UIC CODE 510-2

4th edition, May 2004

Translation

OR

Trailing stock: wheels and wheelsets. Conditions concerning the use of wheels of various diameters

Matériel remorqué : roues et essieux montés - Conditions concernant l'utilisation des roues de différents diamètres
Wagen. Bedingungen für die Verwendung von Rädern verschiedener Durchmesser in Laufwerken unterschiedlicher Bauart

UNION INTERNATIONALE DES CHEMINS DE FER
INTERNATIONALER EISENBAHNVERBAND
INTERNATIONAL UNION OF RAILWAYS

Leaflet to be classified in Volumes:

V - Rolling Stock

VII - Way and Works

Application:

With effect from 1 July 2000
All members of the International Union of Railways
Exemptions are nonetheless granted to:
- all railways: for the small number of existing axle types, the minimum diameter of which may be slightly less than 630 mm, the 680-630 range (point 1.2) may be extended to 680-625;
- SNCF: unlimited exemption regarding the application of zone A_1B_1 of the wheel profile as defined in points B.1, B.2 and B.3;
- SBB/CFF, DB AG, FS and JŽ:until 1.1.2002 as regards the deadline for the initial inspection referred to in point 7.3.

This leaflet applies to standard gauge lines

Record of updates

1st edition, January 1969	and 4 Amendments
2nd edition, January 1978	and 10 Amendments
3rd edition, January 1998	not published
4th edition, May 2004	Addition of Appendix H

The person responsible for this leaflet is named in the UIC Code

Contents

Summary

This leaflet contains the conditions relating to the design and maintenance of wheels and wheelsets for coaches and wagons used on international services. It covers wheel diameters from 330 to 1 000 mm, and indicates the permissible axle loads from the standpoint of stresses of the metal used for the wheel and the rail.

It also stipulates the minimum wheel flange height according to wheel diameter:

- for wheel diameters between 760 and 1 000 mm: h = 28 mm,

- for wheel diameters between 630 and 760 mm: h = 30 mm or 32 mm (h = 30 mm is preferable for financial reasons),

- for wheel diameters between 330 and 630 mm: h = 32 mm.

To guarantee safe running when passing over fixed noses with a minimum tangent of 1/9 in plain obtuse crossings and obtuse crossings with slips in curves with a 450 m radius (which, from the point of view of running, are the most unfavourable points in the track), the leaflet also deals with the dimensions to be observed during construction, when laying the track, and for the maintenance of these crossings. In addition, it gives the permissible value, in service, of the angle of attack of the axle and the lateral force acting on the latter, valid for the range of wheel diameters from 330 to 840 mm. For wheels with diameters between 840 and 1 000 mm, the safety of which was warranted by current practice, no condition was laid down in this connection.

The conditions of this leaflet are valid for a nominal track gauge of 1 435 mm and cannot be readily transposed to apply to other track gauges.

ERRI document DG4 contains an overview of standardised subgroups and component parts.

O

1 - Characteristics of wheels and wheelsets

1.1 - The wheels

shall be:

- solid wheels made of rolled or forged steel, or
- tyred wheels, in which case they shall consist of a steel-wheel body rolled, cast or wrought and of a rolled-steel tyre, with the separate tyre mounted round the whole circumference of the wheel body without discontinuity and made secure by means of a retention spring-clip.

1.2 - Wheel diameter

NB : it is not possible to give the final values until standardisation has been completed.

The following ranges of diameters are fixed provisionally for the wheels of coaches and wagons used on international services[1]:

Table 1 : Wheel diameter

Nominal diameter D (in mm)	Minimal diameter d (in mm)[a]
1 000	920
920	840
840	760
760	680
680	630
630	550
550	470
470	390
390	330

a. Application of these values is subject to bi- or multilateral agreements.

For the sake of accuracy, the provisions set out hereinafter always specify whether they apply to the nominal diameter D or the minimum diameter d.

1. wheelsets for wagons fitted with wheels of nominal diameter D = 1 000 or D = 920 mm are standardised. Their drawings are managed by UIC. As regards the use of wheelsets with diameter D = 1 000 or D = 920 mm, see UIC Leaflet 510-1.

1.3 - Rim-tyre, tyre

1.3.1 - From 1.1.89, new wagons are to be equipped with solid wheels.

1.3.2 - Limiting dimensions and measurements: see Tables 2 - page 4 and 3 - page 5 of this leaflet.

1.3.3 - Running profile of the rim-tyre or tyre.

The denominations concerning the running profile of the wheels are given in Appendix A - page 15.

This profile must comply for wheels of diameter:

- between D = 1 000 and d = 760 mm: with points B.1.1 - page 16 and B.1.2 - page 18;

- between D = 760 and d = 630 mm: with points B.2.1 - page 21 and B.2.2 - page 23;

- between D = 630 and d = 330 mm: with points B.3.1 - page 26 and B.3.2 - page 28.

These appendices depict new profiles where the flange has a thickness of e = 32,5 mm.

However, profiles with different flange thicknesses may be used within the limiting values given in Tables 2 and 3 hereinafter. Such profiles can be obtained by displacement parallel to the axle-shaft, which causes a peak to appear at the top of the flange. This peak may be tolerated provided it lies at a radial distance of under 2 mm from the top of the flange, in other words outside the profile zone allowing for the joggle for straight-cut switches.

1.4 - Limiting measurements for manufacture and reprofiling

Table 2 : Limiting measurements for manufacture and reprofiling

		Maximum speed (kph) of the vehicles			
		≤ 120	≤ 160	≤ 200	> 200
1.4.1	Manufacture of the profile (recommended)		Reprofiling to be effected, if possible, on lathes fitted with reproducers or digital control	Reprofiling to be effected on lathes fitted with reproducers or digital control	
1.4.2	Axial run-out on the inside surface of each wheel[a]	≤ 1 mm	≤ 0,8 mm	≤ 0,5 mm	to be defined[b]
1.4.3	Radial cut-out of the running tread[a]	≤ 0,5 mm	≤ 0,3 mm		to be defined[b]
1.4.4	Deformation of the running profile		≤ 0,5 mm		
1.4.5	Flange height		mini. 28 (for wheels of diameter between D = 1 000 mm and d = 760 mm) mini. 30 (for wheels of diameter between D = 760 mm and d = 630 mm) mini. 32 (for wheels of diameter between D = 630 mm and d = 330 mm)		
1.4.6	Flange thickness		max. 33 mm		
1.4.7	Width of the rim-tyre or tyre	Manufacture	135 ± 1 mm		
		Reprofiling	≥ 133 mm		
1.4.8	Difference in diameters of the running treads of the wheels of the same wheelset		≤ 0,5 mm		to be defined[b]
1.4.9	Roughness of the profile surface Ra		≤ 12,5 µm[c]		
1.4.10	Maximum residual dynamic out-of-balance of wheelset in each plane of equilibrium (see *UIC Leaflet 813*)		125 g.m[d e]	75 g.m[d]	50 g.m[d]

a. The geometric notion of "run-out" is defined in ISO Standard 1101/1.
b. For manufacture, tolerances should be agreed in the invitation to tender and the order.
c. Where ultrasonic testing is stipulated, mean roughness Ra should be ≤ 6,3 µm.
d. Not obligatory for reprofiling.
e. To be stipulated on order.

1.5 - Limiting measurements for operating

Table 3 : Limiting measurements for operating

		Maximum speed (kph) of the vehicles			
		≤ 120	≤ 160	≤ 200	> 200
1.5.1	Shape of the flange	The flange of the wheel, measured with a gauge, must always have a value of q_R greater than 6,5 mm, with no edge or burring on the outside profile of the flange, at a distance of more than 2 mm from the top of the flange.			
1.5.2	Height of the flange	≤ 36 mm			
1.5.3	Thickness of the flange[a]	For wheel diameters between D = 1 000 and d = 840 mm: ≥ 22 mm For wheel diameters between D = 840 and d = 330 : ≥ 27,5 mm (see point 1.7 - page 6)			
1.5.4	Minimum thickness of the rim-tyre	For solid wheels of rolled or forged steel, the minimum thickness of the rim-tyre must be indicated by means of a groove on the outer face of the rim-tyre. The groove must always remain visible in its total width (see Appendix C - page 31).			
1.5.5	Minimum thickness of the tyre of tyred wheels	Coaches = 35 mm		Solid wheels are the only ones permitted	
		Wagons for V > 120 kph Wagons for V = 120 kph Wagons for V = 100 kph Wagons for V < 100 kph		Solid wheels are the only ones permitted 35 mm 30 mm[b] 25 mm	
1.5.6	Width of the rim-tyre or tyre	133 ≤ b < 140			
1.5.7	Length of the wheel flats or re-surfacing metal				
	∅ between D = 1 000 mm and d = 630 mm		≤ 60 mm	≤ 30 mm	to be fulfilled later
	∅ between D = 630 mm and d = 330 mm		≤ 30 mm	not allowed	

a. These values do not apply to the intermediate wheelsets of vehicles not fitted with bogies and to the intermediate axles of bogies.
b. Wagons fitted in this way may be worked at 120 kph when empty.

1.6 - Distance between the wheels of the same axle

The distance between the wheels of the same axle between the inner surfaces of the flanges, measured at rail level, with the vehicle empty or loaded, must be:

- 1 363 mm max. — for wheels with diameters between
- 1 357 mm min. — D = 1 000 mm and d = 840 mm

- 1 363 mm max. — for wheels with diameters between
- 1 359 mm min. — D = 840 mm and d = 330 mm

These measurements take account of any flexible and permanent distorsions occurring in service. Compliance with the accurate measurements of the wheel centres must be guaranteed.

To enable these tolerances to be observed, the nominal measurements for the distance between the inner surfaces of the rim-tyres or tyres of new or restored wheelsets not under load must come within the tolerance of 2 mm in width situated asymetrically:

- upwards $\begin{pmatrix} +2 \\ 0 \end{pmatrix}$ = for external axle-boxes;

- downwards $\begin{pmatrix} 0 \\ -2 \end{pmatrix}$ = for internal axle-boxes.

1.7 - Distance between the outside surfaces of wheel flanges

The distance between the outside surface of wheel flanges of external wheelsets in an underframe or a bogie, measured beneath the running tread, with the vehicle empty or loaded, must be:

- max. 1 426 mm,
- min. 1 410 mm for wheel diameters between D = 1 000 mm and d = 840 mm

  1 415 mm for wheel diameters between D = 840 mm and d = 330 mm

  1 418 mm for axles suitable for 22,5 t with 2-axle wagons

NB : for a period up to at least 1.1.1999.
The quoted values for this distance do not result from the addition of the maximum or minimum values of the distance between wheels and of the flange thicknesses.

2 - Permissible weights per axle

The static weights per axle of new vehicles must not exceed the following values:

Table 4 : Permissible weights per axle

Range of wheel diameters (mm)	Permissible weight (t) per axle at a maximum vehicle speed (kph) of:[a]		
	120		140
	Normal values	Exceptional values	
1 000 to 920	20[b]		
920 to 840	20[b]		
840 to 760	18		
760 to 680	16		
680 to 630	14		
630 to 550	12 [c]	14 [c, d]	
550 to 470	10 [c]	12 [c, d]	
470 to 390	7,5	9,5	
390 to 330	5	7,5	

a. Definitive values cannot be defined until studies of behaviour under running conditions and braking and standardisation procedures have been completed.
b. With type B wheelsets incorporating standard wheels (ERRI B 136 Specialists' Committee), UIC Leaflet 510-1 permits maximum axle-loads of 22,5 t for speeds of 120 kph.
However, conditions for running vehicles with an axle load of 22,5 t in international traffic are set out in UIC Leaflet 432.
c. The values shown are applicable to standard-quality rails. The values for high tensile rails have yet to be defined.
d. Application of these values is subject to bi- or multilateral agreements.

Wagons suitable for running under S or SS conditions must comply with the conditions set out in *UIC Leaflet 432* (see Bibliography - page 67).

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3 - Track characteristics

Crossings of minimum tangent 1/9 are authorised for use in plain obtuse crossings and obtuse crossings with slips up to a minimum radius of 450 m. The following technical details, which must be compatible with the use of wheels of various diameters, must be observed:

Table 5 : Track characteristics

Description	Nominal dimensions (mm)	Design tolerance (mm)	Tolerance in service (mm)
1	**2**	**3**	**4**
Track gauge of the crossing A_1, A_2, A_3, A_4	1 435	+ 1 - 1	+ 4 - 2
Width of flangeways	40	+ 0,5 - 0,5	a
Dimensions for nose protection C_1, C_2, C_3, C_4	1 395	+ 0,5 - 0,5	+ 3 - 2
Running clearance measurements B_1, B_2	1 355	$\leq$ 1 356	$\leq$ 1 356
Additional height H of the check rail	45 $\leq$ H $\leq$ 60	+ 2 - 1	+ 10

a. The flangeway measurement is a design value for crossings which may vary with existing track equipment. The track gauge and running clearance measurements must enable the protective measurement to be observed in all cases in relation to this flangeway measurement.

Reference points for measurement purposes are situated in accordance with Fig. 10 and 11 - page 32 of point D.1. The measurement plane is situated 0,014 m below rail level.

The outline of the noses of crossings is defined in Fig. 12 - page 33 of point D.2.

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4 - Running safety

Standard wheels (d ≥ 840 mm) having proved to be satisfactory, it was not deemed necessary to lay down special regulations for wheels of this diameter regarding running safety when passing over the unguided gap of plain obtuse crossings and of obtuse crossings with slips, provided, however, that the essential elements (flange profile and distance between the internal surfaces of tyres or of rim-tyres) are not altered. Therefore, from the point of view of running safety, this leaflet only deals with wheel diameters between D = 840 mm and d = 330 mm.

The conditions for the acceptance of trailing stock fitted with wheels with a diameter of less than d = 840 mm, in international traffic, are as follows:

- on the one hand: when passing over crossings with a minimum tangent of 1/9, there must be no risk of derailment;

- on the other hand: the impacts of the flanges against the noses must not be very strong, in order to prevent these noses from being too heavily worn or seriously damaged.

On account of the large variety of running gear in existence and of the constant progress in the field of railway technology, it is not worth defining the characteristics of the types of running gear enabling these requirements to be observed. On the other hand, the definition of the permissible value of the angle of attack (see Glossary - page 65) of the axle against the crossing, in relation to the diameter of its wheels, is absolutely necessary. The curves shown in Appendix E - page 34 give these values. They are applicable if the conditions laid down in points 1.3 - page 3, 1.4 - page 4 and 3 - page 8 are fulfilled.

The lateral force exerted, in service, on the axle boxes must not exceed:

$H_y = 0{,}25 \times 2Q_o$ for wheel diameters between D = 840 mm and d = 330 mm,

$2Q_o$ being the nominal weight of the axle of the vehicle brought to a standstill on the rail.

Recordings taken during the course of research into performance in service, under normal service conditions, will be used to confirm that the permissible values of the angle of attack and of the lateral force on the boxes are definitely complied with. The values in question must be determined in accordance with *RP 8 of ERRI C 9 Specialists' Committee*. The angle of attack must not exceed the values shown in Appendix E. The calculation of the permissible value of the angle of attack α is based on theory 3 (see point I.2.4 - page 41), according to which the axle follows a trajectory with a certain angle of attack α combined with lateral sliding in respect of such trajectory. Details of this calculation are shown in point I.8 - page 48.

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5 - Lower gauge of vehicles fitted with very small wheels

If a reduction of the lower horizontal proves necessary for constructional reasons in the case of vehicles equipped with very small wheels, it will be necessary to comply with a lower gauge situated either at 100 mm for certain wagons, or at 80 mm, as indicated in *UIC Leaflet 505-1* (see Bibliography - page 67) for tractive units.

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6 - Operating conditions applicable to vehicles fitted with small wheels

Use of the vehicles mentioned below on the lines of foreign railways shall be agreed bi- or multilaterally for:

- coaches equipped with wheels with a diameter d < 840 mm;

- wagons, including UIC-type open two-tier wagons for the conveyance of motor cars, with a diameter between D = 630 mm and d = 330 mm;

- as an exemption to these provisions, special agreements must be reached for wagons which will run on the lines of BR and MAV if the wheel diameter d is < 760 mm, and on the lines of CD and ZSR if the wheel diameter is less than 680 mm.

7 - Steel grades for wheel manufacture

7.1 - Wheels with treated rim-tyres are recommended because they are less liable to crack and are more cost-effective.

O **7.2 -** All new shoe-braked wagons or existing wagons with load-graduated shoe brakes for SS running shall not be fitted with solid wheels in categories R2, R3, R8 and R9, as defined in *UIC Leaflet 812-3* (see Bibliography - page 67).

As of June 1984, wheels manufactured for these wagons with the above steel grades must no longer be supplied.

O **7.3 -** Wheels of steel grades R2, R3, R8 and R9 shall not be subject to the restrictions laid down in point 7.2 provided they undergo the following special inspections in order to comply with the provisions set out in point 7.3.1:

- an initial inspection to be carried out at the first suitable opportunity; repair in the event of incidental wagon repairs or servicing; this inspection must be carried out before 1.1.1998;
- a systematic inspection each time the wagon is serviced;
- an inspection after dismantling wheels presumed to have suffered thermal overload (see *RIV, paragraph 35-25*).

7.3.1 - The special marking defined in point 7.3.2 shall be carried out at the same time as the first inspection.

The inspections described in point 7.3 shall be performed by the registering railway.

After inspection, a written document shall be drawn up for each wheel giving details of the results obtained and tests carried out.

7.3.1.1 - The rims of solid wheels must not display any traces of lathe marks. Any notches found must be removed.

7.3.1.2 - The rims of solid wheels must not be subject to any significant constraints affecting traction. Solid wheels which have constraints exceeding 250 Mpa and wheels on which the constraints cannot be measured, must be destroyed.

7.3.1.3 - Rims must be checked for cracking. If solid wheels have cracks that cannot be removed by reprofiling, they must be destroyed.

7.3.2 - Marking on wheelsets

7.3.2.1 - The steel grades of solid wheels shall be marked on the axle ring or in another suitable place.

7.3.2.2 - When wheelsets equipped with solid wheels of grades R2, R3, R8 and R9 undergo their first inspection, they shall be stamped with a triangular tin stamp showing the steel grade. This stamp shall be placed next to the bolt securing the cover of the axle-box housing in order that the wheelset may be easily identified.

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8 - Treatment of block-braked solid wheels

8.1 - Block-braked solid wheels of steel grades R6 and R7 should be treated as shown in the flow= chart in Appendix F - page 35 when thermal damage has been sustained.

8.2 - The following limit values shall apply for residual tensile stresses in the tyred rim of category-2 wheels:

- 300 MPa for solid wheels with unknown toughness value;

- 400 MPa for solid wheels whose toughness value is (or is presumed to be) compliant with the conditions of *ERRI report B 169/RP 8, point 5.2*. They shall also apply in the case of existing wheels for which samplings have shown that these conditions are fulfilled.

8.3 - Wheels in respect of which these values are exceeded shall be destroyed, or reconditioned.

8.4 - Wheels on which stress measurements cannot be carried out shall be destroyed.

o # 9 - Marking of solid wheels resistant to high thermal loadings

Block-braked solid wheels R6 and R7 which are compliant with *UIC Leaflet 510-5* - even after a brake failure - shall not require any specific treatment even if signs of overheating are observed; they do not even need to be scrapped.

Wheels exposed to high thermal stesses should be marked in accordance with Appendix H - page 37.

Appendix A - Descriptions concerning the wheel running profile

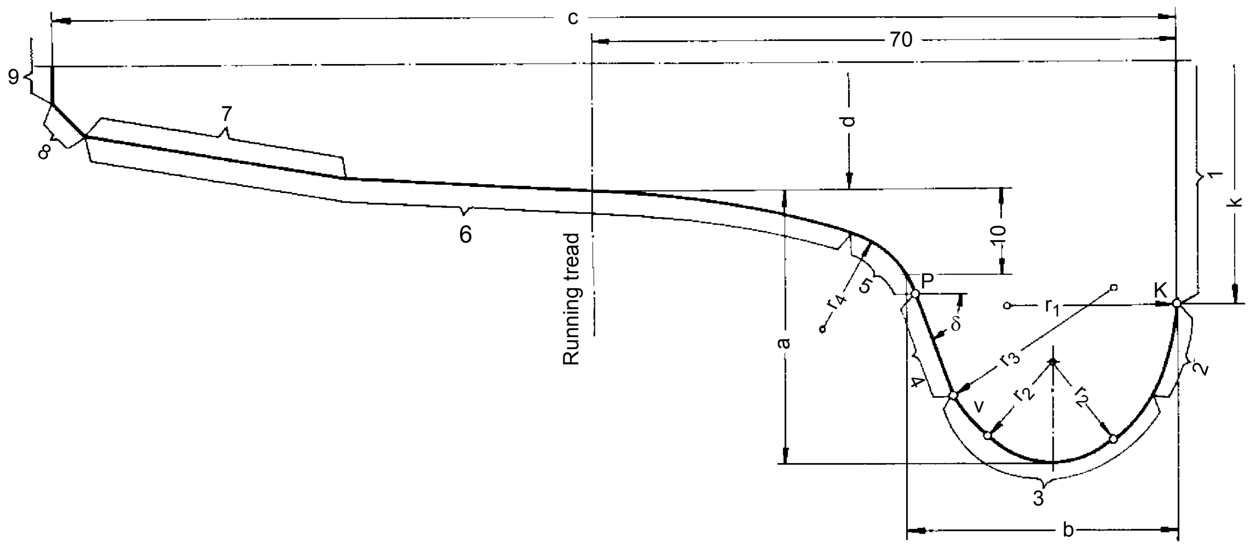


Fig. 1 - Wheel running profile

Table 1 : Descriptions concerning the wheel running profile

Reference figure	Description of wheel-profile zone	Reference letter	
1	Internal surface of rim-tyre	a	Flange height
	Internal surface of tyre		
2	Internal surface of flange	b	Flange thickness
3	Top of flange	c	Width of rim-tyre
			Width of tyre
4	External surface of flange	d	Diameter of running tread
5	Running profile fillet	r_1, r_2, r_3	Radii of rounded end of flange
6	Running surface	r_4	Radius of running profile fillet
7	Slope of external section of running surface	δ	Angle of external surface of flange
8	External bevel of running profile		
9	External surface of rim-tyre		
	External surface of tyre		

Appendix B - UIC/ERRI - Profiles of running surfaces

B.1 - UIC-ERRI profile: wheels with a diameter between D = 1 000 mm and d = 760 mm (flange height: 28 mm)

B.1.1 - Profile

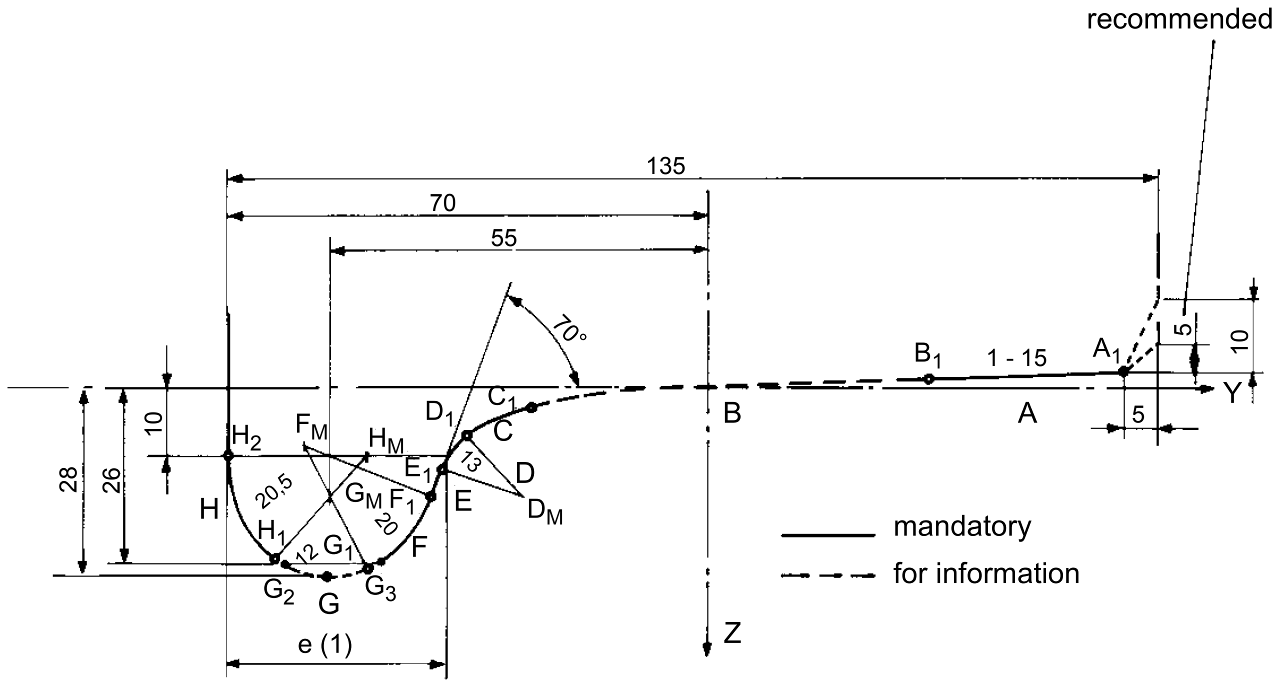


Fig. 2 - Profile for wheels with a diameter D = 1 000 mm and d = 760 mm

(1) See point 1.3.2 - page 3 of this leaflet.

