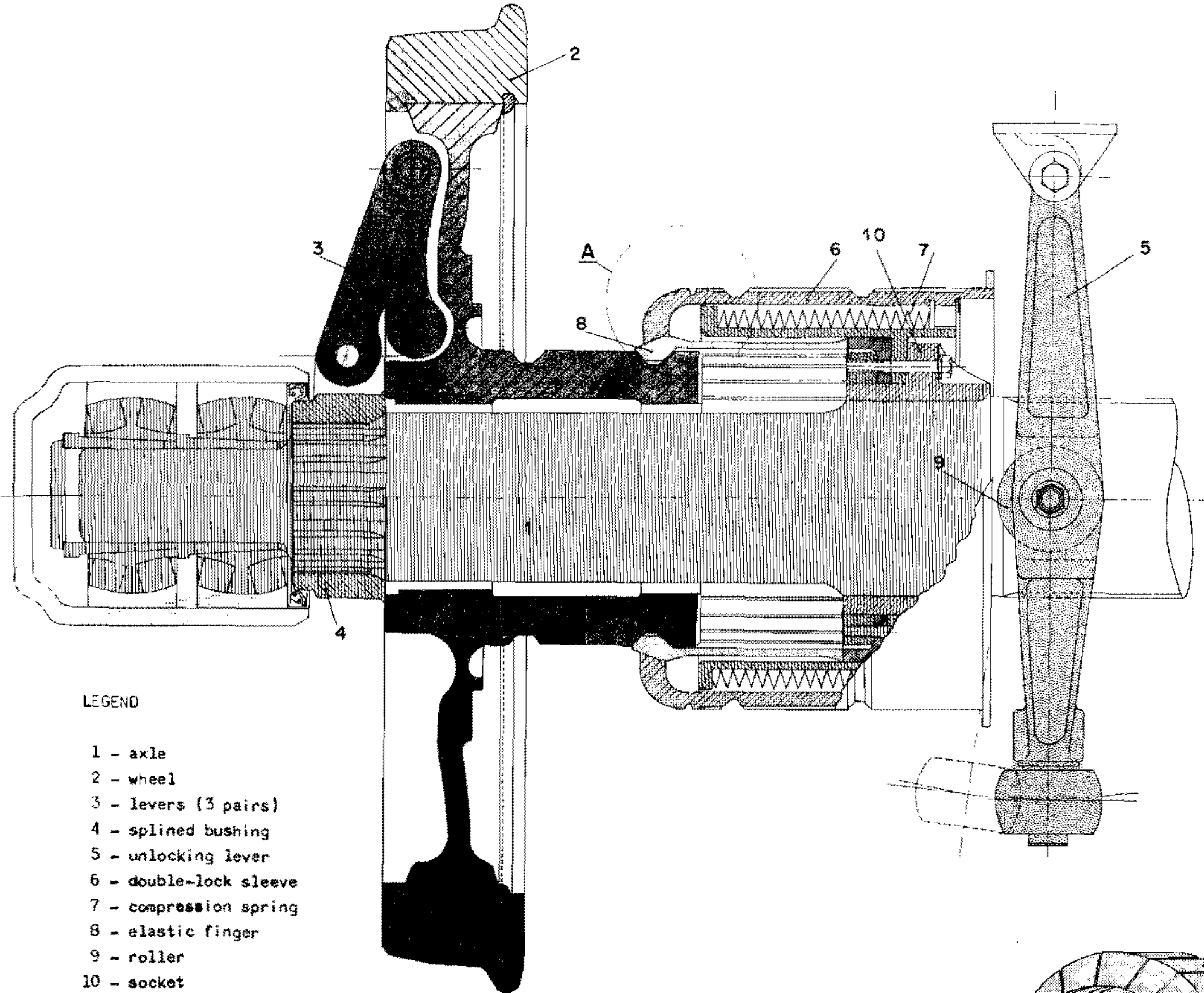
1 - fixed axle
2 - wheel, axially-shiftable (free-turning)
3 - ball-bearing case
4 - cylinder
5 - helmet
6 - cross
7 - conductor rail ramp
8 - trapezoidal pin
9 - roller-bearing, axially-shiftable
10 - ball bearing
11 - roller
12 - compression springs