Zone A	$Z = 1{,}364\ 323\ 640 - 0{,}066\ 666\ 667\ y$
Zone B	$Z = 0 - 3{,}358\ 537\ 058 \cdot 10^{-2}\ y + 1{,}565\ 681\ 624 \cdot 10^{-3}y^2 - 2{,}810\ 427\ 944 \cdot 10^{-5}y^3 + 5{,}844\ 240\ 864 \cdot 10^{-8}y^4 - 1{,}562\ 379\ 023 \cdot 10^{-8}y^5 + 5{,}309\ 217\ 349 \cdot 10^{-15}y^6 - 5{,}957\ 839\ 843 \cdot 10^{-12}y^7 + 2{,}646\ 656\ 573 \cdot 10^{-13}y^8$
Zone C	$Z = -4{,}320\ 221\ 063 \cdot 10^{+3} - 1{,}038\ 384\ 026 \cdot 10^{+3}y - 1{,}065\ 501\ 873 \cdot 10^{+2}y^2 - 6{,}051\ 367\ 875 \cdot 10^{0}y^3 - 2{,}054\ 332\ 446 \cdot 10^{-1}y^4 - 4{,}169\ 739\ 389 \cdot 10^{-3}y^5 - 4{,}687\ 195\ 829 \cdot 10^{-5}y^6 - 2{,}252\ 755\ 540 \cdot 10^{-7}y^7$
Zone D	$Z = +\ 16{,}446 - \sqrt{13^2 - (y + 26{,}210\ 665)^2}$
Zone E	$Z = +\ 93{,}576\ 667\ 419 - 2{,}747\ 477\ 419 \cdot y$
Zone F	$Z = +\ 8{,}834\ 924\ 130 + \sqrt{20^2 - (y + 58,\ 558\ 326\ 413)^2}$
Zone G	$Z = +\ 16 + \sqrt{12^2 - (y + 55)^2}$
Zone H	$Z = +\ 9{,}519\ 259\ 302 + \sqrt{20,\ 5^2 - (y + 49,\ 5)^2}$

Zone of validity	A de	y = + 60	to	y = + 32,157 96
	B von	y = + 32,157 96		y = - 26
	C from	y = - 26		y = -35
	D	y = - 35		y = - 38,426 669 071
	E	y = - 38,426 669 071		y = - 39,764 473 993
	F	y = - 39,764 473 993		y = - 49,662 510 381
	G	y = - 49,662 510 381		y = - 62,764 705 882
	H	y = - 62,764 705 882		y = - 70

Coordinates of the limiting points	A_1	y = + 60	Z = - 2,636
	$B_1 = A_2$	y = + 32, 158	Z = - 0,780
	$C_1 = B_2$	y = - 26	Z = + 2,741
	$D_1 = C_2$	y = - 35	Z = + 6,867
	$E_1 = D_2$	y = - 38,427	Z = + 12
	$F_1 = E_2$	y = - 39,764	Z = + 15,675
	$G_1 = F_2$	y = - 49,663	Z = + 25,748
	$H_1 = G_2$	y = - 62,765	Z = + 25,149
	H_2	y = - 70	Z = + 9,519
Coordinates of the centres of curvature	D_1	y = - 26,211	Z = + 16,446
	F_1	y = - 58,558	Z = + 8,835
	G_1	y = - 55	Z = + 16
	H_1	y = - 49,5	Z = + 9,519
Dimension q_r	10,794 mm	Face length at 70°	3,911 mm

Coordinates of the points for which the tangent shows an angle of 40° in relation to the horizontal.

External side	y = - 45,703	Z = 24,156
Internal side	y = - 62,713	Z = 25,193

B.1.2 - Mathematical representation of the "UIC-ERRI" standard profile

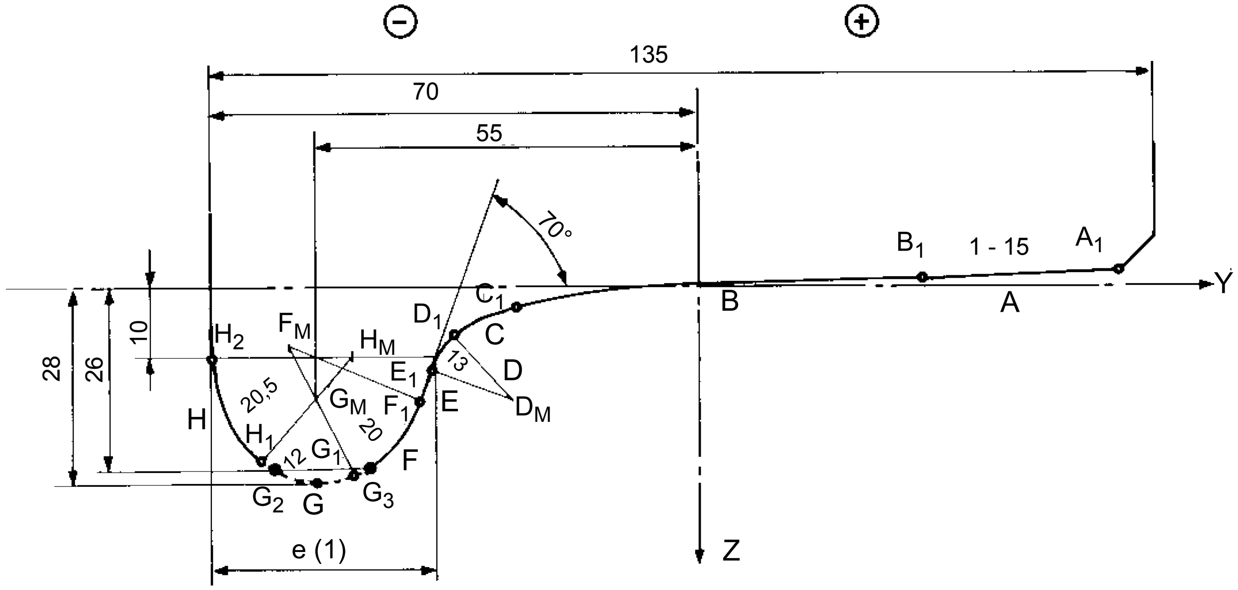


Fig. 3 - Coordinates of the standard profile for wheels with a diameter between D = 1 000 mm and d = 760 mm

(1) See point 1.3.2 - page 3 of this leaflet.

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
1	-70,000	9,519		66	-37,500	10,000	-1,7514
2	-69,500	14,019	4,4444	67	-37,000	9,194	-1,4878
3	-69,000	15,844	3,0832	68	-36,500	8,501	-1,2950
4	-68,500	17,217	2,4684	69	-36,000	7,892	-1,1444
5	-68,000	18,351	2,0947	70	-35,500	7,352	-1,0214
6	-67,500	19,330	1,8347	71	-35,000	6,867	-0,9176
7	-67,000	20,196	1,6390	72	-34,500	6,432	-0,8279
8	-66,500	20,976	1,4839	73	-34,000	6,038	-0,7493
9	-66,000	21,685	1,3563	74	-33,500	5,681	-0,6798
10	-65,500	22,335	1,2484	75	-33,000	5,357	-0,6181
11	-65,000	22,936	1,1553	76	-32,500	5,062	-0,5630
12	-64,500	23,492	1,0735	77	-32,000	4,793	-0,5140
13	-64,000	24,011	1,0006	78	-31,500	4,547	-0,4706
14	-63,500	24,494	0,9349	79	-31,000	4,321	-0,4322
15	-63,000	24,947	0,8751	80	-30,500	4,114	-0,3988
16	-62,500	25,367	0,8006	81	-30,000	3,922	-0,3698
17	-62,000	25,747	0,7182	82	-29,500	3,743	-0,3449
18	-61,500	26,087	0,6444	83	-29,000	3,576	-0,3237
19	-61,000	26,392	0,5774	84	-28,500	3,419	-0,3055
20	-60,500	26,665	0,5157	85	-28,000	3,270	-0,2899
21	-60,000	26,909	0,4583	86	-27,500	3,129	-0,2763
22	-59,500	27,124	0,4045	87	-27,000	2,994	-0,2639
23	-59,000	27,314	0,3536	88	-26,500	2,865	-0,2525
24	-58,500	27,478	0,3049	89	-26,000	2,741	-0,2417
25	-58,000	27,619	0,2582	90	-25,500	2,623	-0,2315
26	-57,500	27,737	0,2130	91	-25,000	2,509	-0,2218
27	-57,000	27,832	0,1690	92	-24,500	2,401	-0,2127
28	-56,500	27,906	0,1260	93	-24,000	2,297	-0,2041
29	-56,000	27,958	0,0836	94	-23,500	2,197	-0,1960
30	-55,500	27,990	0,0417	95	-23,000	2,101	-0,1883
31	-55,000	28,000	0,0	96	-22,500	2,008	-0,1810
32	-54,500	27,990	-0,0417	97	-22,000	1,920	-0,1741
33	-54,000	27,958	-0,0836	98	-21,500	1,834	-0,1675
34	-53,500	27,906	-0,1260	99	-21,000	1,752	-0,1613
35	-53,000	27,832	-0,1690	100	-20,500	1,673	-0,1553
36	-52,500	27,737	-0,2130	101	-20,000	1,597	-0,1497
37	-52,000	27,619	-0,2582	102	-19,500	1,523	-0,1443
38	-51,500	27,478	-0,3049	103	-19,000	1,452	-0,1392
39	-51,000	27,314	-0,3536	104	-18,500	1,384	-0,1342
40	-50,500	27,124	-0,4045	105	-18,000	1,318	-0,1295
41	-50,000	26,909	-0,4583	106	-17,500	1,254	-0,1250
42	-49,500	26,666	-0,5080	107	-17,000	1,193	-0,1207
43	-49,000	26,403	-0,5441	108	-16,500	1,134	-0,1166
44	-48,500	26,122	-0,5819	109	-16,000	1,076	-0,1126
45	-48,000	25,821	-0,6216	110	-15,500	1,021	-0,1088
46	-47,500	25,500	-0,6636	111	-15,000	0,967	-0,1051
47	-47,000	25,157	-0,7081	112	-14,500	0,916	-0,1016
48	-46,500	24,791	-0,7557	113	-14,000	0,866	-0,0981
49	-46,000	24,401	-0,8068	114	-13,500	0,818	-0,0948
50	-45,500	23,984	-1,8620	115	-13,000	0,771	-0,0916
51	-45,000	23,538	-1,9222	116	-12,500	0,726	-0,0885
52	-44,500	23,060	-1,9883	117	-12,000	0,682	-0,0855
53	-44,000	22,548	-1,0616	118	-11,500	0,640	-0,0826
54	-43,500	21,997	-1,1440	119	-11,000	0,600	-0,0798
55	-43,000	21,402	-1,2380	120	-10,500	0,561	-0,0771
56	-42,500	20,757	-1,3470	121	-10,000	0,523	-0,0744
57	-42,000	20,052	-1,4762	122	-9,500	0,486	-0,0718
58	-41,500	19,276	-1,6338	123	-9,000	0,451	-0,0693
59	-41,000	18,411	-1,8335	124	-8,500	0,417	-0,0669
60	-40,500	17,431	-2,1007	125	-8,000	0,384	-0,0645
61	-40,000	16,291	-2,4891	126	-7,500	0,352	-0,0622
62	-39,500	14,949	-2,7475	127	-7,000	0,322	-0,0599
63	-39,000	13,575	-2,7475	128	-6,500	0,292	-0,0577
64	-38,500	12,201	-2,7475	129	-6,000	0,264	-0,0556
65	-38,000	10,968	-2,1520	130	-5,500	0,237	-0,0535

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
131	-5,000	0,211	-0,0514	196	27,500	-0,521	-0,0439
132	-4,500	0,185	-0,0494	197	28,000	-0,543	-0,0464
133	-4,000	0,161	-0,0475	198	28,500	-0,567	-0,0490
134	-3,500	0,138	-0,0456	199	29,000	-0,592	-0,0515
135	-3,000	0,116	-0,0438	200	29,500	-0,619	-0,0541
136	-2,500	0,094	-0,0419	201	30,000	-0,646	-0,0566
137	-2,000	0,074	-0,0402	202	30,500	-0,675	-0,0591
138	-1,500	0,054	-0,0385	203	31,000	-0,705	-0,0615
139	-1,000	0,035	-0,0368	204	31,500	-0,737	-0,0638
140	-0,500	0,017	-0,0352	205	32,000	-0,769	-0,0660
141	0,0	0,0	-0,0336	206	32,500	-0,802	-0,0667
142	0,500	-0,016	-0,0320	207	33,000	-0,836	-0,0667
143	1,000	-0,032	-0,0305	208	33,500	-0,869	-0,0667
144	1,500	-0,047	-0,0291	209	34,000	-0,902	-0,0667
145	2,000	-0,061	-0,0277	210	34,500	-0,936	-0,0667
146	2,500	-0,075	-0,0263	211	35,000	-0,969	-0,0667
147	3,000	-0,087	-0,0250	212	35,500	-1,002	-0,0667
148	3,500	-0,100	-0,0237	213	36,000	-1,036	-0,0667
149	4,000	-0,111	-0,0224	214	36,500	-1,069	-0,0667
150	4,500	-0,122	-0,0212	215	37,000	-1,102	-0,0667
151	5,000	-0,132	-0,0201	216	37,500	-1,136	-0,0667
152	5,500	-0,142	-0,0189	217	38,000	-1,169	-0,0667
153	6,000	-0,151	-0,0179	218	38,500	-1,202	-0,0667
154	6,500	-0,160	-0,0169	219	39,000	-1,236	-0,0667
155	7,000	-0,168	-0,0159	220	39,500	-1,269	-0,0667
156	7,500	-0,176	-0,0150	221	40,000	-1,302	-0,0667
157	8,000	-0,183	-0,0141	222	40,500	-1,336	-0,0667
158	8,500	-0,190	-0,0133	223	41,000	-1,369	-0,0667
159	9,000	-0,196	-0,0126	224	41,500	-1,402	-0,0667
160	9,500	-0,203	-0,0119	225	42,000	-1,436	-0,0667
161	10,000	-0,208	-0,0113	226	42,500	-1,469	-0,0667
162	10,500	-0,214	-0,0107	227	43,000	-1,502	-0,0667
163	11,000	-0,219	-0,0102	228	43,500	-1,536	-0,0667
164	11,500	-0,224	-0,0098	229	44,000	-1,569	-0,0667
165	12,000	-0,229	-0,0094	230	44,500	-1,602	-0,0667
166	12,500	-0,234	-0,0091	231	45,000	-1,636	-0,0667
167	13,000	-0,238	-0,0089	232	45,500	-1,669	-0,0667
168	13,500	-0,242	-0,0088	233	46,000	-1,702	-0,0667
169	14,000	-0,247	-0,0087	234	46,500	-1,736	-0,0667
170	14,500	-0,251	-0,0088	235	47,000	-1,769	-0,0667
171	15,000	-0,256	-0,0089	236	47,500	-1,802	-0,0667
172	15,500	-0,260	-0,0091	237	48,000	-1,836	-0,0667
173	16,000	-0,265	-0,0094	238	48,500	-1,869	-0,0667
174	16,500	-0,269	-0,0097	239	49,000	-1,902	-0,0667
175	17,000	-0,274	-0,0102	240	49,500	-1,936	-0,0667
176	17,500	-0,280	-0,0108	241	50,000	-1,969	-0,0667
177	18,000	-0,285	-0,0115	242	50,500	-2,002	-0,0667
178	18,500	-0,291	-0,0123	243	51,000	-2,036	-0,0667
179	19,000	-0,298	-0,0132	244	51,500	-2,069	-0,0667
180	19,500	-0,304	-0,0142	245	52,000	-2,102	-0,0667
181	20,000	-0,312	-0,0153	246	52,500	-2,136	-0,0667
182	20,500	-0,320	-0,0165	247	53,000	-2,169	-0,0667
183	21,000	-0,328	-0,0178	248	53,500	-2,202	-0,0667
184	21,500	-0,338	-0,0192	249	54,000	-2,236	-0,0667
185	22,000	-0,348	-0,0208	250	54,500	-2,269	-0,0667
186	22,500	-0,358	-0,0224	251	55,000	-2,302	-0,0667
187	23,000	-0,370	-0,0241	252	55,500	-2,336	-0,0667
188	23,500	-0,382	-0,0260	253	56,000	-2,369	-0,0667
189	24,000	-0,396	-0,0279	254	56,500	-2,402	-0,0667
190	24,500	-0,410	-0,0300	255	57,000	-2,436	-0,0667
191	25,000	-0,426	-0,0321	256	57,500	-2,469	-0,0667
192	25,500	-0,443	-0,0343	257	58,000	-2,502	-0,0667
193	26,000	-0,460	-0,0366	258	58,500	-2,536	-0,0667
194	26,500	-0,479	-0,0390	259	59,000	-2,569	-0,0667
195	27,000	-0,499	-0,0414	260	59,500	-2,602	-0,0667

B.2 - UIC-ERRI profile: wheels with a diameter between D = 760 mm and d = 630 mm (flange height: 30 mm)

B.2.1 - Profile

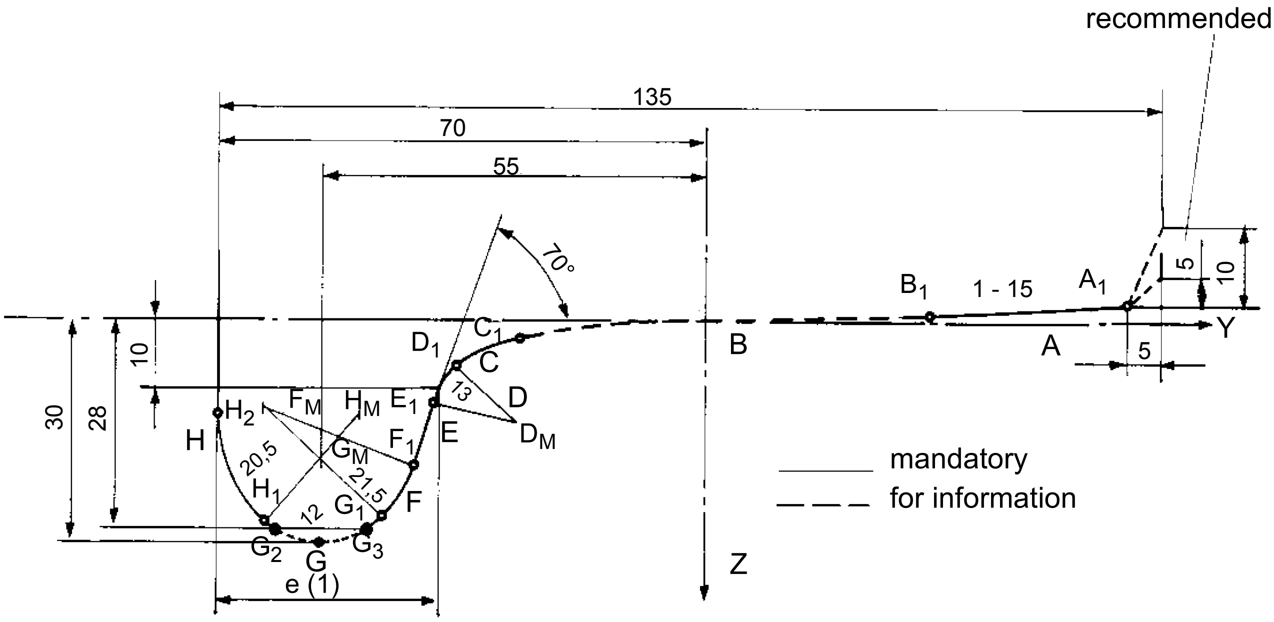


Fig. 4 - Profile for wheels with a diameter D = 760 mm and d = 630 mm

(1) See point 1.3.2 - page 3 of this leaflet.

Zone A	$Z = 1{,}364\ 323\ 640 - 0{,}066\ 666\ 667\ y$
Zone B	$Z = 0 - 3{,}358\ 537\ 058 \cdot 10^{-2}\ y + 1{,}565\ 681\ 624 \cdot 10^{-3}y^2 - 2{,}810\ 427\ 944 \cdot 10^{-5}y^3 + 5{,}844\ 240\ 864 \cdot 10^{-8}y^4 - 1{,}562\ 379\ 023 \cdot 10^{-8}y^5 + 5{,}309\ 217\ 349 \cdot 10^{-15}y^6 - 5{,}957\ 839\ 843 \cdot 10^{-12}y^7 + 2{,}646\ 656\ 573 \cdot 10^{-13}y^8$
Zone C	$Z = -4{,}320\ 221\ 063 \cdot 10^{+3} - 1{,}038\ 384\ 026 \cdot 10^{+3}y - 1{,}065\ 501\ 873 \cdot 10^{+2}y^2 - 6{,}051\ 367\ 875 \cdot 10^{0}y^3 - 2{,}054\ 332\ 446 \cdot 10^{-1}y^4 - 4{,}169\ 739\ 389 \cdot 10^{-3}y^5 - 4{,}687\ 195\ 829 \cdot 10^{-5}y^6 - 2{,}252\ 755\ 540 \cdot 10^{-7}y^7$
Zone D	$Z = +\ 16{,}446 - \sqrt{13^2 - (y + 26{,}210\ 665)^2}$
Zone E	$Z = +\ 93{,}576\ 667\ 419 - 2{,}747\ 477\ 419\ .\ y$
Zone F	$Z = +\ 10{,}425\ 416 + \sqrt{21,5^2 - (y + 60,733\ 329)^2}$
Zone G	$Z = 18 + \sqrt{12^2 - (y + 55)^2}$
Zone> H	$Z = +\ 11{,}519\ 259\ 302 + \sqrt{20,5^2 - (y + 49,5)^2}$

Zone of validity	A de	y = + 60	to	y = + 32,157 96
	B von	y = + 32,157 96		y = - 26
	C from	y = - 26		y = - 35
	D	y = - 35		y = - 38,426 669 071
	E	y = - 38,426 669 071		y = - 40,530
	F	y = - 40,530		y = - 47,757 82
	G	y = - 47,757 82		y = - 62,764 705 882
	H	y = - 62,764 705 882		y = - 70

Coordinates of the limiting points	A_1	y = + 60	Z = - 2,636
	$B_1 = A_2$	y = + 32, 158	Z = - 0,780
	$C_1 = B_2$	y = - 26	Z = + 2,741
	$D_1 = C_2$	y = - 35	Z = + 6,867
	$E_1 = D_2$	y = - 38,427	Z = + 12
	$F_1 = E_2$	y = - 40,530	Z = + 17,779
	$G_1 = F_2$	y = - 47,758	Z = + 27,568
	$H_1 = G_2$	y = - 62,765	Z = + 29,149
	H_2	y = - 70	Z = + 11,519

Coordinates of the centres of curvature	D_M	y = - 26,211	Z = + 16,446
	F_M	y = - 60,733	Z = + 10,425
	G_M	y = - 55	Z = + 18
	H_M	y = - 49,5	Z = + 11,519

Dimension q_r	10,867 mm	Face length at 70°	6,150 mm

Coordinates of the points for which the tangent shows an angle of 40° in relation to the horizontal.

External side	y = - 47,287	Z = 29,193
Internal side	y = - 62,713	Z = 29,193

B.2.2 - Mathematical representation of the "UIC-ERRI" standard profile

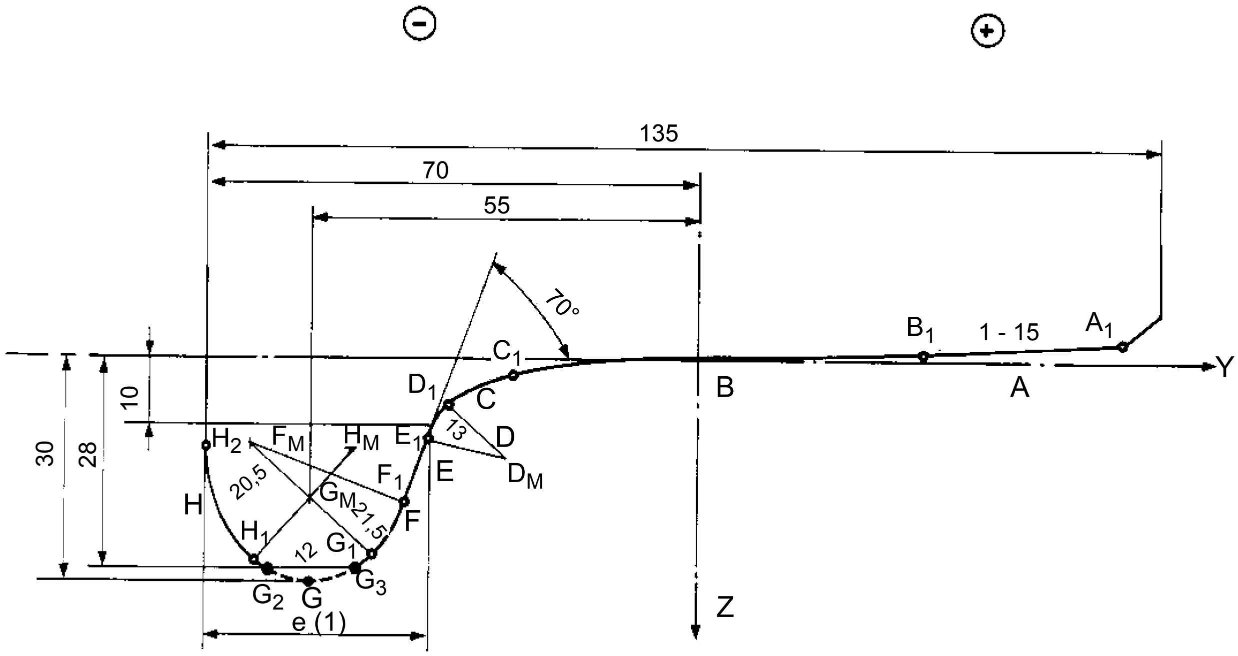


Fig. 5 - Coordinates of the standard profile for wheels with a diameter between D = 760 mm and d = 630 mm

(1) See point 1.3.2 - page 3 of this leaflet.

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
1	-70,000	11,519		66	-37,500	10,000	-1,7514
2	-69,500	16,019	4,4444	67	-37,000	9,194	-1,4878
3	-69,000	17,844	3,0832	68	-36,500	8,501	-1,2950
4	-68,500	19,217	2,4684	69	-36,000	7,892	-1,1444
5	-68,000	20,351	2,0947	70	-35,500	7,352	-1,0214
6	-67,500	22,330	1,8347	71	-35,000	6,867	-0,9176
7	-67,000	22,196	1,6390	72	-34,500	6,432	-0,8279
8	-66,500	22,976	1,4839	73	-34,000	6,038	-0,7493
9	-66,000	23,685	1,3563	74	-33,500	5,681	-0,6798
10	-65,500	24,335	1,2484	75	-33,000	5,357	-0,6181
11	-65,000	24,936	1,1553	76	-32,500	5,062	-0,5630
12	-64,500	25,492	1,0735	77	-32,000	4,793	-0,5140
13	-64,000	26,011	1,0006	78	-31,500	4,547	-0,4706
14	-63,500	26,494	0,9349	79	-31,000	4,321	-0,4322
15	-63,000	26,947	0,8751	80	-30,500	4,114	-0,3988
16	-62,500	27,370	0,8006	81	-30,000	3,922	-0,3698
17	-62,000	27,747	0,7182	82	-29,500	3,743	-0,3449
18	-61,500	28,087	0,6444	83	-29,000	3,576	-0,3237
19	-61,000	28,392	0,5774	84	-28,500	3,419	-0,3055
20	-60,500	28,665	0,5157	85	-28,000	3,270	-0,2899
21	-60,000	28,909	0,4583	86	-27,500	3,129	-0,2763
22	-59,500	29,124	0,4045	87	-27,000	2,994	-0,2639
23	-59,000	29,314	0,3536	88	-26,500	2,865	-0,2525
24	-58,500	29,478	0,3049	89	-26,000	2,741	-0,2417
25	-58,000	29,619	0,2582	90	-25,500	2,623	-0,2315
26	-57,500	29,737	0,2130	91	-25,000	2,509	-0,2218
27	-57,000	29,832	0,1690	92	-24,500	2,401	-0,2127
28	-56,500	29,906	0,1260	93	-24,000	2,297	-0,2041
29	-56,000	29,958	0,0836	94	-23,500	2,197	-0,1960
30	-55,500	29,990	0,0417	95	-23,000	2,101	-0,1883
31	-55,000	30	0,0	96	-22,500	2,008	-0,1810
32	-54,500	29,990	-0,0417	97	-22,000	1,920	-0,1741
33	-54,000	29,958	-0,0836	98	-21,500	1,834	-0,1675
34	-53,500	29,906	-0,1260	99	-21,000	1,752	-0,1613
35	-53,000	29,832	-0,1690	100	-20,500	1,673	-0,1553
36	-52,500	29,737	-0,2130	101	-20,000	1,597	-0,1497
37	-52,000	29,619	-0,2582	102	-19,500	1,523	-0,1443
38	-51,500	29,478	-0,3049	103	-19,000	1,452	-0,1392
39	-51,000	29,314	-0,3536	104	-18,500	1,384	-0,1342
40	-50,500	29,123	-0,4045	105	-18,000	1,318	-0,1295
41	-50,000	28,909	-0,4583	106	-17,500	1,254	-0,1250
42	-49,500	28,665	-0,5157	107	-17,000	1,193	-0,1207
43	-49,000	28,392	-0,5774	108	-16,500	1,134	-0,1166
44	-48,500	28,087	-0,6444	109	-16,000	1,076	-0,1126
45	-48,000	27,747	-0,7182	110	-15,500	1,071	-0,1088
46	-47,500	27,370	-0,7810	111	-15,000	0,967	-0,1051
47	-47,000	26,967	-0,8302	112	-14,500	0,916	-0,1016
48	-46,500	26,539	-0,8833	113	-14,000	0,866	-0,0981
49	-46,000	26,083	-0,9409	114	-13,500	0,818	-0,0948
50	-45,500	25,597	-1,0040	115	-13,000	0,771	-0,0916
51	-45,000	25,078	-1,0737	116	-12,500	0,726	-0,0885
52	-44,500	24,522	-1,1515	117	-12,000	0,682	-0,0855
53	-44,000	23,925	-1,2395	118	-11,500	0,640	-0,0826
54	-43,500	23,281	-1,3406	119	-11,000	0,600	-0,0798
55	-43,000	22,582	-1,4588	120	-10,500	0,561	-0,0771
56	-42,500	21,818	-1,6004	121	-10,000	0,523	-0,0744
57	-42,000	20,976	-1,7756	122	-9,500	0,486	-0,0718
58	-41,500	20,034	-2,0017	123	-9,000	0,451	-0,0693
59	-41,000	18,960	-2,3121	124	-8,500	0,417	-0,0669
60	-40,500	17,696	-2,7475	125	-8,000	0,384	-0,0645
61	-40,000	16,322	-2,7475	126	-7,500	0,352	-0,0622
62	-39,500	14,949	-2,7475	127	-7,000	0,322	-0,0599
63	-39,000	13,575	-2,7475	128	-6,500	0,292	-0,0577
64	-38,500	12,201	-2,7475	129	-6,000	0,264	-0,0556
65	-38,000	10,968	-2,1520	130	-5,500	0,237	-0,0535

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
131	-5,000	0,211	-0,0514	196	27,500	-0,521	-0,0439
132	-4,500	0,135	-0,0494	197	28,000	-0,543	-0,0464
133	-4,000	0,161	-0,0475	198	28,500	-0,567	-0,0490
134	-3,500	0,138	-0,0456	199	29,000	-0,592	-0,0515
135	-3,000	0,116	-0,0438	200	29,500	-0,619	-0,0541
136	-2,500	0,094	-0,0419	201	30,000	-0,646	-0,0566
137	-2,000	0,074	-0,0402	202	30,500	-0,675	-0,0591
138	-1,500	0,054	-0,0385	203	31,000	-0,705	-0,0615
139	-1,000	0,035	-0,0368	204	31,500	-0,737	-0,0638
140	-0,500	0,017	-0,0352	205	32,000	-0,769	-0,0660
141	0,0	0,0	-0,0336	206	32,500	-0,802	-0,0667
142	0,500	-0,016	-0,0320	207	33,000	-0,836	-0,0667
143	1,000	-0,032	-0,0305	208	33,500	-0,869	-0,0667
144	1,500	-0,047	-0,0291	209	34,000	-0,902	-0,0667
145	2,000	-0,061	-0,0277	210	34,500	-0,936	-0,0667
146	2,500	-0,075	-0,0263	211	35,000	-0,969	-0,0667
147	3,000	-0,087	-0,0250	212	35,500	-1,002	-0,0667
148	3,500	-0,100	-0,0237	213	36,000	-1,036	-0,0667
149	4,000	-0,111	-0,0224	214	36,500	-1,069	-0,0667
150	4,500	-0,122	-0,0212	215	37,000	-1,102	-0,0667
151	5,000	-0,132	-0,0201	216	37,500	-1,136	-0,0667
152	5,500	-0,142	-0,0189	217	38,000	-1,169	-0,0667
153	6,000	-0,151	-0,0179	218	38,500	-1,202	-0,0667
154	6,500	-0,160	-0,0169	219	39,000	-1,236	-0,0667
155	7,000	-0,168	-0,0159	220	39,500	-1,269	-0,0667
156	7,500	-0,176	-0,0150	221	40,000	-1,302	-0,0667
157	8,000	-0,183	-0,0141	222	40,500	-1,336	-0,0667
158	8,500	-0,190	-0,0133	223	41,000	-1,369	-0,0667
159	9,000	-0,196	-0,0126	224	41,500	-1,402	-0,0667
160	9,500	-0,203	-0,0119	225	42,000	-1,436	-0,0667
161	10,000	-0,208	-0,0113	226	42,500	-1,469	-0,0667
162	10,500	-0,214	-0,0107	227	43,000	-1,502	-0,0667
163	11,000	-0,219	-0,0102	228	43,500	-1,536	-0,0667
164	11,500	-0,224	-0,0098	229	44,000	-1,569	-0,0667
165	12,000	-0,229	-0,0094	230	44,500	-1,602	-0,0667
166	12,500	-0,234	-0,0091	231	45,000	-1,636	-0,0667
167	13,000	-0,238	-0,0089	232	45,500	-1,669	-0,0667
168	13,500	-0,242	-0,0088	233	46,000	-1,702	-0,0667
169	14,000	-0,247	-0,0087	234	46,500	-1,736	-0,0667
170	14,500	-0,251	-0,0088	235	47,000	-1,769	-0,0667
171	15,000	-0,256	-0,0089	236	47,500	-1,802	-0,0667
172	15,500	-0,260	-0,0091	237	48,000	-1,836	-0,0667
173	16,000	-0,265	-0,0094	238	48,500	-1,869	-0,0667
174	16,500	-0,269	-0,0097	239	49,000	-1,902	-0,0667
175	17,000	-0,274	-0,0102	240	49,500	-1,936	-0,0667
176	17,500	-0,280	-0,0108	241	50,000	-1,969	-0,0667
177	18,000	-0,285	-0,0115	242	50,500	-2,002	-0,0667
178	18,500	-0,291	-0,0123	243	51,000	-2,036	-0,0667
179	19,000	-0,298	-0,0132	244	51,500	-2,069	-0,0667
180	19,500	-0,304	-0,0142	245	52,000	-2,102	-0,0667
181	20,000	-0,312	-0,0153	246	52,500	-2,136	-0,0667
182	20,500	-0,320	-0,0165	247	53,000	-2,169	-0,0667
183	21,000	-0,328	-0,0178	248	53,500	-2,202	-0,0667
184	21,500	-0,338	-0,0192	249	54,000	-2,236	-0,0667
185	22,000	-0,348	-0,0208	250	54,500	-2,269	-0,0667
186	22,500	-0,358	-0,0224	251	55,000	-2,302	-0,0667
187	23,000	-0,370	-0,0241	252	55,500	-2,336	-0,0667
188	23,500	-0,382	-0,0260	253	56,000	-2,369	-0,0667
189	24,000	-0,396	-0,0279	254	56,500	-2,402	-0,0667
190	24,500	-0,410	-0,0300	255	57,000	-2,436	-0,0667
191	25,000	-0,426	-0,0321	256	57,500	-2,469	-0,0667
192	25,500	-0,443	-0,0343	257	58,000	-2,502	-0,0667
193	26,000	-0,460	-0,0366	258	58,500	-2,536	-0,0667
194	26,500	-0,479	-0,0390	259	59,000	-2,569	-0,0667
195	27,000	-0,499	-0,0414	260	59,500	-2,602	-0,0667

B.3 - UIC-ERRI profile: wheels with a diameter between D = 630 mm and d = 330 mm (flange height: 32 mm)

B.3.1 - Standard profile

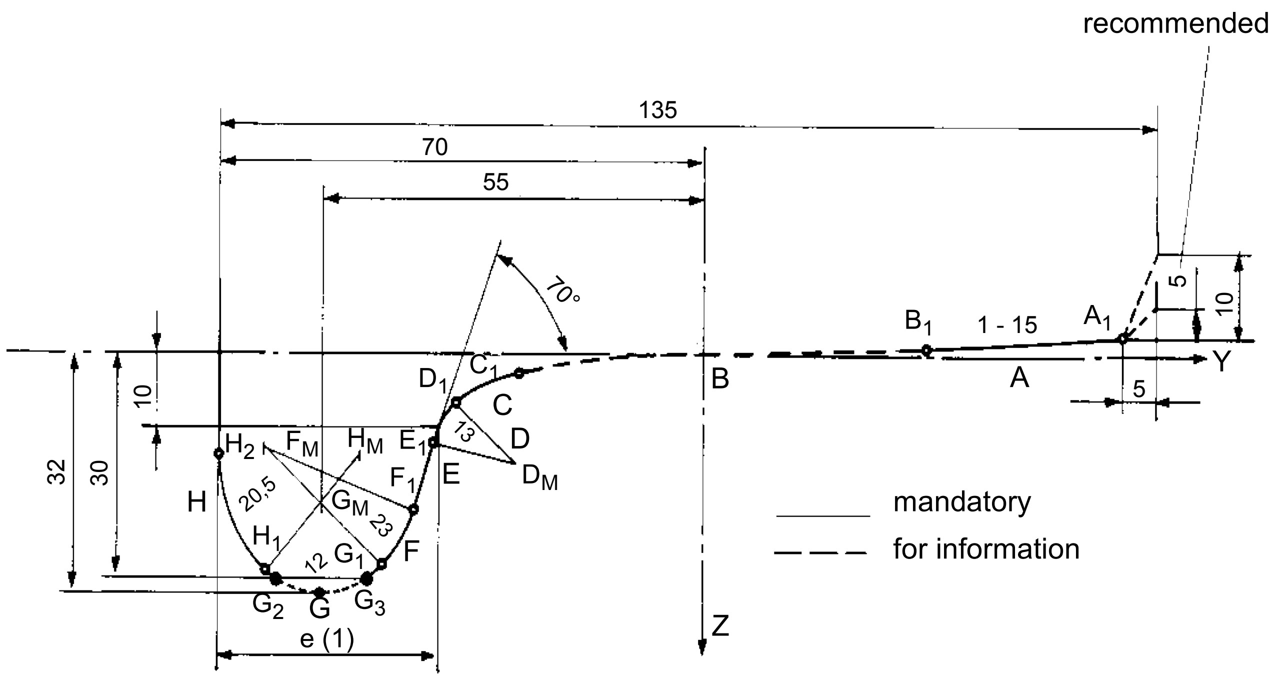


Fig. 6 - Profile for wheels with a diameter D = 630 mm and d = 330 mm

(1) See point 1.3.2 - page 3 of this leaflet.

Zone A	$Z = 1{,}364\ 323\ 640 - 0{,}066\ 666\ 667\ y$
Zone B	$Z = 0 - 3{,}358\ 537\ 058 \cdot 10^{-2}\ y + 1{,}565\ 681\ 624 \cdot 10^{-3}y^2 - 2{,}810\ 427\ 944 \cdot 10^{-5}y^3 + 5{,}844\ 240\ 864 \cdot 10^{-8}y^4 - 1{,}562\ 379\ 023 \cdot 10^{-8}y^5 + 5{,}309\ 217\ 349 \cdot 10^{-15}y^6 - 5{,}957\ 839\ 843 \cdot 10^{-12}y^7 + 2{,}646\ 656\ 573 \cdot 10^{-13}y^8$
Zone C	$Z = -4{,}320\ 221\ 063 \cdot 10^{+3} - 1{,}038\ 384\ 026 \cdot 10^{+3}y - 1{,}065\ 501\ 873 \cdot 10^{+2}y^2 - 6{,}051\ 367\ 875 \cdot 10^{0}y^3 - 2{,}054\ 332\ 446 \cdot 10^{-1}y^4 - 4{,}169\ 739\ 389 \cdot 10^{-3}y^5 - 4{,}687\ 195\ 829 \cdot 10^{-5}y^6 - 2{,}252\ 755\ 540 \cdot 10^{-7}y^7$
Zone D	$Z = +\ 16{,}446 - \sqrt{13^2 - (y + 26{,}210\ 665)^2}$
Zone E	$Z = +\ 93{,}576\ 667\ 419 - 2{,}747\ 477\ 419.\ y$
Zone F	$Z = +\ 12{,}568\ 005\ 260 + \sqrt{23^2 - (y + 63{,}109\ 590\ 233)^2}$
Zone G	$Z = +\ 20 + \sqrt{12^2 - (y + 55)^2}$
Zone H	$Z = +\ 13{,}519\ 259\ 302 + \sqrt{20,5^2 - (y + 49,5)^2}$

Zone of validity	A de	y = + 60	to	y = + 32,157 96
	B von	y = + 32,157 96		y = - 26
	C from	y = - 26		y = - 35
	D	y = - 35		y = - 38,426 669 071
	E	y = - 38,426 669 071		y = - 41,496 659 950
	F	y = - 41,496 659 950		y = - 46,153 174 292
	G	y = - 46,153 174 292		y = - 62,764 705 882
	H	y = - 62,764 705 882		y = - 70

Coordinates of the limiting points	A_1	y = + 60	Z = - 2,636
	$B_1 = A_2$	y = + 32, 158	Z = - 0,780
	$C_1 = B_2$	y = - 26	Z = + 2,741
	$D_1 = C_2$	y = - 35	Z = + 6,867
	$E_1 = D_2$	y = - 38,427	Z = + 12
	$F_1 = E_2$	y = - 41,497	Z = + 20,434
	$G_1 = F_2$	y = - 46,153	Z = + 28,108
	$H_1 = G_2$	y = - 62,765	Z = + 29,149
	H_2	y = - 70	Z = + 13,519

Coordinates of the centres of curvature	D_M	y = - 26,211	Z = + 16,446
	F_M	y = - 63,110	Z = + 12,558
	G_M	y = - 55	Z = + 20
	H_M	y = - 49,5	Z = + 13,519

Dimension q_r 10,807 mm Face length at 70° 8,976 mm

Coordinates of the points for which the tangent shows an angle of 40° in relation to the horizontal.