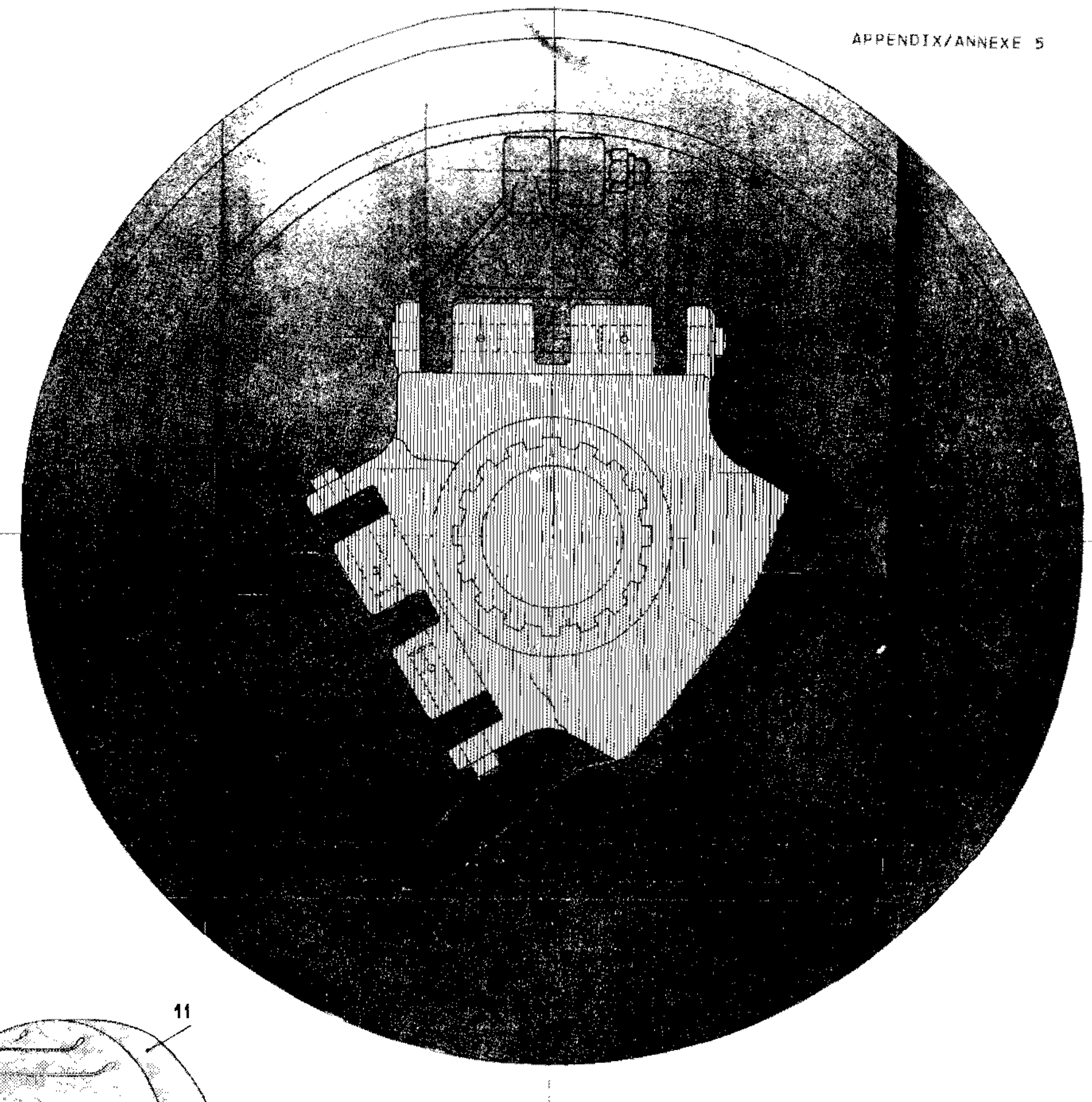
LEGENDE

1 - essieu fixe
2 - roue (libre), coulissant axialement
3 - cage de roulement à billes
4 - manchon
5 - chape
6 - croisillon
7 - rampe de déverrouillage
8 - téton à section trapézoidale
9 - roulement à rouleaux, coulissant axialement
10 - roulement à billes
11 - galet
12 - ressorts de compression

1 Parts fixed at the bogie/ Pièces fixées au bogie
2. Axially shifting parts / Pièces à déplacement axial
3 Vertical shifting parts / Pièces à déplacement vertical
4. Rotating parts / Pieces tournantes
5. Rotating and axially shifting parts / Pièces tournantes à deplacement axial
6 Rotating (lock) / Dispositif de verrouillage tournant
7 Rotating double lock / Dispositif de sécurité (tournant)

GAUGE ADJUSTABLE WHEELSET
Type: ATELIERS DE CONSTRUCTIONS MECANIQUES DE VEVEY
ESSIEU A ECARTEMENT VARIABLE
Type: ATELIERS DE CONSTRUCTIONS MECANIQUES DE VEVEY