External side	y = - 47,287	Z = 29,193
Internal side	y = - 62,713	Z = 29,193

B.3.2 - Mathematical representation of the "UIC-ERRI" standard profile

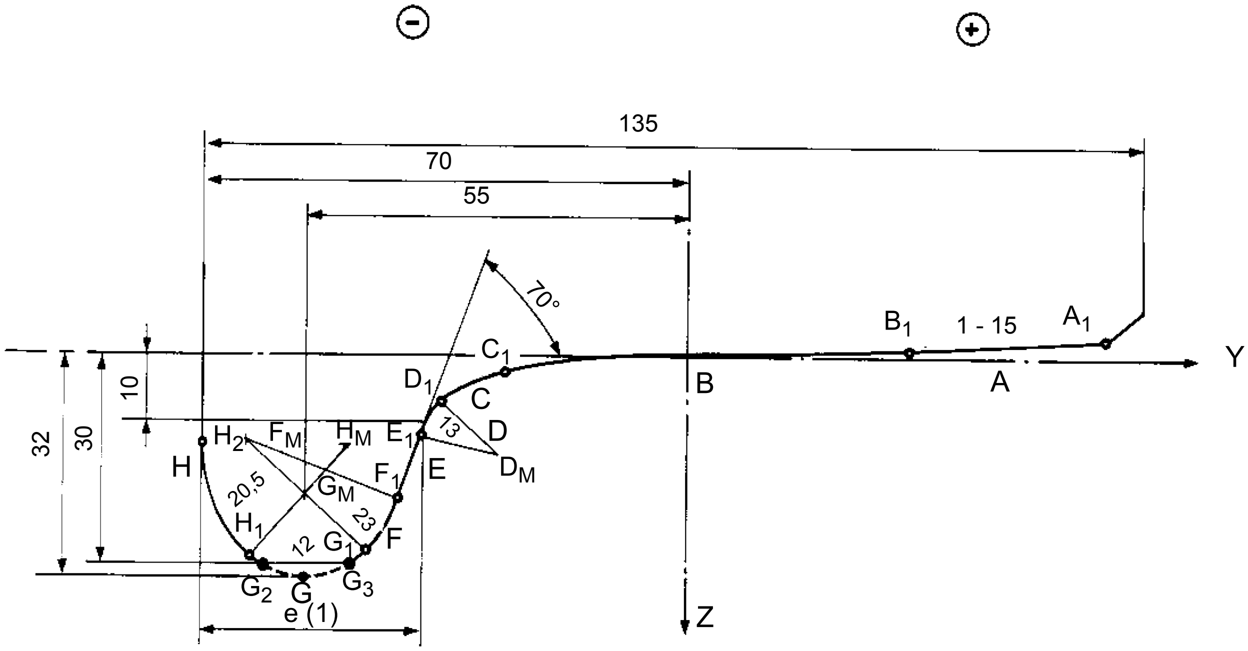


Fig. 7 - Coordinates of the standard profile for wheels with a diameter between D = 630 mm and d = 330 mm

(1) See point 1.3.2 - page 3 of this leaflet.

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
1	-70,000	13,519		66	-37,500	10,000	-1,7514
2	-69,500	18,019	4,4444	67	-37,000	9,194	-1,4878
3	-69,000	19,844	3,0832	68	-36,500	8,501	-1,2950
4	-68,500	21,217	2,4684	69	-36,000	7,892	-1,1444
5	-68,000	22,351	2,0947	70	-35,500	7,352	-1,0214
6	-67,500	23,330	1,8347	71	-35,000	6,867	-0,9176
7	-67,000	24,196	1,6390	72	-34,500	6,432	-0,8279
8	-66,500	24,976	1,4839	73	-34,000	6,038	-0,7493
9	-66,000	25,685	1,3563	74	-33,500	5,681	-0,6798
10	-65,500	26,335	1,2484	75	-33,000	5,357	-0,6181
11	-65,000	26,936	1,1553	76	-32,500	5,062	-0,5630
12	-64,500	27,492	1,0735	77	-32,000	4,793	-0,5140
13	-64,000	28,011	1,0006	78	-31,500	4,547	-0,4706
14	-63,500	28,494	0,9349	79	-31,000	4,321	-0,4322
15	-63,000	28,947	0,8751	80	-30,500	4,114	-0,3988
16	-62,500	29,367	0,8006	81	-30,000	3,922	-0,3698
17	-62,000	29,747	0,7182	82	-29,500	3,743	-0,3449
18	-61,500	30,087	0,6444	83	-29,000	3,576	-0,3237
19	-61,000	30,392	0,5774	84	-28,500	3,419	-0,3055
20	-60,500	30,665	0,5157	85	-28,000	3,270	-0,2899
21	-60,000	30,909	0,4583	86	-27,500	3,129	-0,2763
22	-59,500	31,124	0,4045	87	-27,000	2,994	-0,2639
23	-59,000	31,314	0,3536	88	-26,500	2,865	-0,2525
24	-58,500	31,478	0,3049	89	-26,000	2,741	-0,2417
25	-58,000	31,619	0,2582	90	-25,500	2,623	-0,2315
26	-57,500	31,737	0,2130	91	-25,000	2,509	-0,2218
27	-57,000	31,832	0,1690	92	-24,500	2,401	-0,2127
28	-56,500	31,906	0,1260	93	-24,000	2,297	-0,2041
29	-56,000	31,958	0,0836	94	-23,500	2,197	-0,1960
30	-55,500	31,990	0,0417	95	-23,000	2,101	-0,1883
31	-55,000	32,000	0,0	96	-22,500	2,008	-0,1810
32	-54,500	31,990	-0,0417	97	-22,000	1,920	-0,1741
33	-54,000	31,958	-0,0836	98	-21,500	1,834	-0,1675
34	-53,500	31,906	-0,1260	99	-21,000	1,752	-0,1613
35	-53,000	31,832	-0,1690	100	-20,500	1,673	-0,1553
36	-52,500	31,737	-0,2130	101	-20,000	1,597	-0,1497
37	-52,000	31,619	-0,2582	102	-19,500	1,523	-0,1443
38	-51,500	31,478	-0,3049	103	-19,000	1,452	-0,1392
39	-51,000	31,314	-0,3536	104	-18,500	1,384	-0,1342
40	-50,500	31,124	-0,4045	105	-18,000	1,318	-0,1295
41	-50,000	30,909	-0,4583	106	-17,500	1,254	-0,1250
42	-49,500	30,665	-0,5157	107	-17,000	1,193	-0,1207
43	-49,000	30,392	-0,5774	108	-16,500	1,134	-0,1166
44	-48,500	30,087	0,6444	109	-16,000	1,076	-0,1126
45	-48,000	29,747	-0,7182	110	-15,500	1,071	-0,1088
46	-47,500	29,367	-0,8006	111	-15,000	0,967	-0,1051
47	-47,000	28,944	-0,8944	112	-14,500	0,916	-0,1016
48	-46,500	28,471	-1,0035	113	-14,000	0,866	-0,0981
49	-46,000	27,939	-1,1131	114	-13,500	0,818	-0,0948
50	-45,500	27,363	-1,1902	115	-13,000	0,771	-0,0916
51	-45,000	26,747	-1,2772	116	-12,500	0,726	-0,0885
52	-44,500	26,084	-1,3769	117	-12,000	0,682	-0,0855
53	-44,000	25,367	-1,4930	118	-11,500	0,640	-0,0826
54	-43,500	24,587	-1,6315	119	-11,000	0,600	-0,0798
55	-43,000	23,731	-1,8015	120	-10,500	0,561	-0,0771
56	-42,500	22,778	-2,0186	121	-10,000	0,523	-0,0744
57	-42,000	21,700	-2,3117	122	-9,500	0,486	-0,0718
58	-41,500	20,444	-2,7439	123	-9,000	0,451	-0,0693
59	-41,000	19,070	-2,7475	124	-8,500	0,417	-0,0669
60	-40,500	17,696	-2,7475	125	-8,000	0,384	-0,0645
61	-40,000	16,322	-2,7475	126	-7,500	0,352	-0,0622
62	-39,500	14,949	-2,7475	127	-7,000	0,322	-0,0599
63	-39,000	13,575	-2,7475	128	-6,500	0,292	-0,0577
64	-38,500	12,201	-2,7475	129	-6,000	0,264	-0,0556
65	-38,000	10,968	-2,1520	130	-5,500	0,237	-0,0535

NR	Y mm	Z mm	TG	NR	Y mm	Z mm	TG
131	-5,000	0,211	-0,0514	196	27,500	-0,521	-0,0439
132	-4,500	0,135	-0,0494	197	28,000	-0,543	-0,0464
133	-4,000	0,161	-0,0475	198	28,500	-0,567	-0,0490
134	-3,500	0,138	-0,0456	199	29,000	-0,592	-0,0515
135	-3,000	0,116	-0,0438	200	29,500	-0,619	-0,0541
136	-2,500	0,094	-0,0419	201	30,000	-0,646	-0,0566
137	-2,000	0,074	-0,0402	202	30,500	-0,675	-0,0591
138	-1,500	0,054	-0,0385	203	31,000	-0,705	-0,0615
139	-1,000	0,035	-0,0368	204	31,500	-0,737	-0,0638
140	-0,500	0,017	-0,0352	205	32,000	-0,769	-0,0660
141	0,0	0,0	-0,0336	206	32,500	-0,802	-0,0667
142	0,500	-0,016	-0,0320	207	33,000	-0,836	-0,0667
143	1,000	-0,032	-0,0305	208	33,500	-0,869	-0,0667
144	1,500	-0,047	-0,0291	209	34,000	-0,902	-0,0667
145	2,000	-0,061	-0,0277	210	34,500	-0,936	-0,0667
146	2,500	-0,075	-0,0263	211	35,000	-0,969	-0,0667
147	3,000	-0,087	-0,0250	212	35,500	-1,002	-0,0667
148	3,500	-0,100	-0,0237	213	36,000	-1,036	-0,0667
149	4,000	-0,111	-0,0224	214	36,500	-1,069	-0,0667
150	4,500	-0,122	-0,0212	215	37,000	-1,102	-0,0667
151	5,000	-0,132	-0,0201	216	37,500	-1,136	-0,0667
152	5,500	-0,142	-0,0189	217	38,000	-1,169	-0,0667
153	6,000	-0,151	-0,0179	218	38,500	-1,202	-0,0667
154	6,500	-0,160	-0,0169	219	39,000	-1,236	-0,0667
155	7,000	-0,168	-0,0159	220	39,500	-1,269	-0,0667
156	7,500	-0,176	-0,0150	221	40,000	-1,302	-0,0667
157	8,000	-0,183	-0,0141	222	40,500	-1,336	-0,0667
158	8,500	-0,190	-0,0133	223	41,000	-1,369	-0,0667
159	9,000	-0,196	-0,0126	224	41,500	-1,402	-0,0667
160	9,500	-0,203	-0,0119	225	42,000	-1,436	-0,0667
161	10,000	-0,208	-0,0113	226	42,500	-1,469	-0,0667
162	10,500	-0,214	-0,0107	227	43,000	-1,502	-0,0667
163	11,000	-0,219	-0,0102	228	43,500	-1,536	-0,0667
164	11,500	-0,224	-0,0098	229	44,000	-1,569	-0,0667
165	12,000	-0,229	-0,0094	230	44,500	-1,602	-0,0667
166	12,500	-0,234	-0,0091	231	45,000	-1,636	-0,0667
167	13,000	-0,238	-0,0089	232	45,500	-1,669	-0,0667
168	13,500	-0,242	-0,0088	233	46,000	-1,702	-0,0667
169	14,000	-0,247	-0,0087	234	46,500	-1,736	-0,0667
170	14,500	-0,251	-0,0088	235	47,000	-1,769	-0,0667
171	15,000	-0,256	-0,0089	236	47,500	-1,802	-0,0667
172	15,500	-0,260	-0,0091	237	48,000	-1,836	-0,0667
173	16,000	-0,265	-0,0094	238	48,500	-1,869	-0,0667
174	16,500	-0,269	-0,0097	239	49,000	-1,902	-0,0667
175	17,000	-0,274	-0,0102	240	49,500	-1,936	-0,0667
176	17,500	-0,280	-0,0108	241	50,000	-1,969	-0,0667
177	18,000	-0,285	-0,0115	242	50,500	-2,002	-0,0667
178	18,500	-0,291	-0,0123	243	51,000	-2,036	-0,0667
179	19,000	-0,298	-0,0132	244	51,500	-2,069	-0,0667
180	19,500	-0,304	-0,0142	245	52,000	-2,102	-0,0667
181	20,000	-0,312	-0,0153	246	52,500	-2,136	-0,0667
182	20,500	-0,320	-0,0165	247	53,000	-2,169	-0,0667
183	21,000	-0,328	-0,0178	248	53,500	-2,202	-0,0667
184	21,500	-0,338	-0,0192	249	54,000	-2,236	-0,0667
185	22,000	-0,348	-0,0208	250	54,500	-2,269	-0,0667
186	22,500	-0,358	-0,0224	251	55,000	-2,302	-0,0667
187	23,000	-0,370	-0,0241	252	55,500	-2,336	-0,0667
188	23,500	-0,382	-0,0260	253	56,000	-2,369	-0,0667
189	24,000	-0,396	-0,0279	254	56,500	-2,402	-0,0667
190	24,500	-0,410	-0,0300	255	57,000	-2,436	-0,0667
191	25,000	-0,426	-0,0321	256	57,500	-2,469	-0,0667
192	25,500	-0,443	-0,0343	257	58,000	-2,502	-0,0667
193	26,000	-0,460	-0,0366	258	58,500	-2,536	-0,0667
194	26,500	-0,479	-0,0390	259	59,000	-2,569	-0,0667
195	27,000	-0,499	-0,0414	260	59,500	-2,602	-0,0667

Appendix C - Profile with minimal permissible diameter following last reprofiling

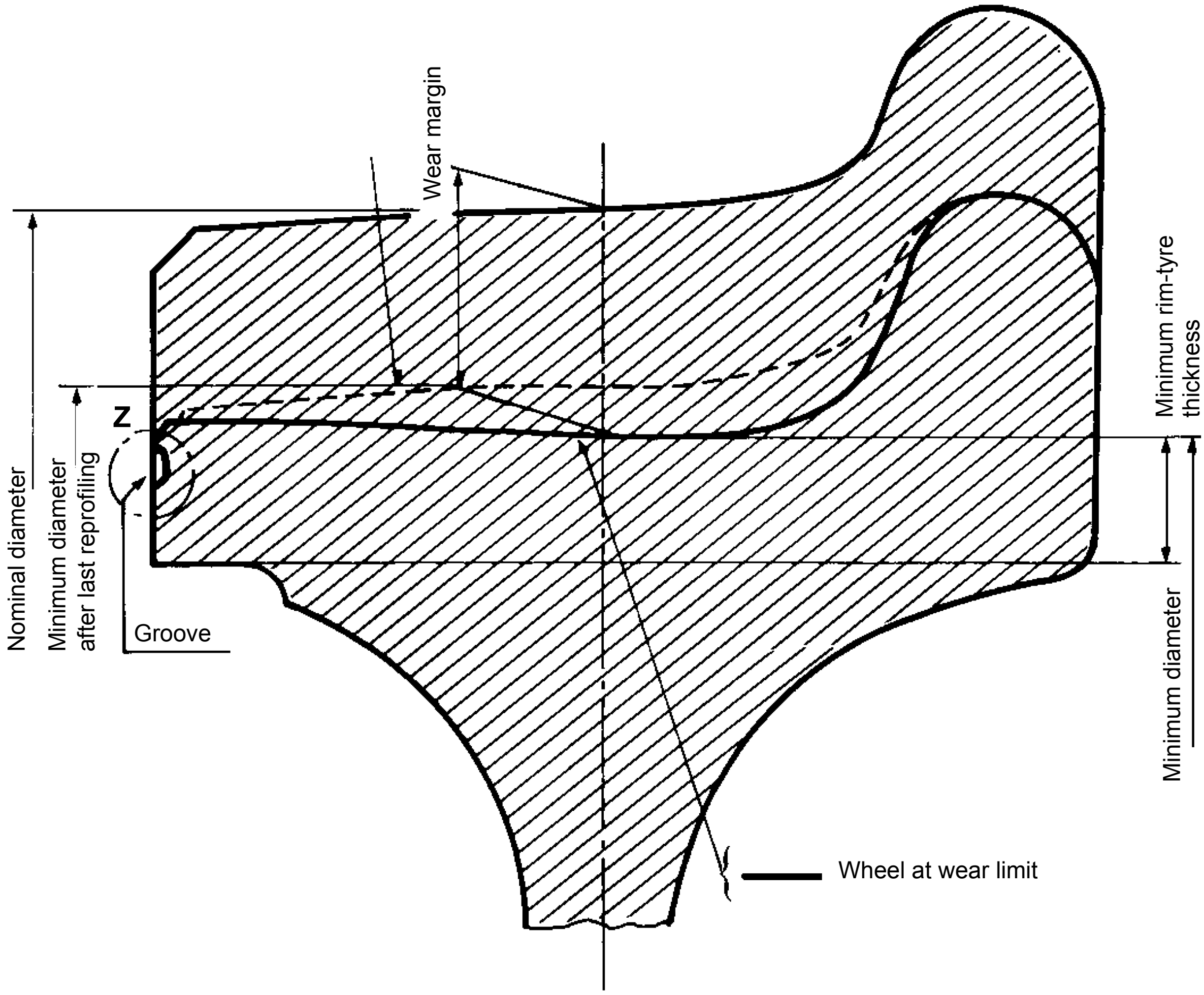


Fig. 8 - Profile with minimal permissible diameter following last reprofiling

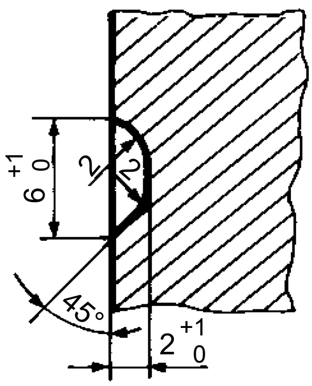


Fig. 9 - Detail Z

Appendix D - Obtuse crossings with a minimum tangent 1:9

D.1 - Positions of the measuring points

Measuring plane located 0,014 m beneath the running surface

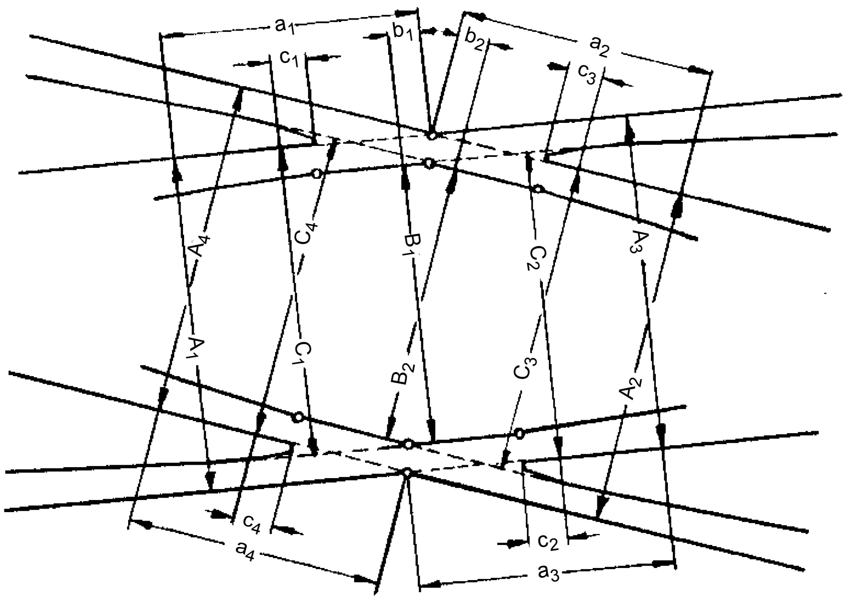


Fig. 10 - Positions of the measuring points

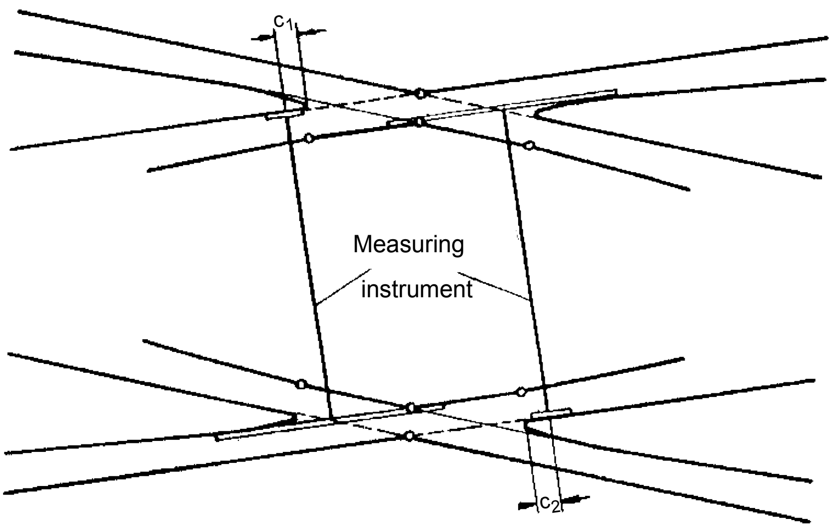


Fig. 11 - Positions of the measuring points

a_1, a_2, a_3, a_4 = 0,750 m
b_1, b_2, c_1, c_2, c_3, c_4 = 0 - 0,080 m

For Fig. 10 and 11: check the alignment of the running edges and of the check faces.