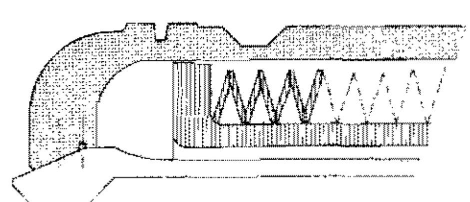


LEGEND

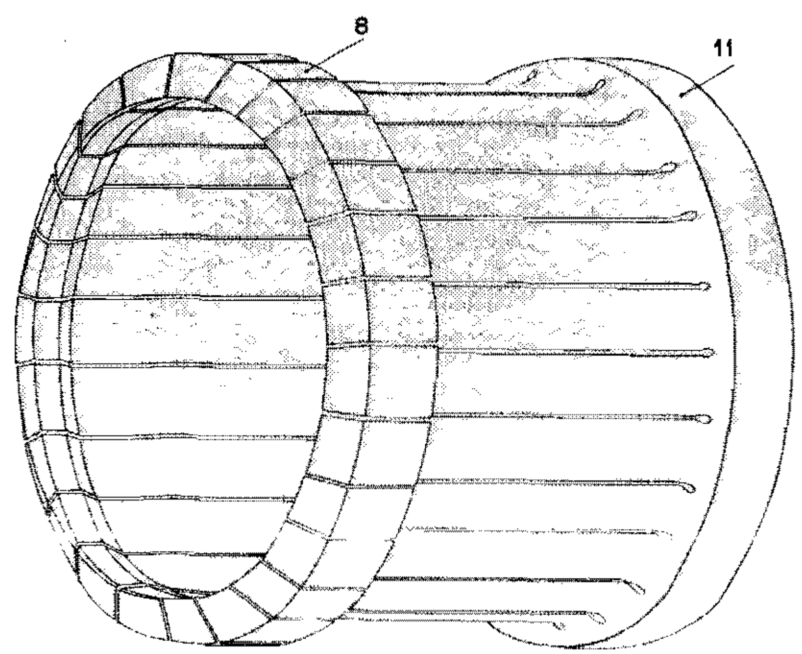
1 - axle
2 - wheel
3 - levers (3 pairs)
4 - splined bushing
5 - unlocking lever
6 - double-lock sleeve
7 - compression spring
8 - elastic finger
9 - roller
10 - socket
11 - split bushing

LEGENDE

1 - essieu
2 - roue
3 - biellettes (3 paires)
4 - bague cannelée
5 - levier de déverrouillage
6 - manchon de verrouillage
7 - ressort de compression
8 - lame élastique
9 - galet
10 - collier à bride
11 - manchon à fentes