D.2 - Outline of the noses of obtuse crossings with a minimum tangent 1:9

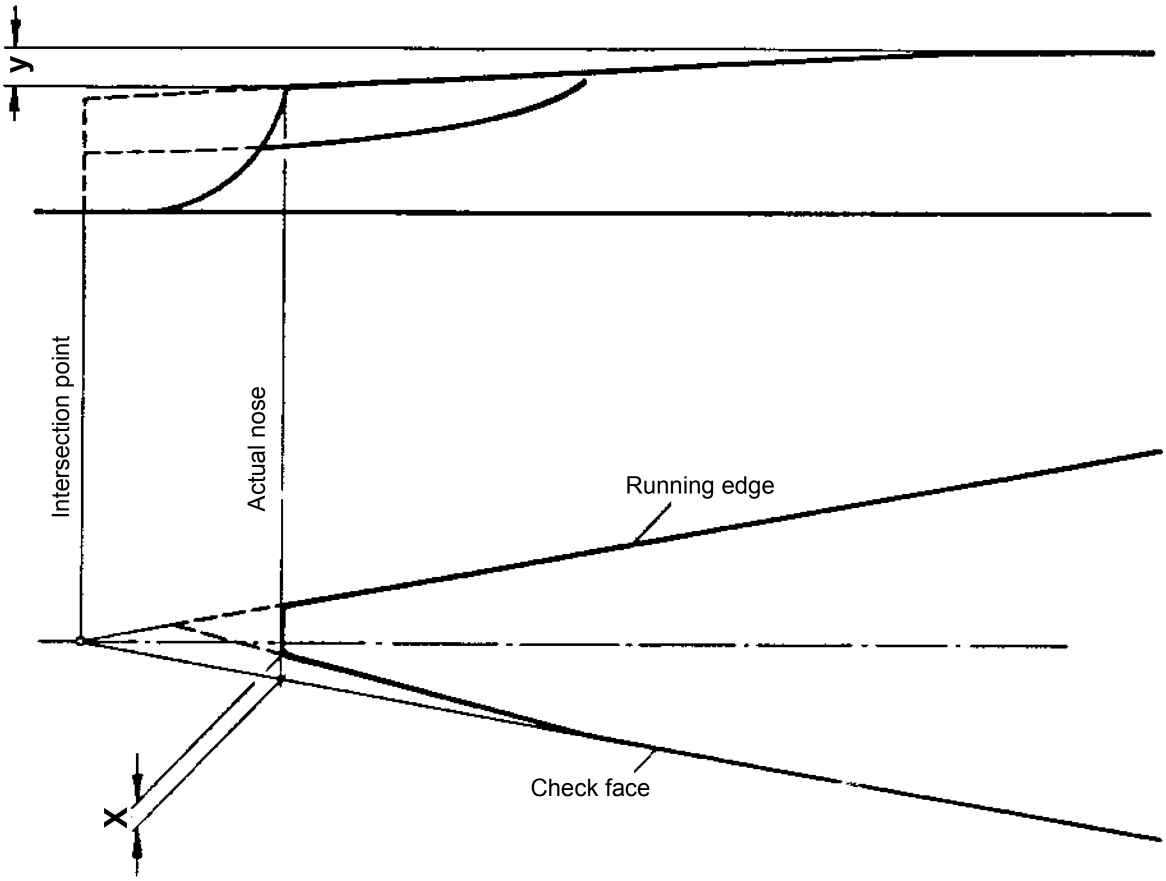
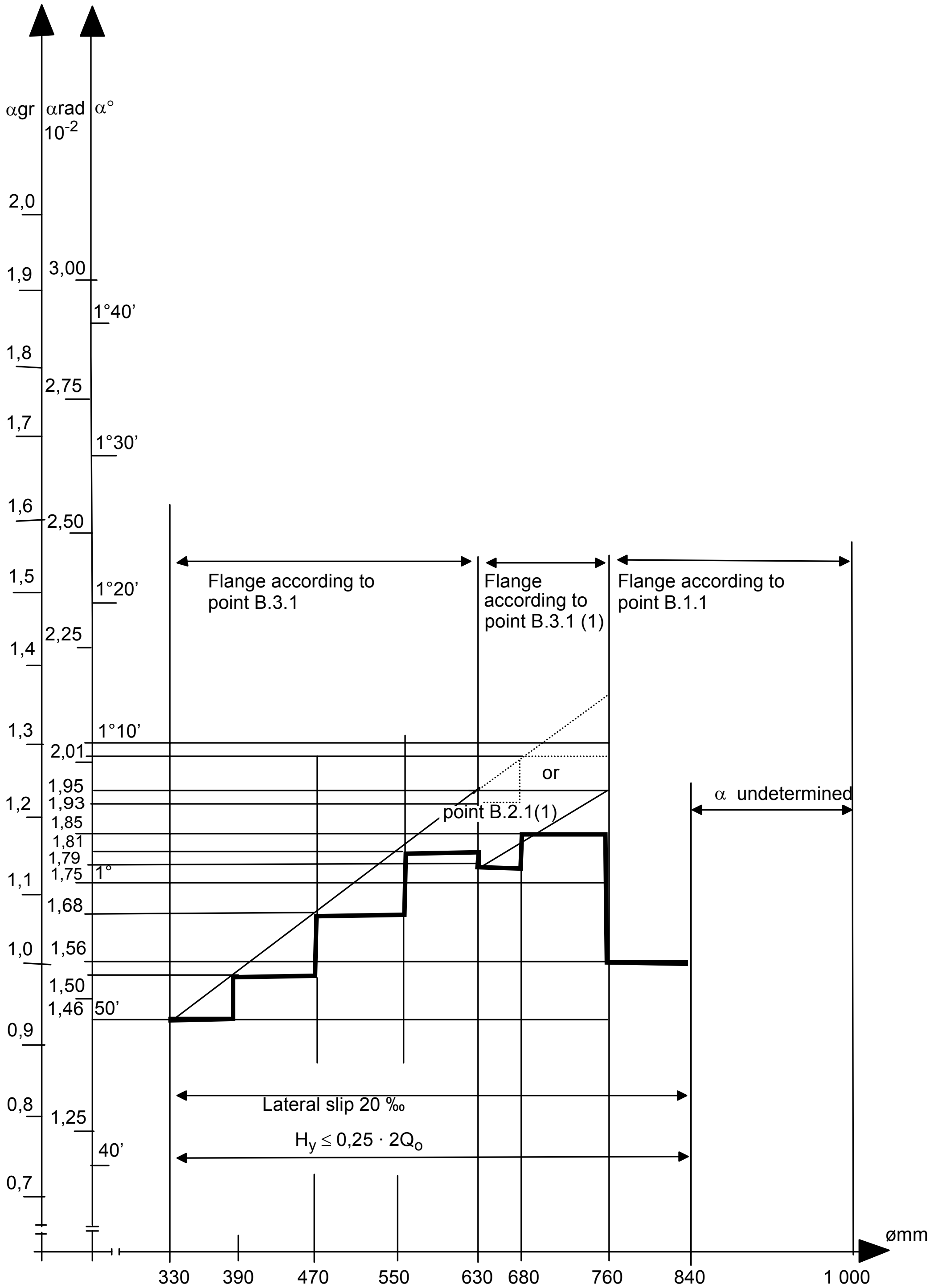


Fig. 12 - Outline of the noses of obtuse crossings

x = 0,003 m (over a length of 0,150 m)
y = 0,008 m (over a length of 0,200 to 0,500 m approximately)

Appendix E - Angle of displacement α_1 of the wheel of a free axle in relation to the wheel diameter

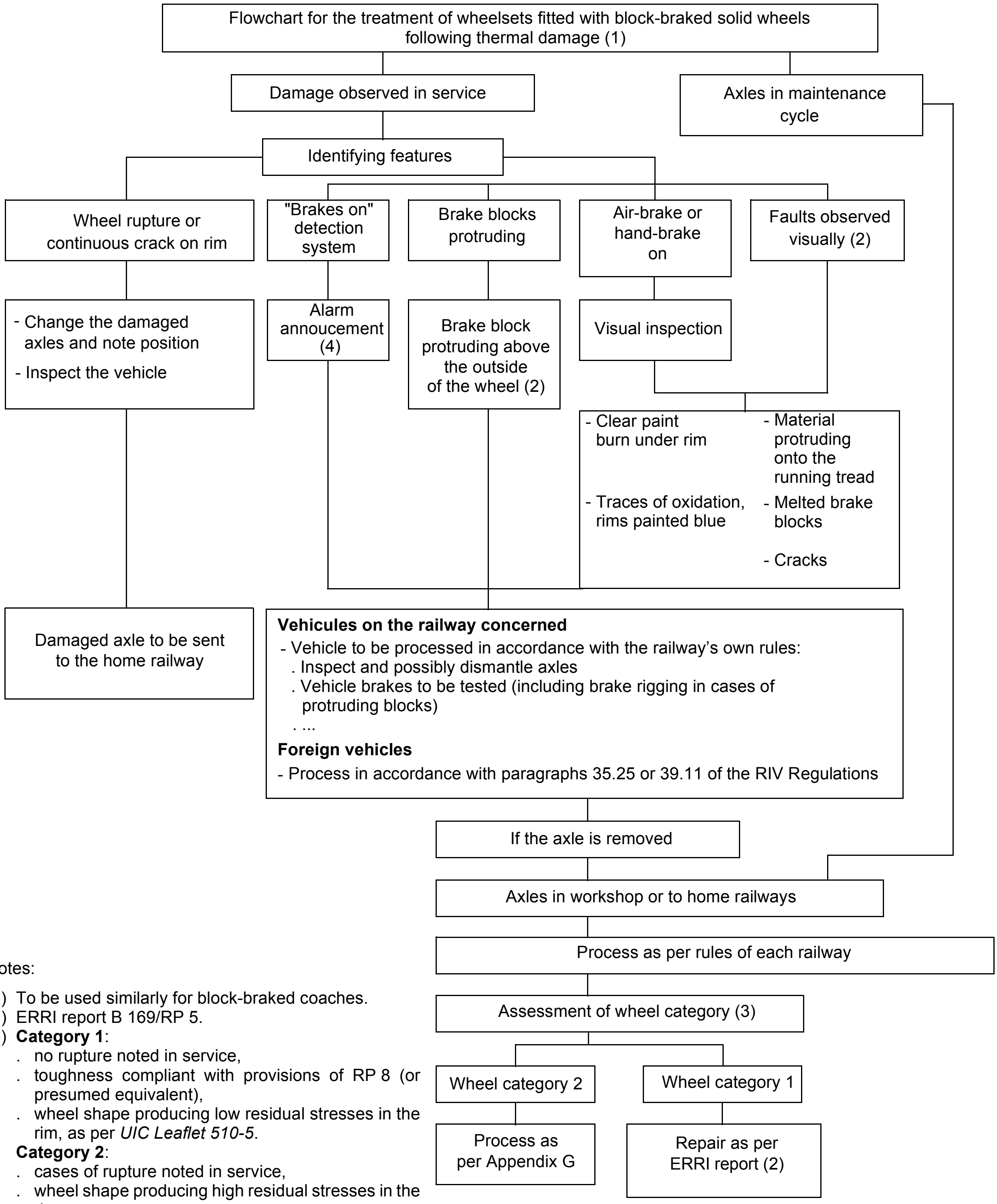
Locking measurement 1 363 mm (1 360 + 3)



(1) The flange according to point B.2.1 - page 21 is preferable for financial reasons (see point 9 - page 14).

Fig. 13 - Diagram of the angle of displacement α_1

Appendix F - Treatment of wheelsets fitted with block-braked solid wheels



Notes:

(1) To be used similarly for block-braked coaches.
(2) ERRI report B 169/RP 5.
(3) **Category 1**:
  . no rupture noted in service,
  . toughness compliant with provisions of RP 8 (or presumed equivalent),
  . wheel shape producing low residual stresses in the rim, as per *UIC Leaflet 510-5*.
Category 2:
  . cases of rupture noted in service,
  . wheel shape producing high residual stresses in the rim,
  . severe braking conditions.
(4) Will be applied progressively by the railways in line with their programme for installing "brakes on" detectors.

Fig. 14 - Flowchart for the treatment of wheelsets fitted with block-braked solid wheel

Appendix G - Treatment of solid wheels

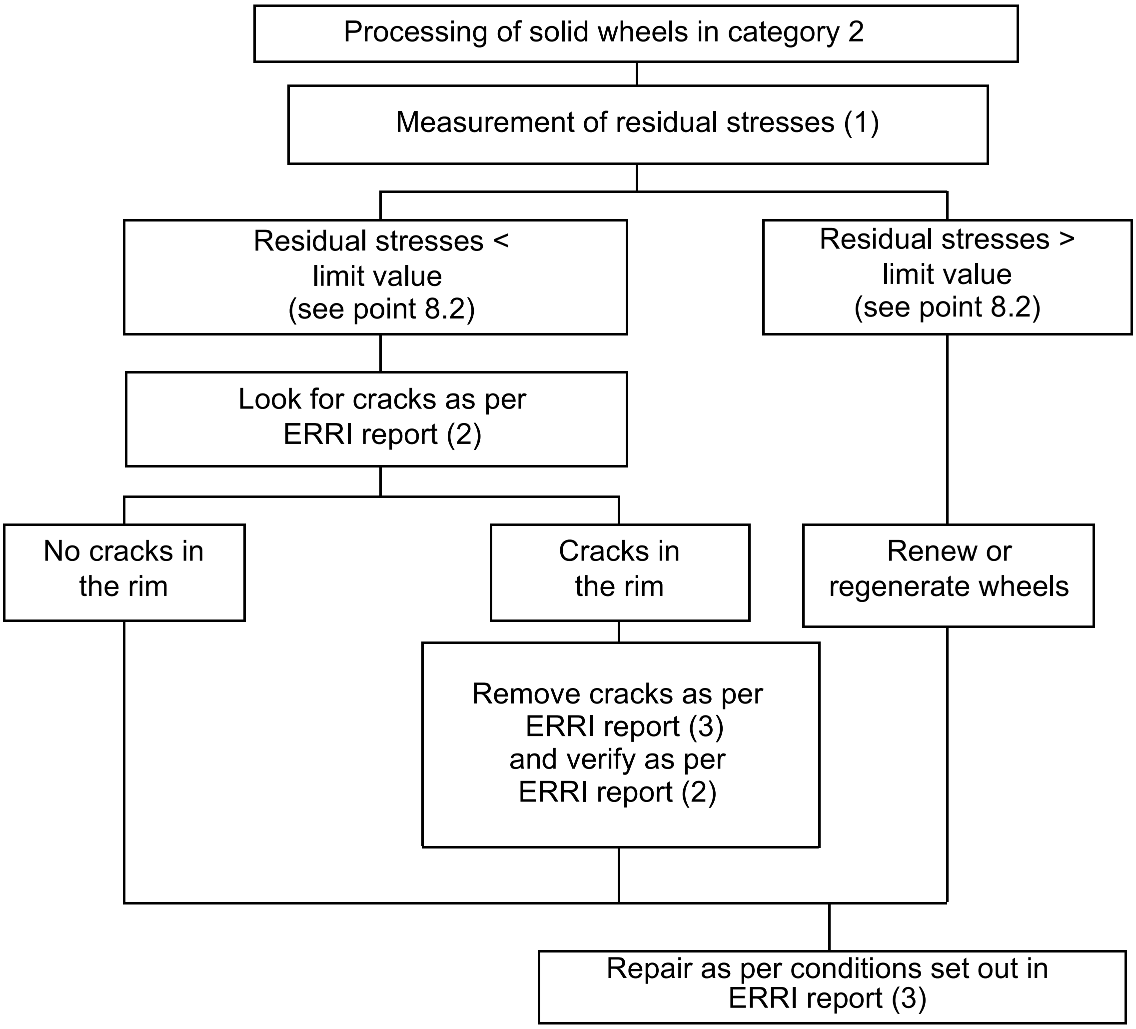


Fig. 15 - Flowchart for processing of solid wheels

(1) *ERRI report B 169/RP 6.*
(2) *ERRI report B 169/RP 7.*
(3) *ERRI report B 169/RP 5* (see Bibliography - page 67).

Appendix H - Examples of markings of axles with wheels subjected to high thermal loadings

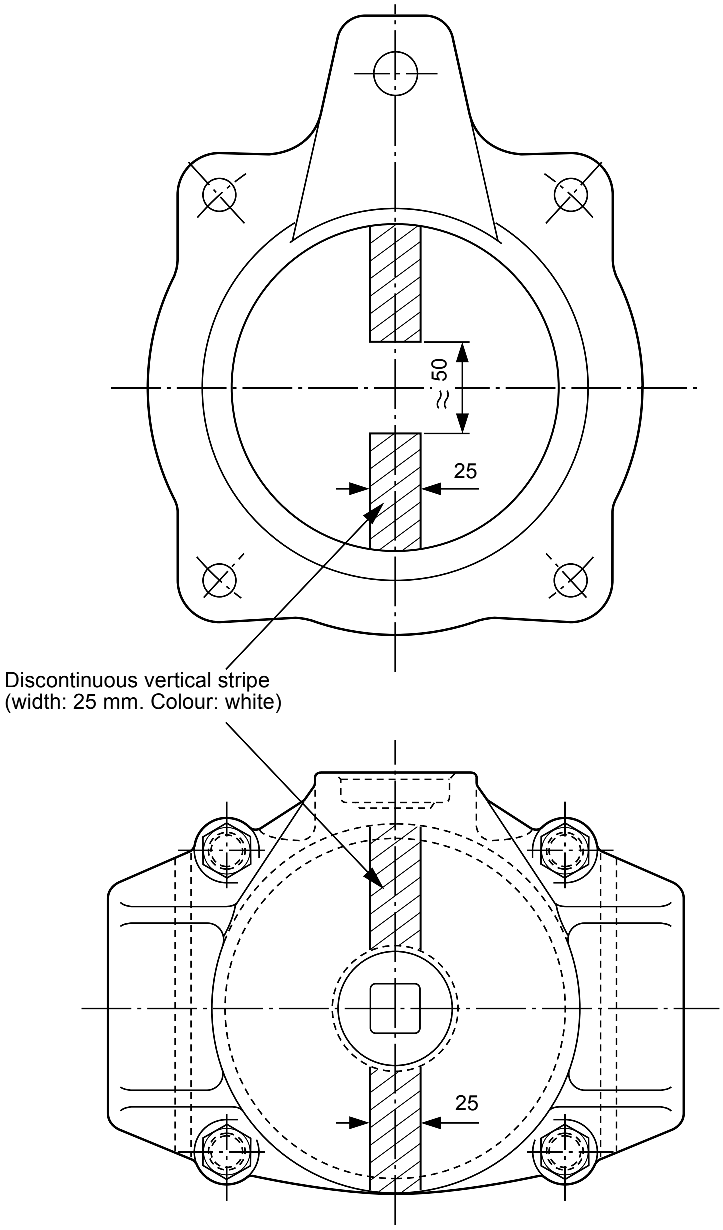


Fig. 16 - Axles - Examples of markings

Appendix I - Safety against derailment

I.1 - Introduction

The regulations of the International Union of Railways originally (as from 1.1.1995) laid down a value ≥ 840 mm for the diameter of wheels to be fitted to coaches and wagons. At the time, this minimum value was defined in order to guarantee running safety when passing over flangeways in obtuse crossings.

For quite some time now, wagons fitted with wheels with a diameter < 840 mm have become interesting for various reasons (increase in effective height, reduction of the tare of the empty wagon and reduction of unsprung weights, etc. in relation to wagons running on wheels with a diameter exceeding 840 mm). A similar situation applies to coaches. A lowered floor allows passengers easier access and increases compartment height in coaches with more than one deck.

In 1960, these reasons prompted UIC to examine whether it would be possible to use wheels with a diameter of less than 840 mm on international services.

These studies were undertaken by the UIC Working Party "Wheels for coaches and wagons to be used in international traffic" (UIC Question 57/Z/1).

The research to be carried out (1960) dealt, above all, with "small wheels" in the range of diameters < 840 mm and of at least 630 mm. The studies were finalised in 1969 (*UIC Leaflet 510-2, 1st edition 1969*). In 1970, research was extended to "very small wheel" with a diameter < 630 mm and of at least 330 mm. In 1973, the Working Party was entrusted with the task of including "ordinary wheels" (diameter ranges 1 000/920 and 920/840 mm) in *UIC Leaflet 510-2*.

The number of axles fitted with wheels falling into the diameter ranges 1 000/920 and 920/840 mm is very high (several million). Numbers are also already relatively high for axles fitted with wheels of a diameter < 840 mm and of at least 630 mm but low for axles fitted with wheels with a diameter < 630 mm and of at least 330 mm.

Given that ordinary wheels (diameters ≥ 840 mm) had proven satisfactory, it was not deemed necessary to lay down special regulations for these diameters with regard to running safety when passing over the unguided distance in plain obtuse crossings and in obtuse crossings with slips, provided, however, that the essential parameters, i.e. the flange profile and the distance between the internal surfaces of tyres or rim-tyres, are not altered. Therefore, as regards running safety, this leaflet only deals with wheel diameters < 840 mm and of at least 330 mm.

The basis for the studies on running safety of wheels with a diameter < 840 mm (which is, partly, of a theoretical and partly of an experimental nature) is set out in the following points (see points I.2 - page 39 to I.11 - page 64.

The first edition of the leaflet, dating from 1969, admitted for bogies in the diameter range 760 ≤ d < 840, the same distance between the internal surfaces and the same flange profile as for wheels with a diameter ≥ 840 mm. As regards vehicles equipped with pivoting axles, a flange height of 29 mm was specified.

The 2nd edition, dating from 1978, provided for the standard UIC/ERRI wheel profile with a flange height of 28 mm, irrespective of the vehicle construction type (pivoting axles or bogies). Given that this profile with a flange height of 28 mm is less favourable in terms of running safety when passing over an obtuse crossing, it was necessary, in order to offset this drawback, to reduce the permissible value of lateral slip to 20 ‰ and, consequently, the value H_y of the lateral force to 0,25 x $2Q_o$ also for the diameter range from 840 to 760 mm to make it possible to comply with the permissible angle of attack of 1 gr (previously 1°).

I.2 - Conditions for the passing of an axle over an obtuse crossing

The adoption of wheelsets with wheels of a diameter less than 840 mm necessitates an examination of the conditions obtaining when passing over points and crossings, in order to guarantee safety against derailment.

The problem concerns solely those crossings where both diamonds guide the wheels when passing over the flangeways.

I.2.1 - Outline of the problem

When a wheelset passes over a crossing, the guiding of the wheels, which is normally obtained, on ordinary track, by the bracing of the flanges against the heads of the rails, no longer occurs level with the flangeways (see *ERRI Question D 72*).

The risk of the axle being misdirected in the gap SB of the flangeway (see Fig. 17 - page 50), will increase as:

- the gap SB increases, i.e. as the angle δ of the crossing decreases,
- the diameter d of the wheel decreases, in view of the fact that the wheels of the wheelset are likely to assume an angle of attack α in relation to the direction of the gauge line and to move laterally to the track by a quantity λ.

Taking a given lower limit of δ, the diameter d acceptable for a given geometry of the wheelset and the crossing, is governed by the theories accepted in relation to the two parameters α and λ.

Safety against derailment must be guaranteed when a wheelset passes over the area of the gaps in obtuse crossings, in the most unfavourable circumstances possible. Therefore, all studies must take into account the most probable theories relating to these most unfavourable circumstances.

The manner in which a wheel approaches the nose of an obtuse crossing may differ depending on whether we consider (see Fig. 17):

- wheel I approaching nose **A on the running side**,
- wheel II approaching nose **B on the check side**.

This approach may take place in two ways:

- the wheel and the respective nose will have no more than tangential contact (α = 0) or will not make contact at all,
- the wheel will engage the nose by a quantity y known as **extent of lateral fouling** (see Fig. 24 - page 52).

The **unguided distance x_1** (see Fig. 17 - page 50) is the distance travelled by the axle between the instant the wheel II leaves the knuckle S of the raised check rail, and that when the wheel I engages the nose A on the **running side**.

There are three theories, for solving the problem of negotiating obtuse crossings by small diameter wheels as follows:

- wheelset running along a rectilinear trajectory, parallel to the gauge line ($\alpha = 0$),
- wheelset running along a trajectory with an angle of attack α= constant or $\alpha = f(t)$,
- wheelset running along a trajectory with an angle of attack $\alpha = f(t)$, with lateral slip $\lambda(t)$.

The decision relating to the possibility or obligation of accepting one of these three theories is governed by the experimental probability of a derailment risk.

I.2.2 - Theory 1: Axle running along a rectilinear trajectory, parallel to the gauge line ($\alpha = 0$)

The theory according to which the wheelset runs along a rectilinear trajectory parallel to the gauge line, is entirely theoretical. In practice, we know that it cannot be so.

The value of this theory is proven by the following analogical reasoning:

Given that the risk of derailment with existing internationally accepted wheels of diameter $\varnothing \approx 840$ mm is practically non existent if the tyre profile of a wheel of diameter $\varnothing_1 < 840$ mm is such that, for crossings of tg $\delta \geq 1/9$ or 0,11, the unguided distance x_1 remains the same as that for the wheel of $\varnothing$ 840 mm, it may be accepted that the smaller diameter $\varnothing_1$ poses practically no risk.

This theory favours the authorisation of wheels of diameter $\varnothing_1 < 840$ mm, giving, in the case of a raised check rail (see Fig. 18 - page 50), an unguided distance as follows:

- $x_1 = 55$ mm with H = 42 mm (DB),
- or $x_1 = 32$ mm with H = 57 mm (SNCF).

I.2.3 - Theory 2: Axle running along a trajectory with an angle of attack α = constant or $\alpha = f(t)$

The theory of a wheelset running along a trajectory with an angle of attack α = constant or $\alpha = f(t)$ presupposes a straightforward running motion.

The angle of attack α results from (see Fig. 19 to Fig. 23 - page 51):

- the angle of displacement ψ_1, between the longitudinal axes of the wheelset and the running gear (ratio of the return action of the axle and the side movement of the latter),
- the angle of displacement ψ_2 of the longitudinal axis of the running gear in relation to the longitudinal axis of straight track, and

- the angle ψ_3 formed by the tangent of the gauge line with the direction of an imaginary line having the same length as the wheelbase of the running gear.

This gives: $\alpha = \psi_3 + \psi_2 - \psi_1$.

This angle α may be constant, or change over time if the straightforward running of the dicone is taken as being of a sinusoidal nature.

The unfavourable factors in this theory are:

- the inequalities of diameters between wheels on the same axle,
- the non-parallelism of the axles,
- the play of the axle guards,
- the insufficiency of the adjusting forces.

I.2.4 - Theory 3: Axle running along a trajectory with an angle of attack α = f (t), with a lateral slip λ (t)

With this theory, the influence of the angle of attack α = f (t), is supplemented by a sliding movement of the wheelset laterally in relation to its trajectory, of amplitude λ (t) (see Fig. 17 - page 50).

In this case, consideration must be given to the forces exerted on the wheelset and to the law of slip between wheel and rail.

This gives rise to a full analysis of the derailment conditions, with particular emphasis on the lateral forces exerted on the wheelset (lateral force H_y applied to the axle box).

This theory led the SNCF to accept a minimum wheel diameter of Ø = 630 mm in the worn condition which is at present the lowest in service.

The most unfavourable factors for the displacement λ (t) are:

- a low wheel/rail friction coefficient (damp rail),
- a low axle load and shedding of the wheel load,
- lateral forces applied to the axle boxes, exceeding a certain level.

To these influences should be added that of the angle of attack α (t) in accordance with theory 2 (see page 40).

I.3 - Synthesis of the three theories

The most probable theory is that of a simultaneous angle of attack α and lateral slip λ, which, in actual fact, supplies the only valid method for defining the minimum diameter of the wheels of an axle.

The first theory only permits a minimum diameter $\varnothing_1$ = 730 mm, even with the best flange outline.

The problem of smaller diameters, which are very much favoured by the manufacturers, cannot therefore be solved in this way.

The second theory, that of rectilinear running with an angle of attack α = constant, without lateral movement, does not fully cover the actual possibilities of axle displacement.

To determine the minimum diameter of the wheels of an axle, it is necessary to have recourse to a theory which takes into account a certain angle of attack α and a certain lateral slip λ.

With this latter theory, the wheel may engage with a lateral fouling y (see Fig. 24 - page 52).

In principle, it is not intended to avoid this impact, but its value y_{lim} shall be defined so that derailment cannot occur and the nose of the crossing cannot be damaged.

It remains to define, by means of the studies, the respective values to be accepted for:

- the angle of attack α of the wheelset, taking into account the given characteristics of the track and the stock,
- the lateral movement λ, taking into account the coefficients of slip, the minimum axle loads, the shedding of the load from the wheel, and the probable lateral forces,
- the maximum impact y_{lim}.

However, these values will only have significance if precise conditions are observed in the construction and maintenance of the crossing, the wheelset and the vehicle.

With this in mind, tests have been undertaken on the derailment test bench at MINDEN (DB), with a view to determining a flange profile and a minimum wheel diameter (see point I.9 - page 57), and the experimental limiting values obtained have been analysed in relation to the geometrical characteristics of the functional wheel-crossing-vehicle combination.

Two methods of analysis can be used, graphical or analytical.

The graphical study makes use of horizontal sections across the flange (known as "lunes") for the wheelset (see Fig. 25 - page 52) and of the main outline for the crossing.

The analytical study is based on previous studies on the geometry of the contact between the flange and parts of the track (see Bibliography - page 67). This method is described in *Interim Report No. 7 (RP 7) of ERRI C 9 Specialists' Committee* and allows for a comprehensive study of the influence of the main parameters.

I.4 - Tests carried out on the derailment test bench in Minden

In order to study the influence exerted by the angle of attack α and by a lateral force H_y on the running behaviour of small wheels passing over obtuse crossings, tests have been carried out in connection with *ERRI Question C 9* on the derailment test bench in MINDEN (Westf), which is described in point I.9 - page 57.

The theoretical studies carried out by *ERRI C9 Specialists' Committee* in this connection, the description of said tests and their results and conclusions, are given in *document RP n° 7* of the above Committee.

An explanation is given below of the elements subjected to the tests in question, and of the conditions under which these were effected, the results thereof being given in condensed form and partly in the form of extracts.

I.4.1 - Components tested

The studies in question were carried out on the following types of crossings:

- standard SNCF crossing, with an angle δ = 6° 16', in manganese steel,

- DB crossing, with an angle δ = 6° 20', of the type assembled with bolts.

These crossings, although widely similar as regards their main measurements, incorporate flangeways of different widths (SNCF = 42 mm, DB = 41 mm), and the construction of the outline of their crossing noses is different. In addition, the check rails are raised by H = 60 mm in relation to the running surface over the SNCF crossing, with the object of reducing the unguided distance, the corresponding measurement being 45 mm for the DB crossing.

With regard to the SNCF wheel, its running tread diameter is 2r = 642 mm. The inside surface (plane) of its tyre is extended considerably towards the outside diameter of the flange, in order to extend guiding by the raised check rail.

The DB wheel has a diameter 2r = 688 mm. The inside surface of its flange is heavily bevelled in order to exclude, as far as possible, the danger of impact between the guiding surface of the crossing and the surface in question itself, in the event of pronounced lateral wear of the surfaces of the flange, and to ensure better geometrical contact between the inside surface of the flange and the guiding surface of the crossing.

Following tests carried out with full flanges, these same flanges were made thinner by 5 mm to simulate lateral wear in service, after which the tests were repeated in order to study the effect of the wear of the flange surfaces on the guiding of the inside surface of the flange by the guiding surface of the crossing.

I.4.2 - Test conditions

Series of tests were carried out with:

- an axle load of $2Q_o$ = 4 000 kg,

- different angles of attack α' = Cte during each test, for values of α' equivalent to 0°, 0°30', 1°, 1°30', 2° and 2°20',

- shedding of the load of one wheel in relation to the other, i.e. $\frac{\Delta Q_F}{Q_o} = 0$ and $\frac{\Delta Q_F}{Q_o} = -0{,}4$

  (in the light of the results of tests carried out by *ERRI B 55 Specialists' Committee*),

- the application of a lateral force H_y from 0 to 2 000 kg,

- dry and damp rail conditions.

I.4.3 - Test results

If the wheelset is not subjected to the action of a lateral force, it follows easily the running direction imposed by the angle of attack α. If it is subjected to a lateral force H_y, a supplementary lateral movement due to slip is added to the lateral displacement arising from said angle α. This lateral slip is proportional to the lateral force H_y. During the tests, over the unguided distance, it reached a value of 0,8 mm/t on dry rails and 1,6 mm/t on damp rails, with a permissible lateral force on the axle-boxes of up to 1 t, i.e.: $H_y = 0{,}25 \times 2Q_0$. Consequently, as regards wheel diameters of 680 mm and 642 mm, a lateral slip (slip angle ε) of between 14 and 20 ‰, depending upon the type of crossing, occurs on damp rails. In the case of a lateral force on the axle-boxes of $H_y > 1$ t, the slip increases to approximately 3 mm/t on dry rails and 6 mm/t on damp rails. From a value of about 1 500 kg for the lateral force H_y, the axle loaded to 4 t, and running on a damp rail, suddenly slides towards the unguided part of the gap, which it has time to do in view of the low motion speed used on the test bench.

There is a danger of derailment of the wheelset when the angle of the tangential plane with the horizontal plane, at the point of contact between the flange and the nose, drops below 40°.

The wheelset derails at an angle of attack α between 2° and 2° 30', in the absence of any lateral force H_y. The lateral force on the axle-boxes which it can accommodate becomes greater as the angle of attack α becomes smaller. On rails sprayed with water, the acceptable value of the lateral force H_y is reduced by about 30%. Shedding of the load from one of the wheels acts in the same way, although to a much lesser extent.

Tests carried out with worn flanges, over a DB crossing and without applying any lateral force, showed that the DB wheelset, for an angle of attack of not more than 2°, was guided by the single guiding surface of the nose B (see Fig. 17 - page 50) (wheel II, by the inside surface of its flange), without overriding it. Conversely, the SNCF wheelset, after mounting of the nose B, came into contact with the nose A wheel I on the running side (external surface of the flange), and was redirected to the correct flangeway by the nose in question.

I.5 - Running tests over an obtuse crossing with slips in a curve of 450 m radius

In order to supplement the studies carried out at the derailment test bench in MINDEN by *ERRI C 9* Specialists' Committee, the behaviour of small wheels when passing over obtuse crossings has been the subject of in-service tests.

The object of these tests, carried out under unfavourable but feasible conditions, was to confirm the validity of the basic data used in the calculations and tests undertaken at the derailment test bench, both of which are outlined in *report RP 7/C 9* (see Bibliography - page 67).

The tests were required to confirm that the theory of a maximum value of 1° for the angle of attack α of the axle, and the degree of lateral forces exerted on the axle-boxes by virtue of the method of fitting of the axle on to the vehicle, corresponded to those obtaining in practice.

These in-service tests were based on the following conditions:

- as regards the track:
  - crossing on a curve 1/9 R = 450 ;
- as regards the vehicle:
  - articulated vehicle of DB type Offs 60, with three pivoting axles; wheelbase 16,00 m; wheel diameter 730/680 mm;
  - SNCF vehicle, type HMy, with bogies; distance between bogie pivots 9,30 m; wheel diameter 650/630 mm.

An investigation of the unfavourable conditions between vehicle and track gave the following combination:

- maximum play obtained with a locking measurement of 1 359 mm and a distance from running face to back of opposite check rail of 1 398 mm,
- minimum play obtained with a locking measurement of 1 362 mm and a distance from running face to back of opposite check rail of 1 393 mm,
- difference of 2 mm in the diameters of the wheels of the same axle,
- out-of-square of the wheelsets in fitting,
- difference in rigidity of the suspension springs,
- propelling forces applied to the buffers, up to 17 t,
- running speed up to 60 km/h.

The value of the angle of attack α was always less than 1°.

The lateral forces H_y recorded on the boxes reached 2,45 t, taking the nose on the running side. (This value corresponds to a quotient obtained as follows: $\frac{H_y}{2Q_o} = 0,28$. Generally speaking, the value of this quotient was not more than 0,14.)

The results of the tests in question showed that for any of the vehicle types tested, the existing constructional and maintenance possibilities allowed the conditions in the leaflet to be observed.

With regard to the running tests carried out by *ERRI C 9* Specialists' Committee, these, together with their results and the conclusions obtained from them, are given in *document RP 8* of that Committee.

I.6 - Conclusions derived from the bench and running tests

During the bench tests (see point I.4 - page 42), relating to the conditions of contact and safety against derailment of small wheels when passing over an obtuse crossing, recordings were taken of values of the angle of attack α and lateral forces H_y on the axle-boxes, in order to determine which combination of these two values gave rise to a danger of derailing the wheelset. These tests made it possible to define the acceptable limiting values of:

- 1° for the angle of attack α and
- 0,3 for the static axle load $2Q_o$ for the lateral force H_y.

The line tests (see point I.5 - page 44), conducted at various speeds and on a continuous stretch of track with a diamond crossing in a curve of R = 450 m, made it possible to determine in-service values for the angles of attack and lateral forces on the axle-boxes. In the actual crossing, the value of these angles barely reached ½°. Regarding the lateral forces, for reasons of a constructional nature, they could only be measured on the articulated Offs vehicle: the maximum values of the ratio of the lateral force exerted on the box to the axle load were 0,23 to 0,28 for the front axle, with slightly higher values for the rear axle. It should be added that these maximum values applied during extremely short spaces of time. Conversely, the averages of forces H_y of longer duration were notably less than the maximum values.

The tests described above served to show that it is possible to build vehicles, either with bogies or pivoting axles, which do not give an angle of attack of more than about ½° even under unfavourable conditions of service. Consequently, the definition given in *UIC Leaflet 510-2, 1st edition 1969* of a maximum acceptable value of 1° for the angle of attack as a criterion for running safety over obtuse crossings may be regarded as a condition to be complied with by rolling stock design engineers.

I.7 - Recommendations

Recommendations relating to the study and to wheel maintenance regulations with a view to ensuring a satisfactory level of safety against derailment: see points 1.4 - page 4 and 1.5 - page 5.

Recommendations relating to the construction and maintenance regulations of obtuse crossings on routes used by axles bearing small-diameter wheels accepted on international services.

For all obtuse crossings used by axles bearing wheels of small diameter, accepted on international services, the following recommendations shall apply:

- The minimal angle δ of the crossing to be observed is:
  - tg δ = 1/9 or 0,11,
  - or δ = 6,974 gr or 6°16'.

- The following characteristic nominal measurements, with their constructional and maintenance tolerances, measured along a reference plane z = - 14 mm in relation to the running surfaces, shall be as follows for future purposes:

Table 2 :

Description (see Fig. 10 et 11)	Nominal measurement (mm)	Design tolerance (mm)	Tolerance in service (mm)
Track gauge at the crossing A_1, A_2, A_3, A_4	1 435[a]	+ 1 - 1	+ 4 - 2
Flangeway	40[a]	+ 0,5 - 0,5	+ 2 - 0,5[b]
Check-rail gauge C_1, C_2, C_3, C_4	1 395	+ 0,5 - 0,5	+ 3 - 2[c]
Running clearance measurement B_1, B_2	1 355[a]	< 1 356	< 1 356
Additional height H of the check rail	$45 \leq H \leq 60$[d]	+ 2 - 1	

a. The flangeway measurement is a design value for crossings which may vary with existing track crossings. The track gauge and running clearance measurements must allow for compliance with the protective measurement in all cases in relation to this flangeway measurement. The theoretical gap $\frac{D}{tg\delta}$ being a function of the flangeway measurement D and the angle δ of the crossing, it is necessary, for application to cases where tg δ > 1/9, to use the following approximate quotient $\frac{D}{tg\delta} \geq 370$.

b. The flangeway measurement is a design value which may only vary:
- upwards, with wear,
- downwards, with flattening of the noses.
Wear is usually slight, and flattenings can be ground.

c. The above set of tolerances contains incompatibilities. Practically speaking, this means selecting conditions (applicable also to track equipment at present in service), limited to the three following recommendations:
- Track gauge $\leq$ 1 439
- Check-rail gauge $\geq$ 1 393
- Running clearance measurement $\leq$ 1 356.
The various values A, B and C are to be measured as stated in Fig. 26 - page 53.

d. The possibility of raising the check rail is dealt with in *UIC Leaflet 505-5, Chapter II, point 3.5.3* which states: "Rolling stock parts may be below the 0,100 om or 0,080 m plane, providing that they remain within the wheel profile on both curved and straight track, since otherwise there is a danger of their touching fixed structures, especially the check-rails at the deflecting sections of points and crossings and the main sections of turnouts in curved track". Since an increase in the height H leads to a reduction in the unguided distance x_1 of the axle, it is recommended that the authorised maximum value should be used.

The following are recommended (see Fig. 27 - page 53) for the geometry of the noses of crossings:

- a nose easement on the check side E = 3 mm over a distance of more than 150 mm;

- a lowering of the actual nose z = -8 mm, under the running surface, with a connecting ramp of about 200 mm.

All these recommendations, relating to the passing of small diameter wheels over obtuse crossings, are compatible with passing over such crossings by normal RIV/RIC wheelsets.

I.8 - Method for defining the conditions to ensure running safety of wheels

Diameter of less than 630 mm and of at least 330 mm

As regards running safety when passing over plain obtuse crossings and obtuse crossings with slips, the conditions under which the running of axles fitted with wheels with a diameter 330 < d < 630 mm might be authorised were to be defined for *UIC Leaflet 510-2, 2nd edition* (see research to be carried out, in point I.1 - page 38), as was the matter of whether these conditions could be applied to wheels with a diameter 630 ≤ d < 760 mm to obtain uniform regulations for wheels with a flange height of 32 mm. This research was based on the tests undertaken by *ERRI C 9* Specialists' Committee in Minden and Porta and the results from these tests are set out in *reports 7 and 8*.

The calculations were made on the basis of Theory 3 (see point I.2.4 - page 41), according to which the axle follows a trajectory with an angle of attack α combined with a lateral slip in relation to this trajectory. This sliding movement is characterised by the angle ε and is proportionate to the lateral force H_y which is exerted on the axle while it runs over the unguided distance.

An analysis of *ERRI report C 9/RP 7* and in particular of Fig. 14, shows that:

- the value of 0,8 mm/t for the lateral sliding movement on dry rail over the unguided distance, under the action of a force $H_y \leq 0,25 \times 2Q_o$, is valid;
- the representative curve of the sliding movement in relation to the force H_y is, for this range, sufficiently in harmony with the group of points in *report RP 7, Fig. 14*.

As regards the range of forces $0,25 \times 2Q_o \leq H_y \leq 0,3 \times 2Q_o$, the representative curves are not in harmony with the group of points shown in *report RP 7 of ERRI Specialists' Committee C 9 - Fig. 14* - and would, therefore, have to be corrected if $H_y > 0,25 \times 2Q_o$ were to be permitted.

It may be assumed that, for this range, the value of the sliding movement corresponds to approximately to 3 mm/t. As obtained from the report, the value of the sliding movement on damp rail is double that of the sliding movement on dry rail.

Having established the lateral sliding movement in relation to H_y over the unguided distance, as it results from the tests, it is possible to determine the slip angle (lateral slip) as well as the interrelation between the slip angle and the lateral force (H_y).

The combination of the most unfavourable parameters, obtained during the tests, gives:

- a slip angle of 37‰, to which a lateral force $H_y \leq 0,3 \times 2Q_o$ corresponds;
- a slip angle of 20‰, to which a lateral force $H_y \leq 0,25 \times 2Q_o$ corresponds.

Consequently, the value of the permissible lateral force for axles fitted with wheels with a diameter < 760 mm is defined by $H_y \leq 0,25 \times 2Q_o$.

Having obtained this definition, the permissible value of the angle of attack, valid for the wheel diameter ranges from 760 to 330 mm, has been calculated on the basis of the following values:

Distance between the internal surfaces of the 2 wheels fitted to the same axle	= 1 363 mm
Dimension for nose protection	= 1 393 mm
Flange height (see point B.2 - page 21)	= 30 mm
Flange height (see point B.3 - page 26)	= 32 mm
Angle of the tangent at the contact point between the flange and the running edge of the crossing (see Fig. 28 - page 54 to Fig. 30 - page 55)	= 40°

The results from this calculation are represented on the graph of Fig. 31 - page 56.

The results appearing on this Fig. 31 show that, for an identical slip angle (lateral slip), the DB crossing allows for an angle of attack of a value exceeding that of the SNCF crossing, although the latter is fitted with a check rail of 60 mm, whereas the check rail of the DB crossing is 45 mm. This fact can be explained by the more favourable design of the DB crossing. Appendix E - page 34 only refers to the SNCF crossing with the smallest angle of attack.

In view of the fact that the wheelset includes two wheels, it is worth examining the behaviour of wheel No. 2 as it passes over the crossing nose - although safety is not involved. It can then be noted that the shape of the DB nose is less favourable. It would be advisable that the lateral movements of wheels I and II have approximately the same values. For this reason, *ERRI D 72* Specialists' Committee has proposed another shape of nose.

ERRI D 72 Specialists's Committee has pointed out that the distance between the internal surfaces of the wheels of the same axle, increased by the thickness of a flange, i.e. the dimension relating to the guiding of the axle, should not be less than the minimum value of 1 387 mm (1 398 mm = maximum check-rail gauge), less the sum of the nose easement measurement = 3 mm and the permissible extent of lateral impact = 8 mm (more accurately 7,29 mm), therefore less 11 mm as a whole.

Taking these values into consideration, a value of 8 mm remains for wheels ≥ 840 mm with a minimum flange thickness of 22 mm as regards the lateral movement of the wheelset when the impact takes place on the guiding side of the crossing:

(1 398 - 3 - 8) - (1 357 + 22) = 8.

These conditions were accepted by *ERRI D 72* Specialists' Committee.

By virtue of the stipulations of *ERRI D 72* Specialists' Committee, *UIC Leaflet 510-2, 1st edition* imposed a minimum flange thickness of 27,5 mm for wheels < 840 mm.

In the same edition of the leaflet, a measurement of 1 359 mm was specified for the minimum distance between the internal surfaces of the wheels of the same axle. In view of the alteration which occurred for the minimum distance which was reduced from 1 359 mm to 1 357 mm (alteration valid as from 1.1.1970), the stipulation of *D 72 Specialists' Committee*:

Minimum space between the internal surfaces + minimum flange height ≥ 1 387 mm, was no longer fulfilled.

Consequently, an additional lateral movement of 2,5 mm is inevitably obtained when an impact, caused by the flange, occurs on the guiding side of the crossing. This additional lateral movement cannot be accepted for comfort and maintenance reasons. Therefore, the distance between the internal surface of the tyres of wheels < 840 mm must be returned to the previous value of 1 359 mm.