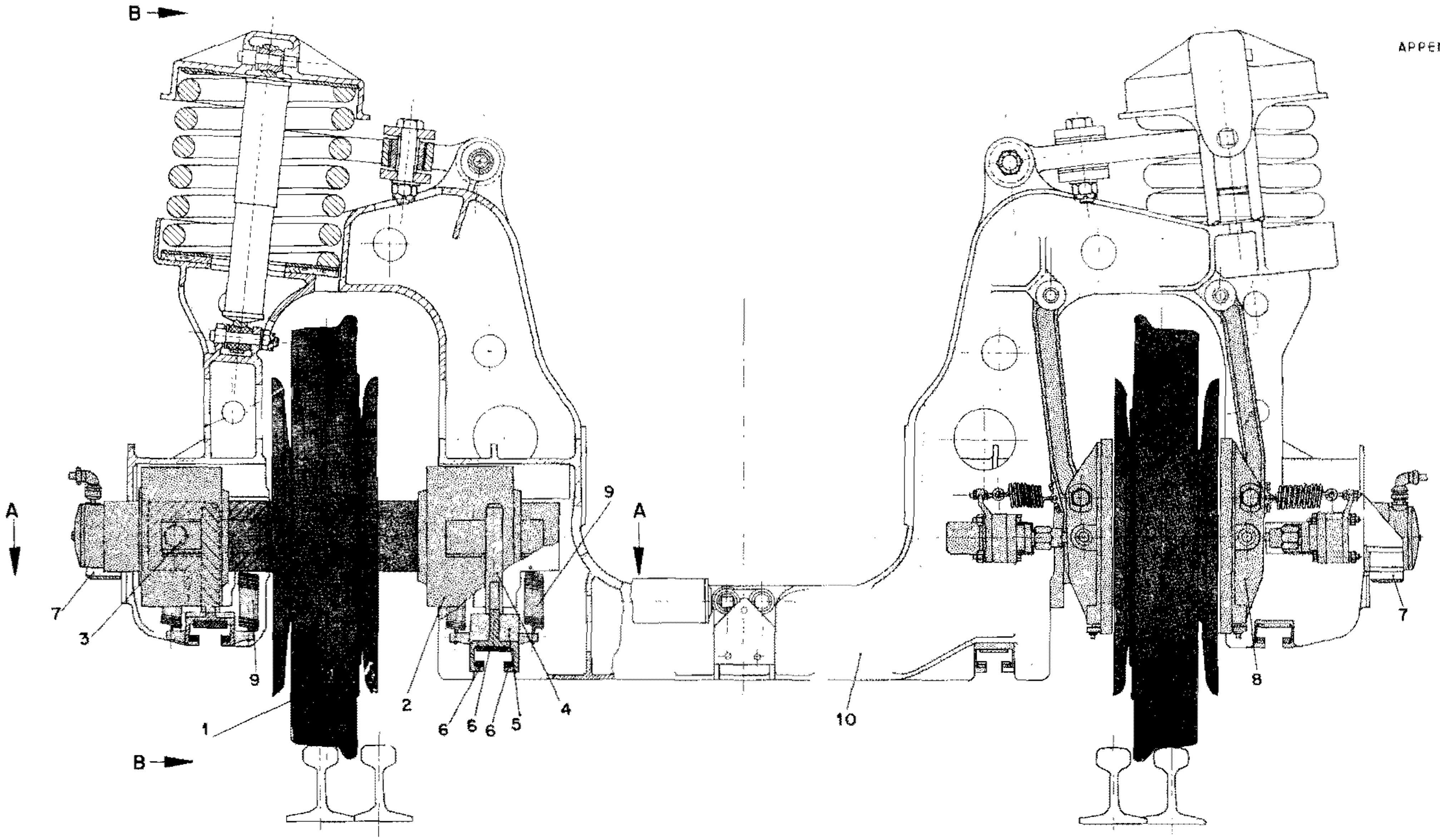


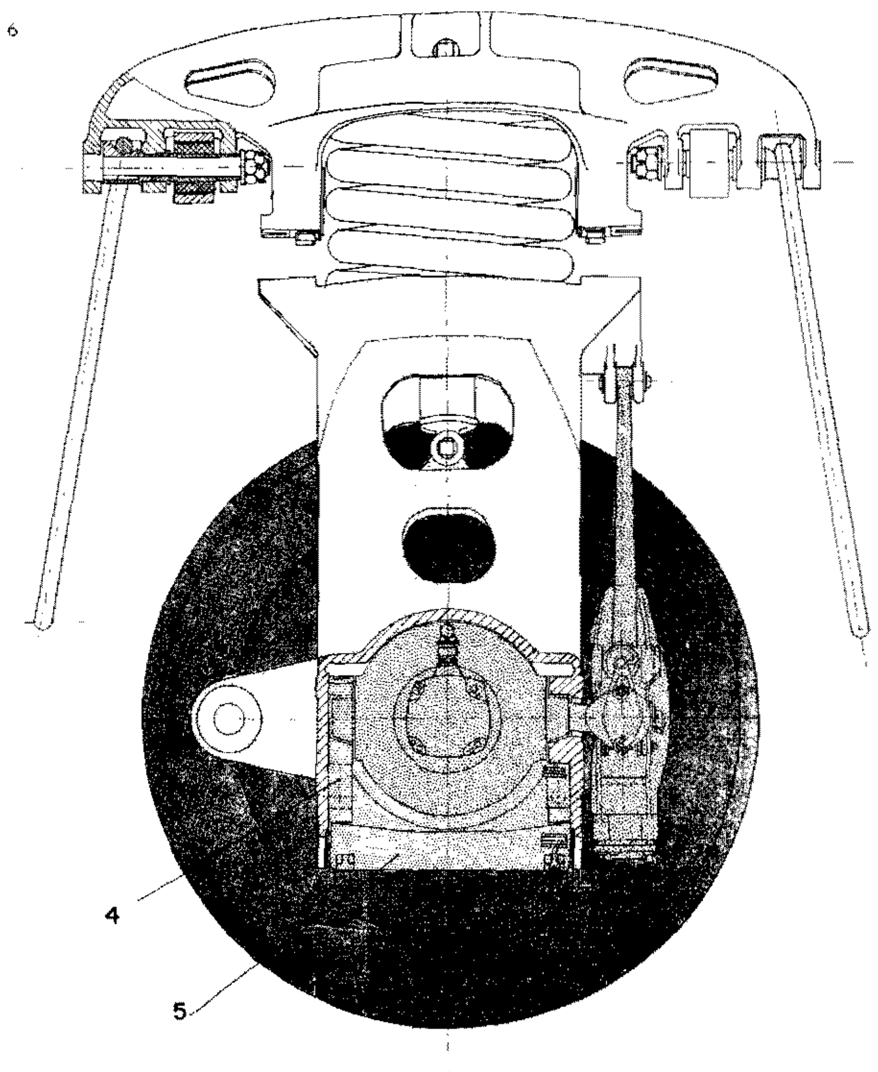
Detail A



GAUGE ADJUSTABLE WHEELSET
Type: OFICINA GENERAL DE INGENIERIA O.G.I.
ESSIEU A ECARTEMENT VARIABLE
Type: OFICINA GENERAL DE INGENIERIA O.G.I.

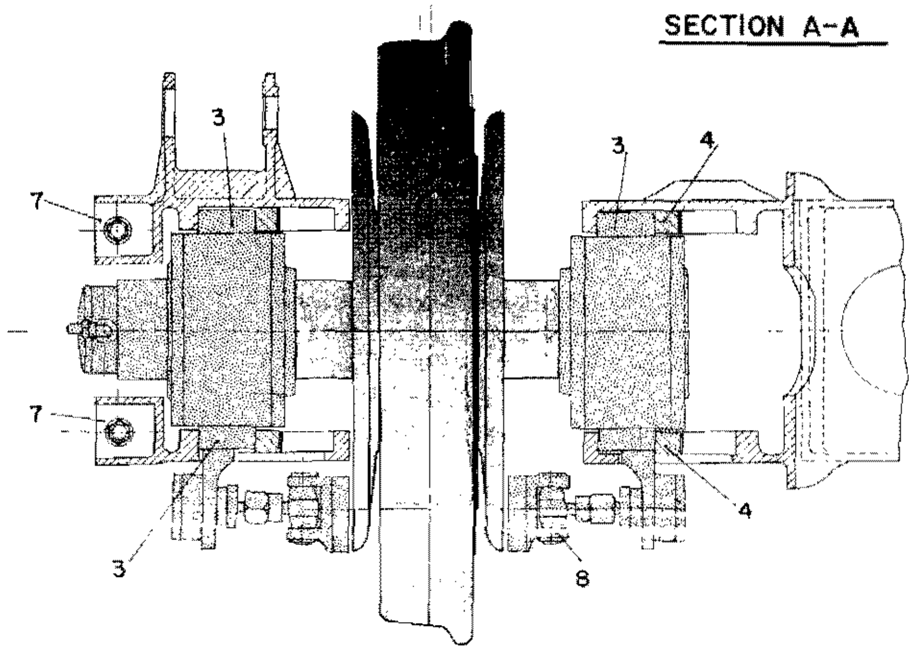
1 Parts fixed at the bogie / Pièces fixées au bogie
2 Axially shifting parts / Pièces à deplacement axial
3. Vertical shifting parts / Pièces à deplacement vertical
4 Rotating parts / Pièces tournantes
Rot...
6. Rotating (lock) / Dispositif de verrouillage tournant
7. Rotating double lock / Dispositif de sécurité (tournant)





SECTION B-B

SECTION A-A



LEGEND

1 - free-turning wheel
2 - axle-box case with roller bearings
3 - rectangular block
4 - pin
5 - yoke
6 - nylon plate
7 - support block
8 - brake
9 - coil spring
10 - cast steel frame

LEGENDE

1 - roue indépendante
2 - boîte d'essieu à rouleaux
3 - tenon à section rectangulaire
4 - barrette de verrouillage
5 - entretoise
6 - garniture en nylon
7 - patin de support
8 - frein
9 - ressort à boudin
10 - armature en acier moulé

GAUGE ADJUSTABLE WHEELSET
Type: TALGO
ESSIEU A ECARTEMENT VARIABLE
Type: TALGO

1 Parts fixed at the bogie / Pièces fixées au bogie
2 Axially shifting parts / Pièces à déplacement axial
3 Vertical shifting parts / Pièces à déplacement vertical
4 Rotating parts / Pièces tournantes
5 Rotating and axially shifting parts / Pièces tournantes à déplacement axial
6. Rotating lock / Dispositif de verrouillage tournant
7 Rotating double lock / Dispositif de sécurité (tournant)