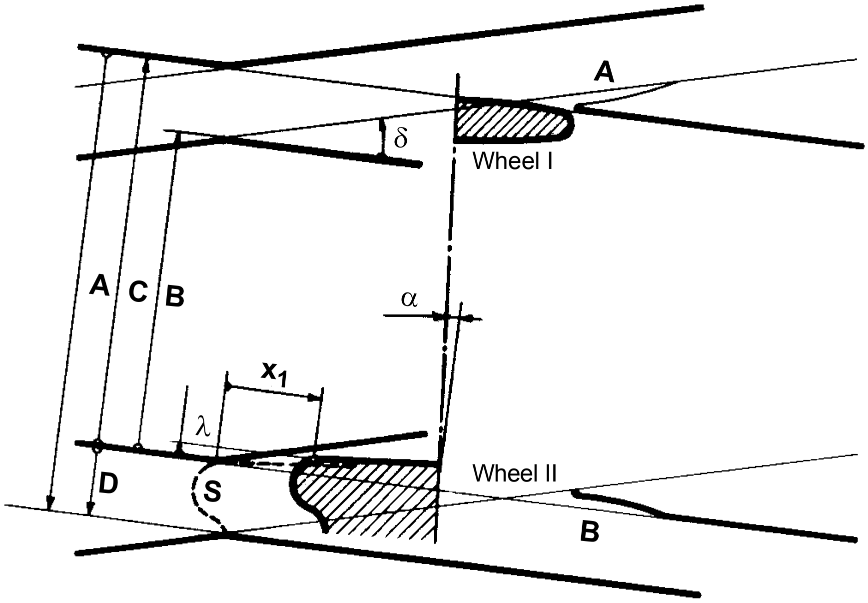


Fig. 17 -

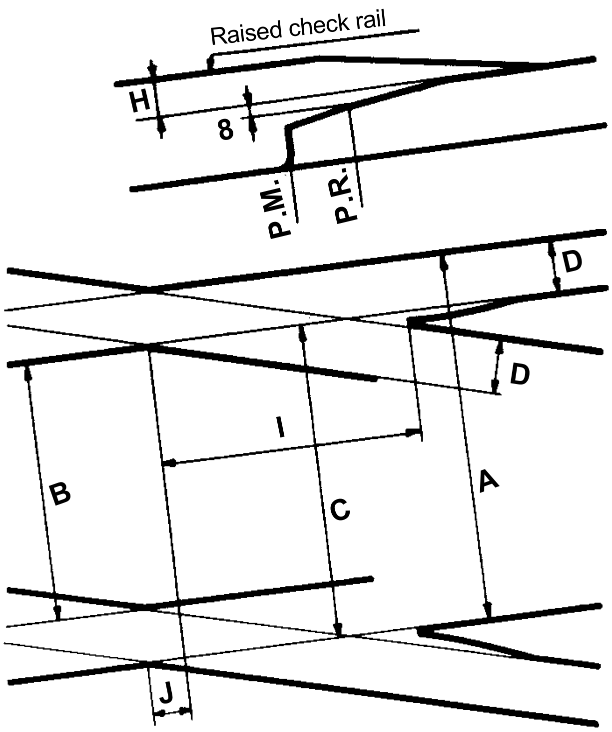


Fig. 18 -

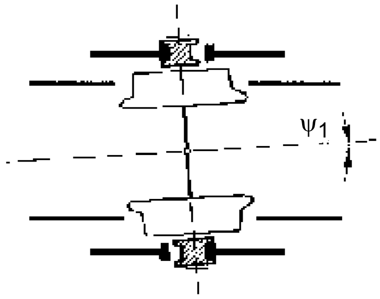


Fig. 19 -

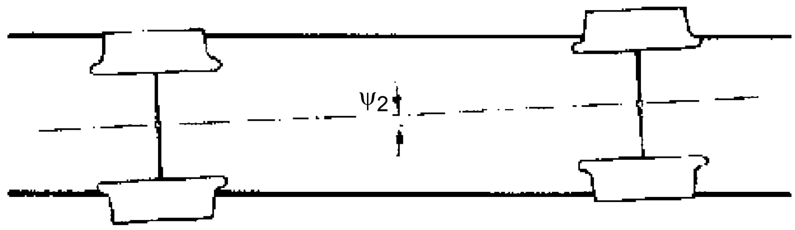


Fig. 20 -

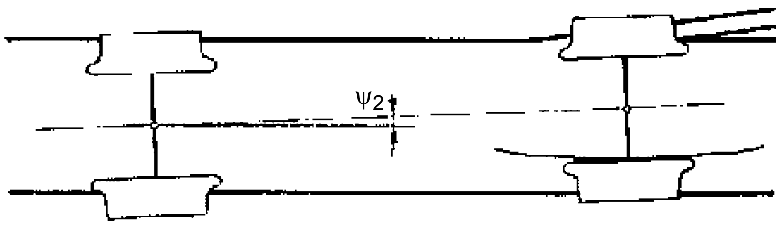


Fig. 21 -

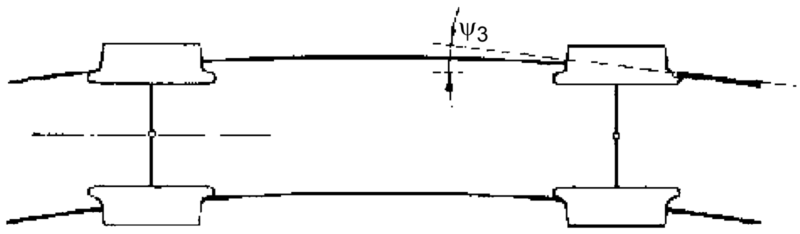


Fig. 22 -

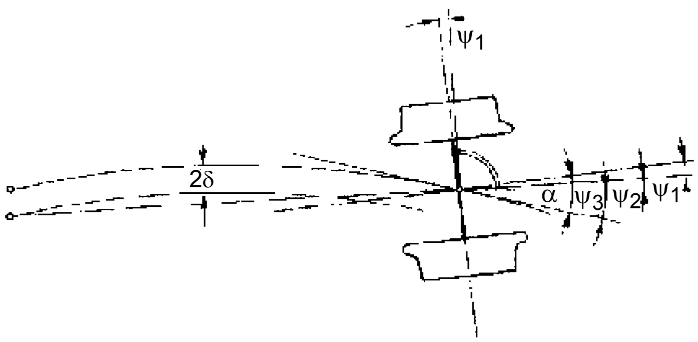


Fig. 23 -

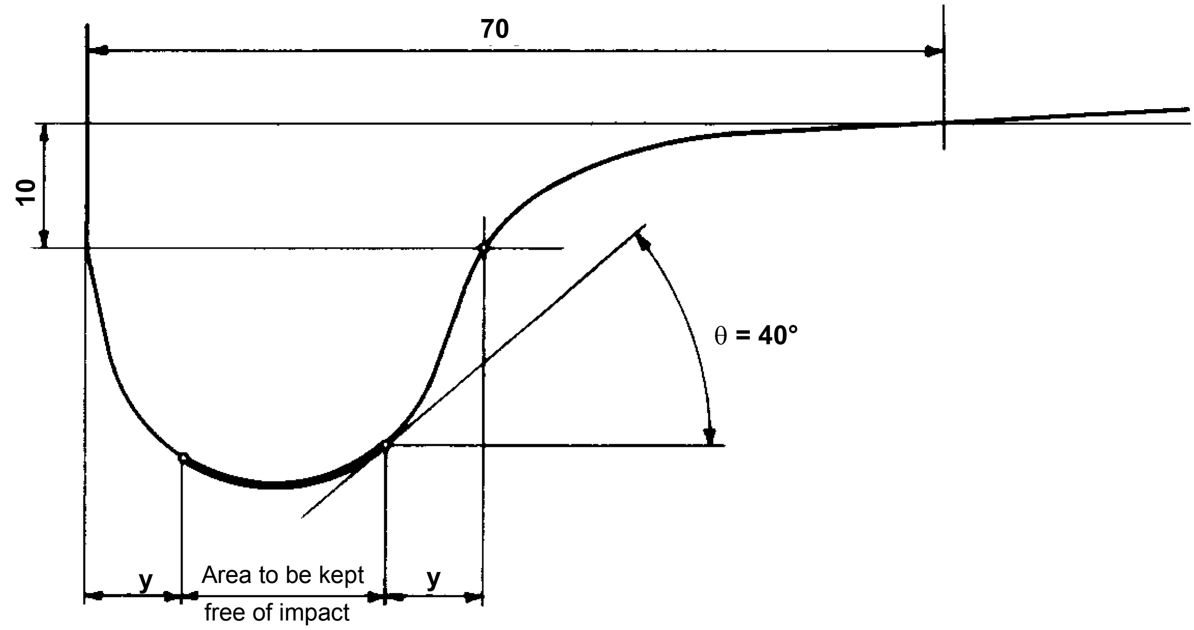

70
10
θ = 40°
y
Area to be kept
free of impact
y

Fig. 24 -

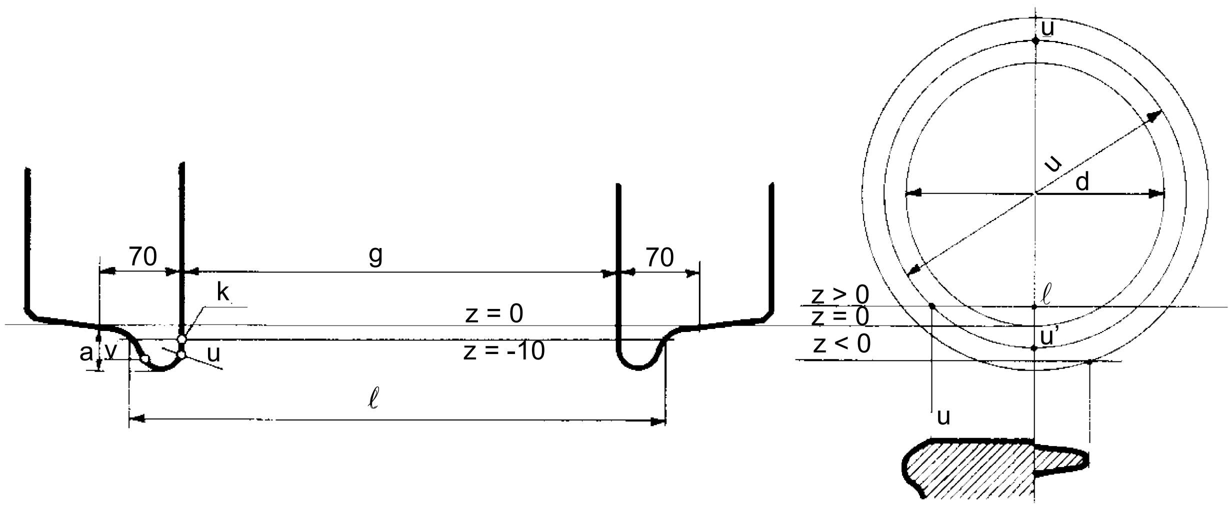
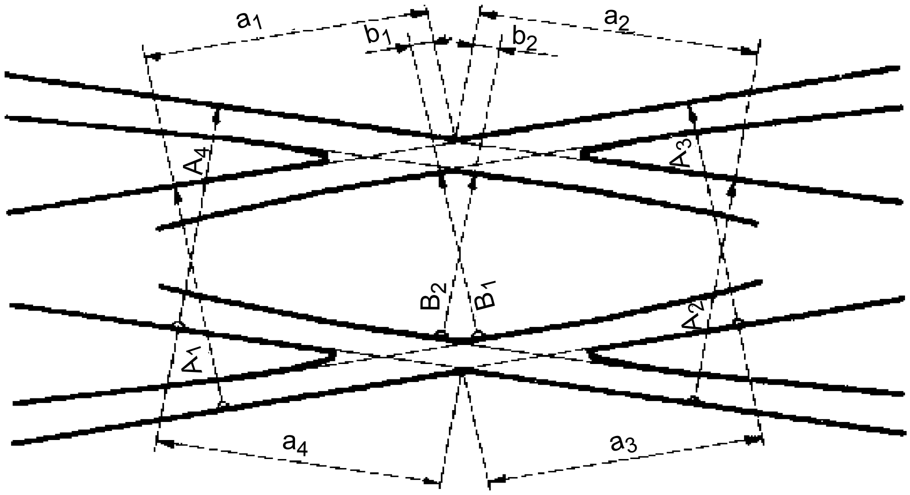

70
g
70
k
z = 0
z = -10
a
y
u
ℓ
u
u
d
z > 0
z = 0
z < 0
ℓ
u'
u

Fig. 25 -



a_1, a_2, a_3, a_4 = 0,750 m

b_1, b_2, c_1, c_2, c_3, c_4 = 0,080 m

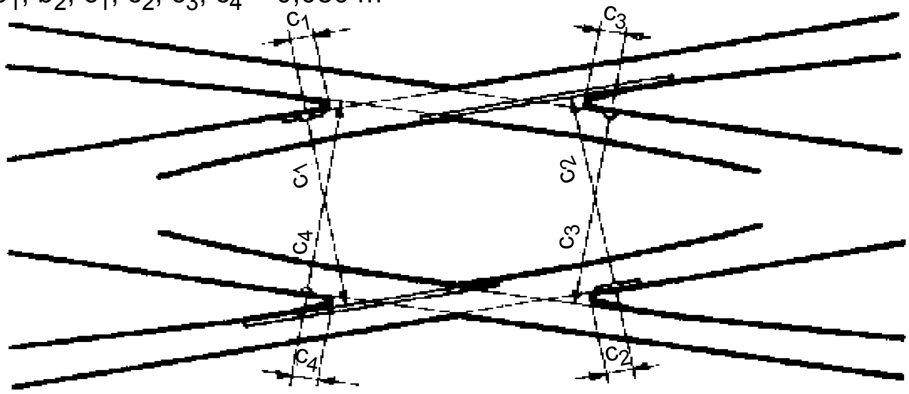


Fig. 26 -

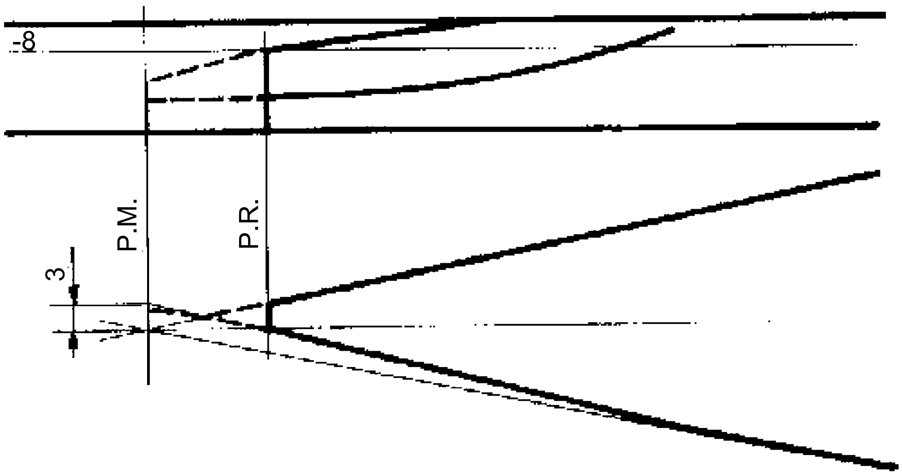


Fig. 27 -

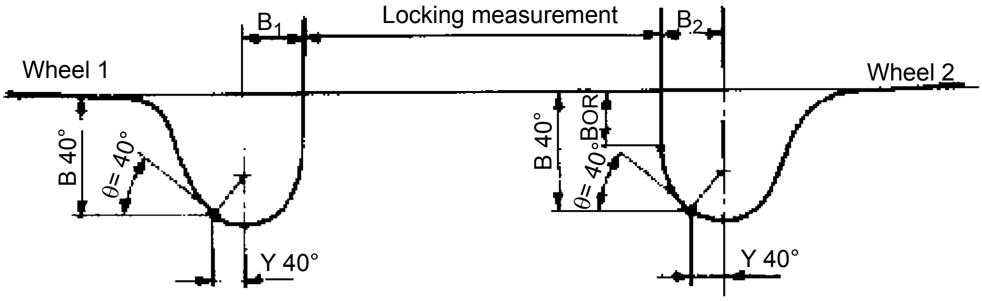


Fig. 28 - Free axle in a crossing

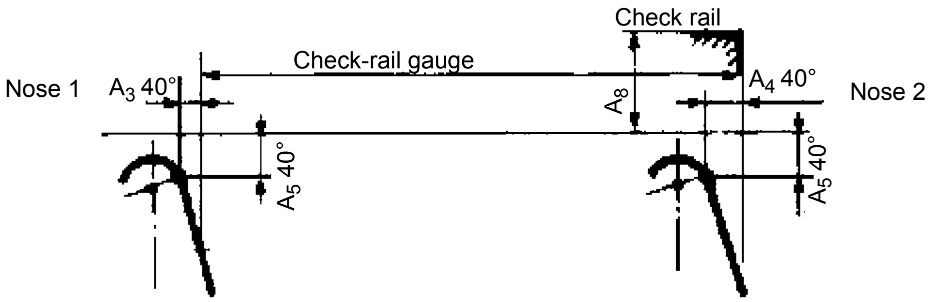
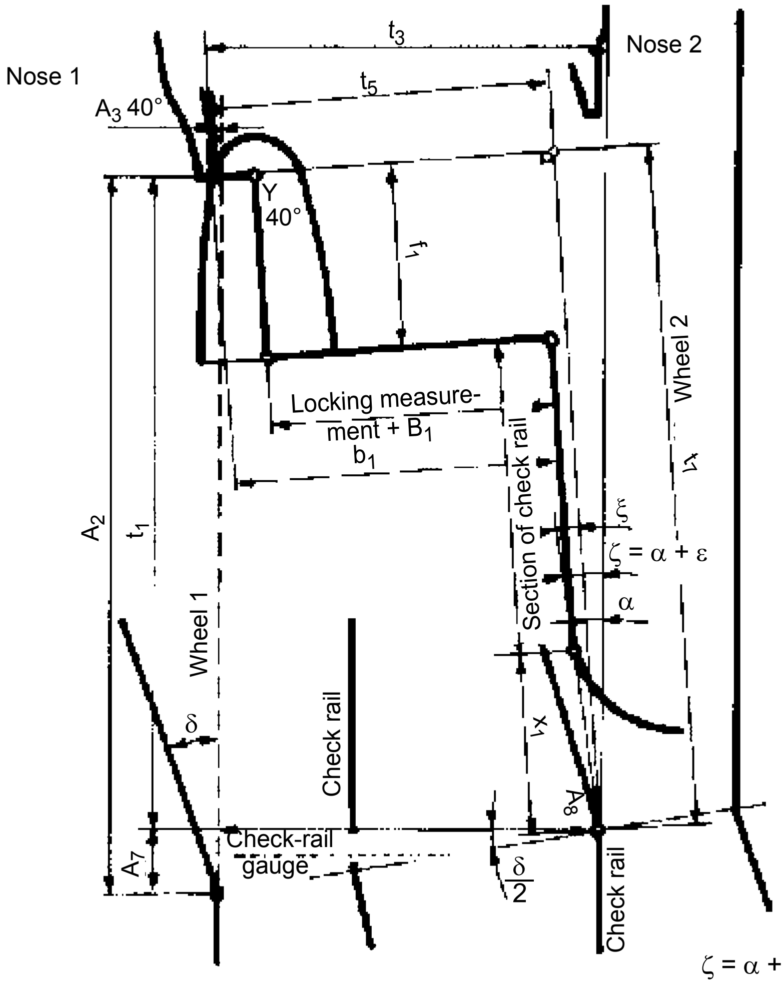
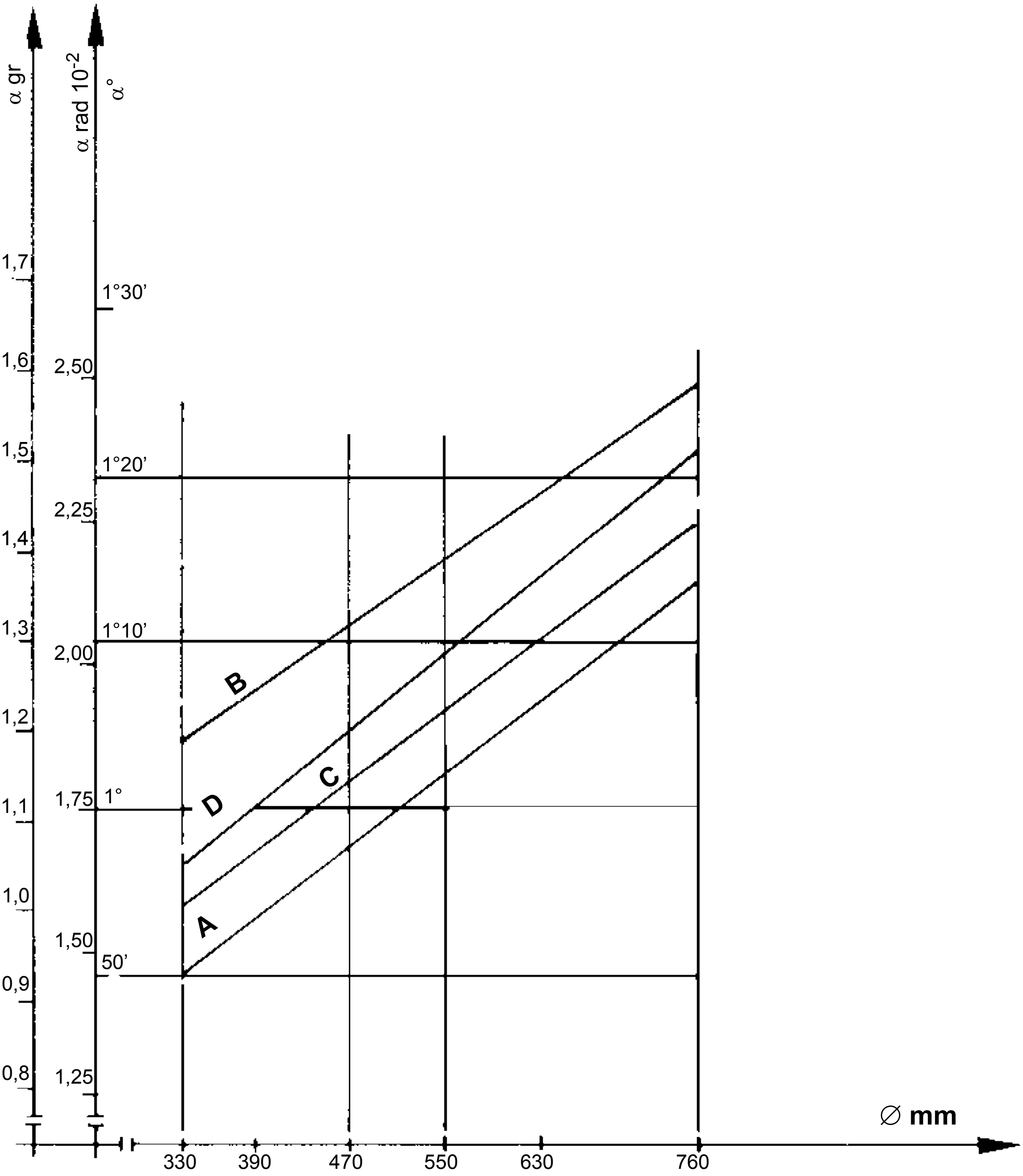


Fig. 29 - Data concerning the axle



α = angle of displacement
ε = slip angle
ζ = α + ε = trajectory angle

Fig. 30 - Data concerning the crossing



D : ERRI POC : CR raised by H = 60 mm
C : ERRI POC : CR raised by H = 45 mm
B : DB POC : CR raised by H = 45 mm
A : SNCF POC : CR raised by H = 60 mm

POC = plain obtuse crossing
CR = check rail

Fig. 31 - Angle of displacement α_1 of wheel 1 of a free axle in relation to the wheel diameter (for a lateral slip (slip angle ε) = 20‰)

I.9 - Description of the derailment test bench in Minden (Westf.)

The immediate study and observation of the phenomena which develop between a wheel in the course of running and the path along which it moves are made difficult by virtue of the fact that the observer is obliged to move at the same time as the wheel. In addition, it is difficult to maintain the axle of a vehicle in a set position in relation to the running path and to apply to it known and constant forces. However, it is essential to fulfill these conditions if an individual study is to be undertaken on the influence of each parameter on the phenomena occurring between wheel and rail. For this reason, the MINDEN Testing Station has constructed a fixed test bench designed to eliminate the difficulties mentioned above.

The basic principle of this installation is as follows: the axle is fixed in space and it is the running path which moves beneath it, as shown in point I.9.3 - page 59. This pathway, i.e. the rail-sleeper assembly, is mounted on the platform of a disused planing machine, with a movable deck. This platform is set in motion by an electric motor at a speed of 10 m/min. over a run of 5 m.

The wheel set running over this "track" is supported on a special auxiliary bogie capable of pivoting round a fixed point situated laterally to the track; the pivoting angle α (which is also the angle of attack of the axle in relation to the centre line of the rail), can be adjusted on the track side opposite the fixed point, and the frame in which the axle is fitted can be fixed in the selected position. The vertical loads (suspended loads) are applied to the bearings of the axle by means of hydraulic jacks (using coil springs of 2 000 kg, ensuring load constancy in the event of the level of the wheels changing). In the lateral direction, the axle is retained in its frame by means of dynamometrical housings, while in the longitudinal direction, oscillating arms are used enabling the axle to move vertically in relation to the frame, without modifying its position in the horizontal plane. The horizontal and vertical forces exerted on the axle are constantly measurable and can be adjusted to the desired values. A photograph of the testing bench is given in point I.9.4 - page 60.

Prior to the tests relating to small wheels, the following studies had been undertaken using this test bench:

1. determination of the laws of dependence between the rail-wheel coefficient of friction and reduced lateral slip,

2. determination of the laws governing derailment phenomena.

I.9.1 - Point 1

For a given vertical load applied to the wheelset, i.e. for a defined axle load, a given angle of attack α is allocated, and the track is moved beneath the wheelset. The wheelset tends to run forward in the direction thus determined, at a running speed v_r, the effect of which is to move it laterally away from the direction in which the track is moving. However, this tendency is offset by the force exerted by the left-hand measuring device, and this brings about a permanent lateral movement of the wheels in relation to the rails at a speed w_y. This speed is necessarily a sliding speed, since its direction coincides with that of the actual rotational axis of the wheelset, and running movements are only possible perpendicular to this axis. As shown in point I.9.3, the tangent of the angle α is the ratio of w_y to v_r, in other words the ratio between the lateral sliding speed and the running speed: in actual fact therefore, it is the lateral reduced slip. The lateral slip is opposed, at the points of support of the wheels, by the lateral tangential forces, the sum of which is equivalent (the tyres being cylindrical) to the lateral force exerted on the axle by the measuring device. If this force (lateral force at the bearings H_y) is divided by the axle load, the quotient thus obtained is the rail-wheel coefficient of friction in the event of simple lateral slip.

The tests were carried out with an axle fitted with wheels of diameter 2r = 1,0 m, the axle loads varying between 4 and 20 t and the lateral reduced slip between 0 and 18‰, the rail being alternately dry and sprayed with water. The results obtained with dry rails are given in points I.9.5 - page 61 and I.9.6 - page 62: point I.9.5 gives the relationship between the lateral force at the bearings H_y and various axle loads (for a variation of the parameter tg α), i.e. the lateral reduced slip ν_y, while point I.9.6 shows the law of dependence between the lateral reduced slip and the coefficient of friction τ for invariable axle loads.

A knowledge of the law governing the coefficient of friction is extremely important in research concerning side movements of vehicles. These recordings were carried out for *ERRI C 9* Specialists' Committee.

I.9.2 - Point 2

The wheelset, the right and left bearings of which are subjected either to equivalent or different vertical loads, is again moved through an angle α in relation to the centre line of the track, so that it runs towards the right-hand rail. A lateral force H_y is exerted on the wheelset by means of a hydraulic jack and of the device for measuring lateral forces. This force is then increased until the derailment limit is reached, i.e. until the flange of the right-hand wheel begins to override the rail. These tests were carried out by varying the angles of attack, the axle loads and the distribution of the loads between the bearings, i.e. by arranging different wheel loads for a given axle load.

Once the tests described above showed that this type of testing installation was practical and reliable, it was a matter of course to use it to study the behaviour of small diameter wheels passing over the unguided area of obtuse crossings. For this purpose, it sufficed to replace the rails of the section of track by an obtuse crossing, and to adapt the height of the running surface to the constructional characteristics of the test bench. It should be pointed out, however, that the prior fixing of the angle of attack α of the wheelset does not permit simple running of the dicone and the variation of α which may result therefrom.

On the other hand, this method of measurement holds the advantage of making it possible to study the influence of the geometry and the forces applied on the behaviour of the axle under clearly definable conditions. Another advantage is that the phenomena are easy to observe and, where applicable, to film.

I.9.3 - Assembly for measuring the coefficient of friction

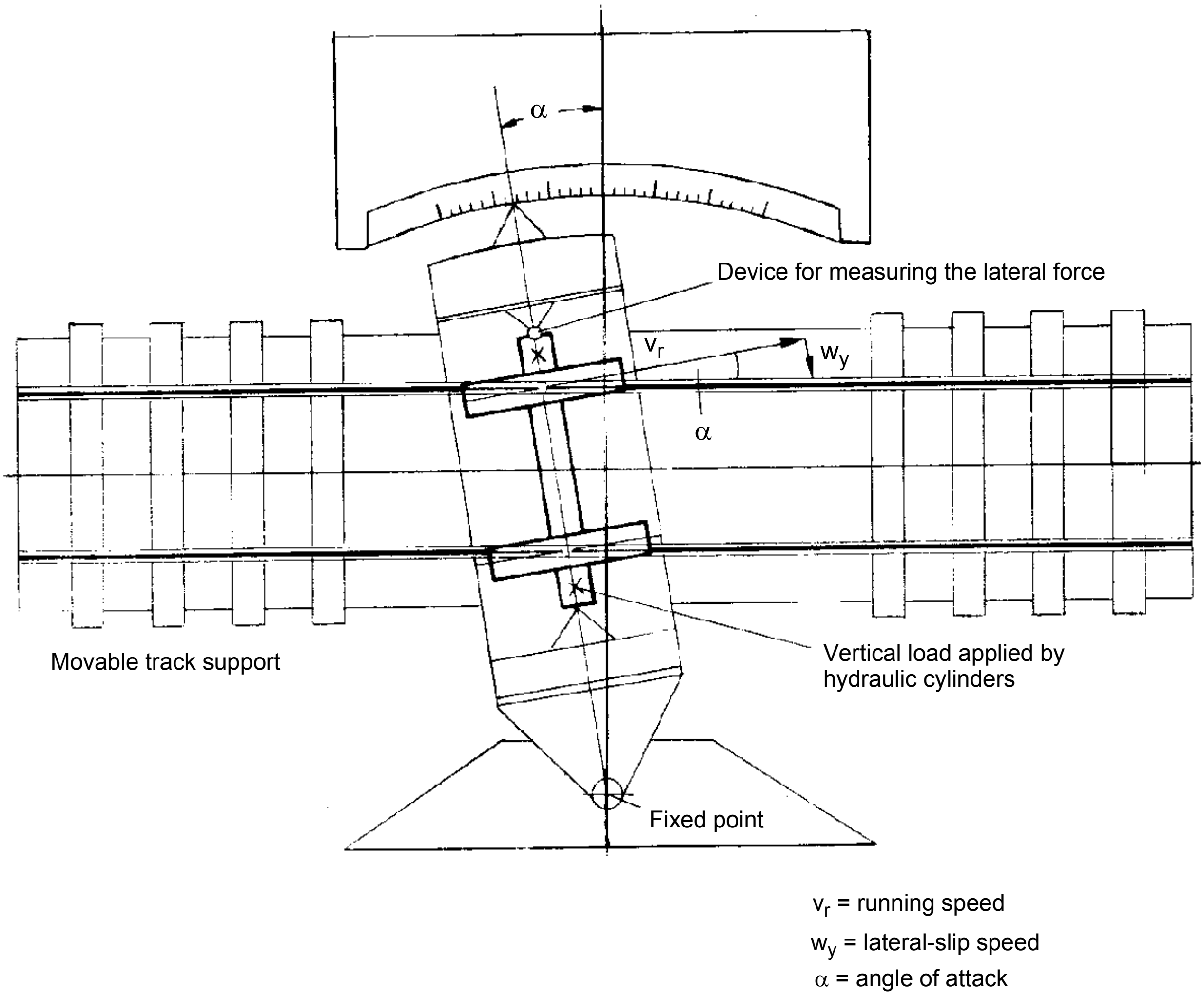


Fig. 32 - Assembly for measuring the coefficient of friction

I.9.4 - Derailment test bench

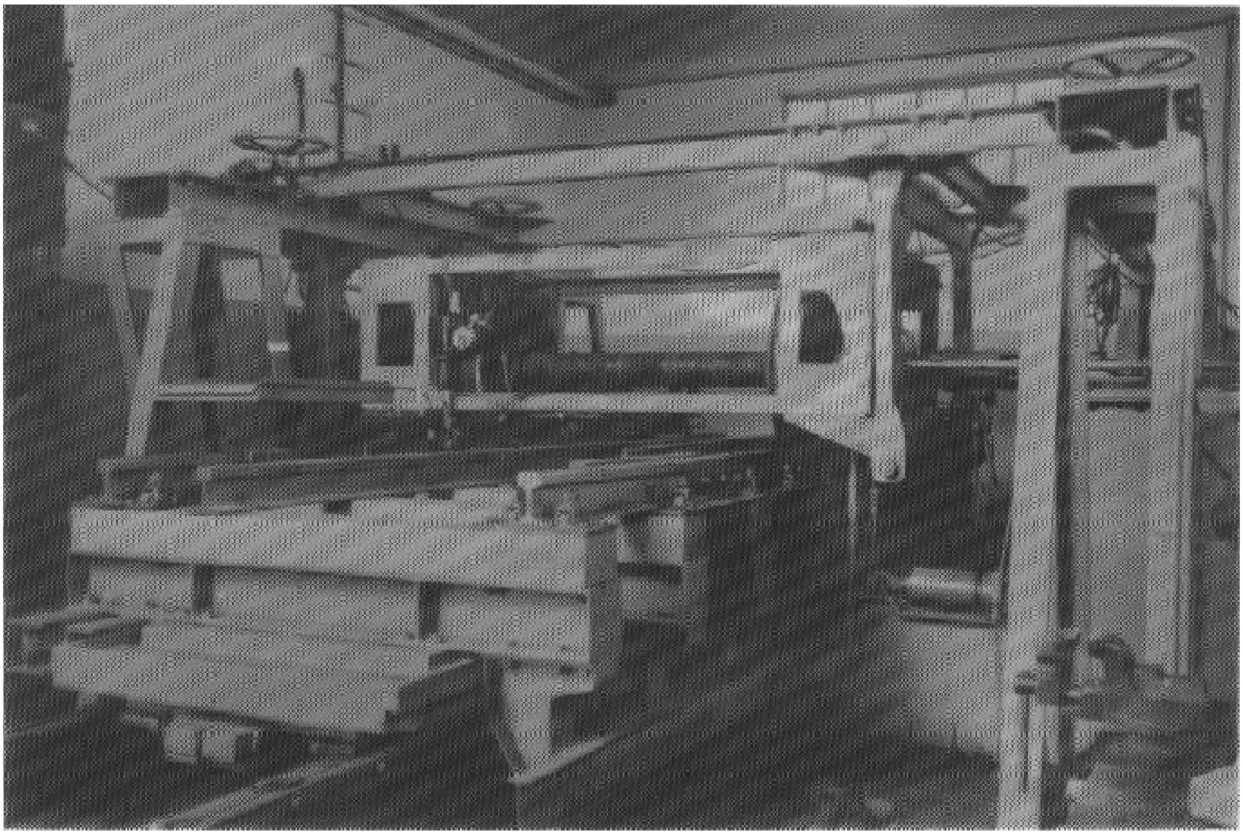


Fig. 33 - Photo

I.9.5 - Lateral force of axle-box in relation to lateral slip

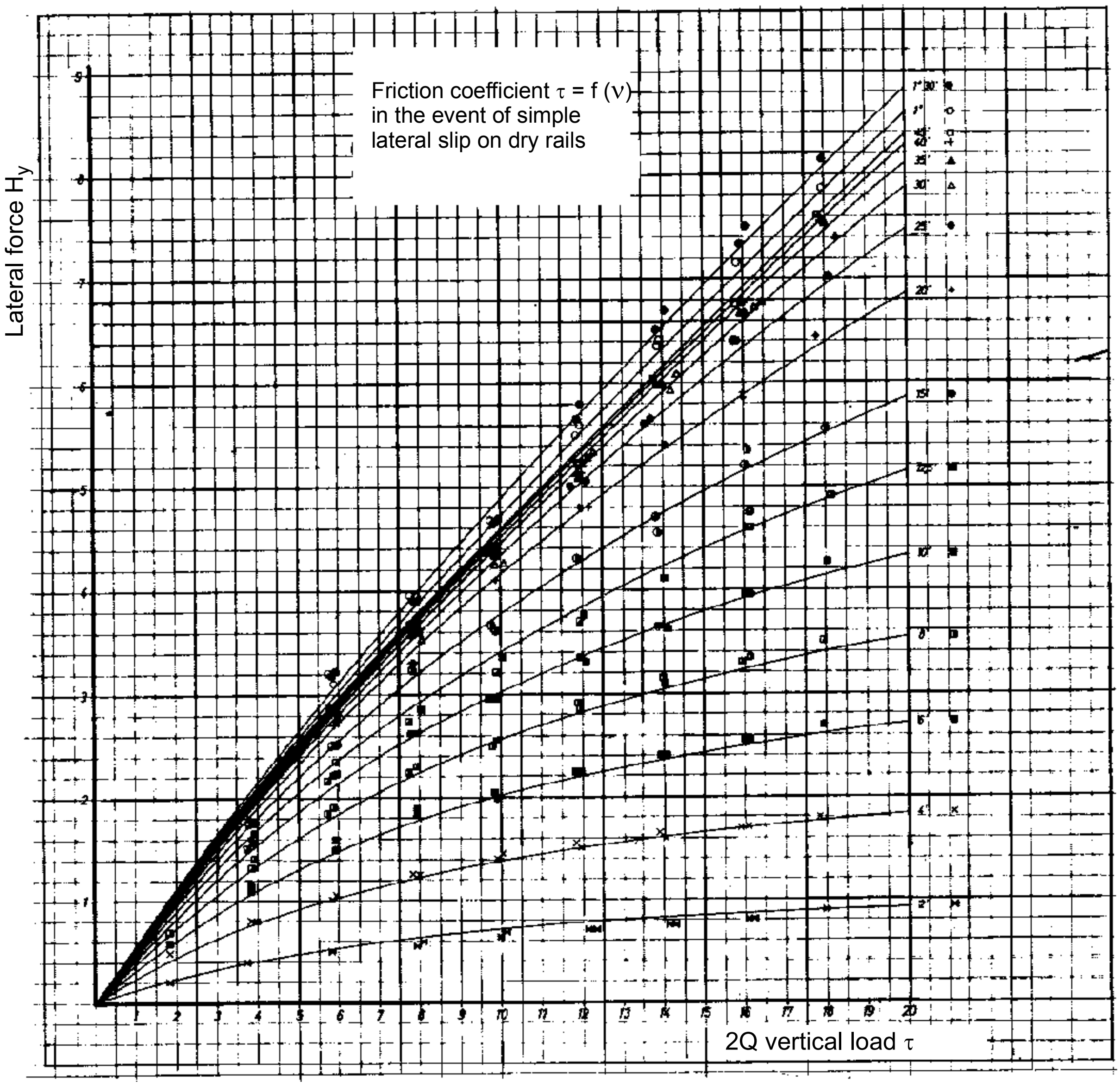


Fig. 34 -

I.9.6 - Friction coefficient $\tau = f(\nu)$ in the event of simple lateral slip

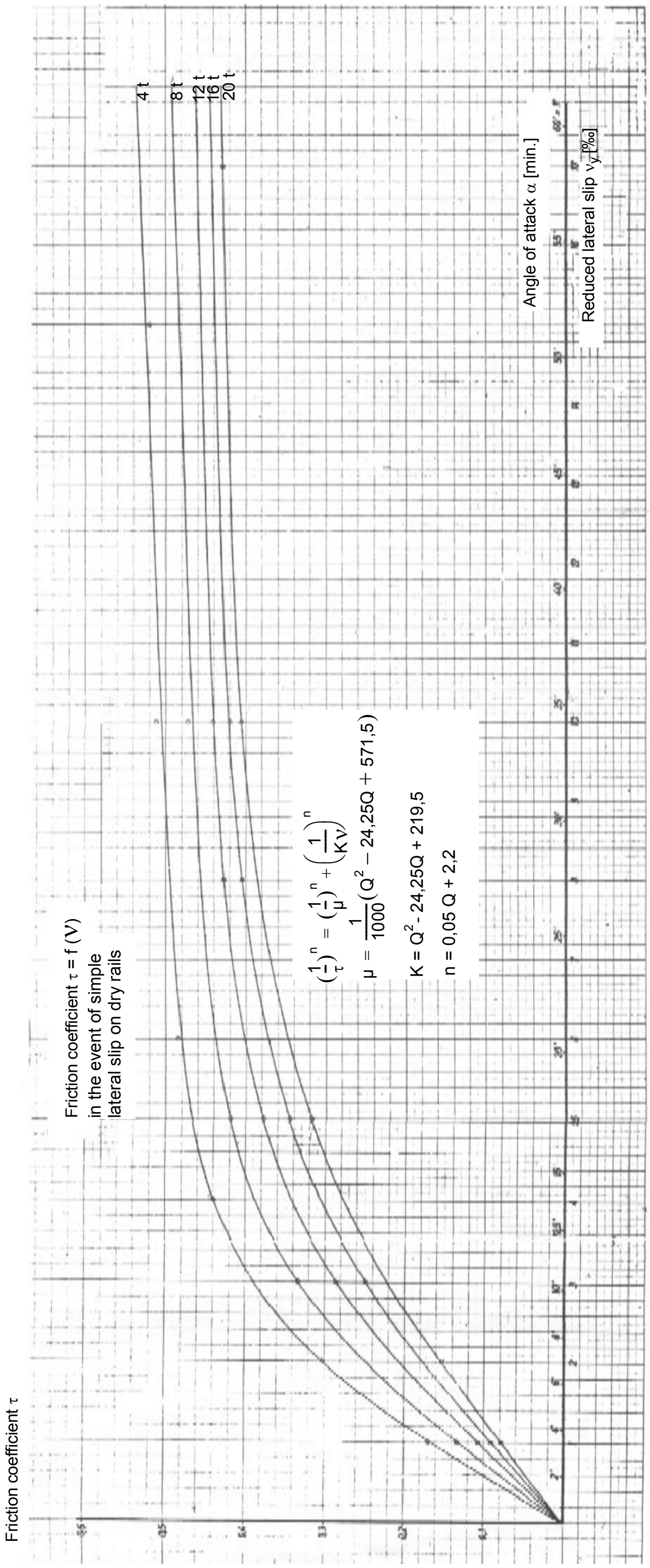


Fig. 35 -

I.10 - Description of the tyre profile

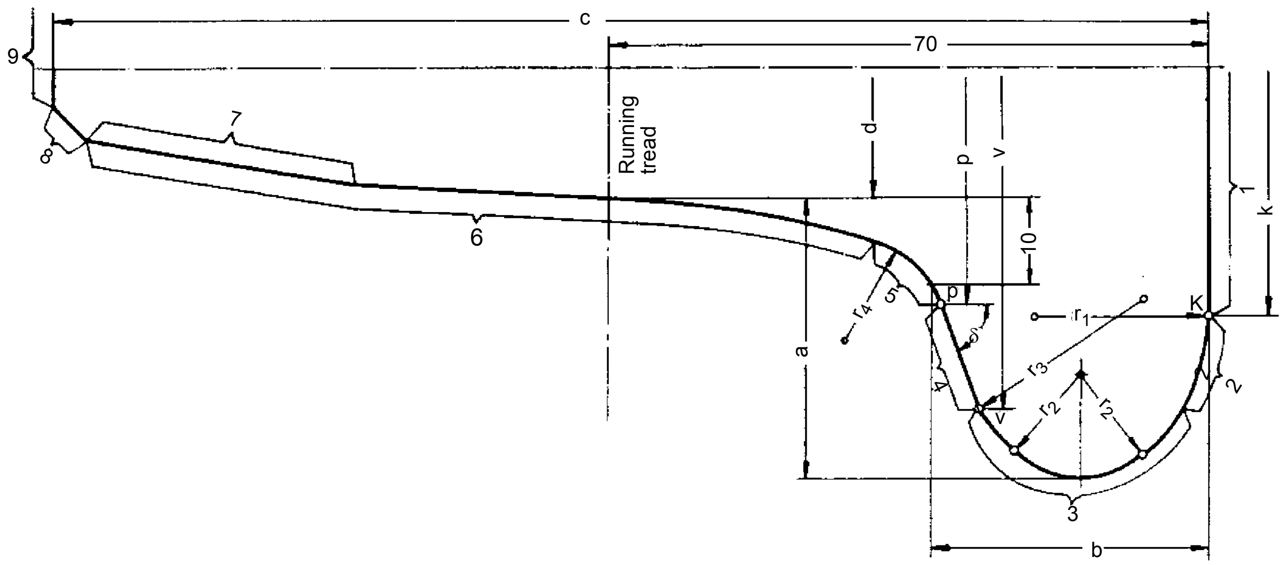


Fig. 36 - Description of the tyre profile

Table 3 : French description

Reference figure	Description of the tyre profile (see Fig. 36)	Corresponding revolution surface		
1	Internal surface of rim-tyre	Internal surface of rim-tyre	a	Flange height
	Internal surface of tyre	Internal surface of tyre	b	Flange thickness
2	Internal surface of flange	Internal surface of flange	c	Tyre width
3	Flange top	Flange top	d	Running tread diameter
4	External surface of flange	External cone of flange	p	Minimum diameter of the external cone of the flange
5	Flange fillet	Flange fillet	v	Maximum diameter of the external cone of the flange
6	Running surface	Running surface	r_1, r_2, r_3	Radii of the flange top
7	Slope of the external section of the running surface	External section of the running surface	r_4	Radius of the fillet
8	External bevel of running profile	Running surface bevel cone	α	Angle of the external surface of the flange
9	External surface of rim-tyre External surface of tyre	External surface of rim-tyre External surface of tyre		

I.11 - Description of obtuse crossings with slips

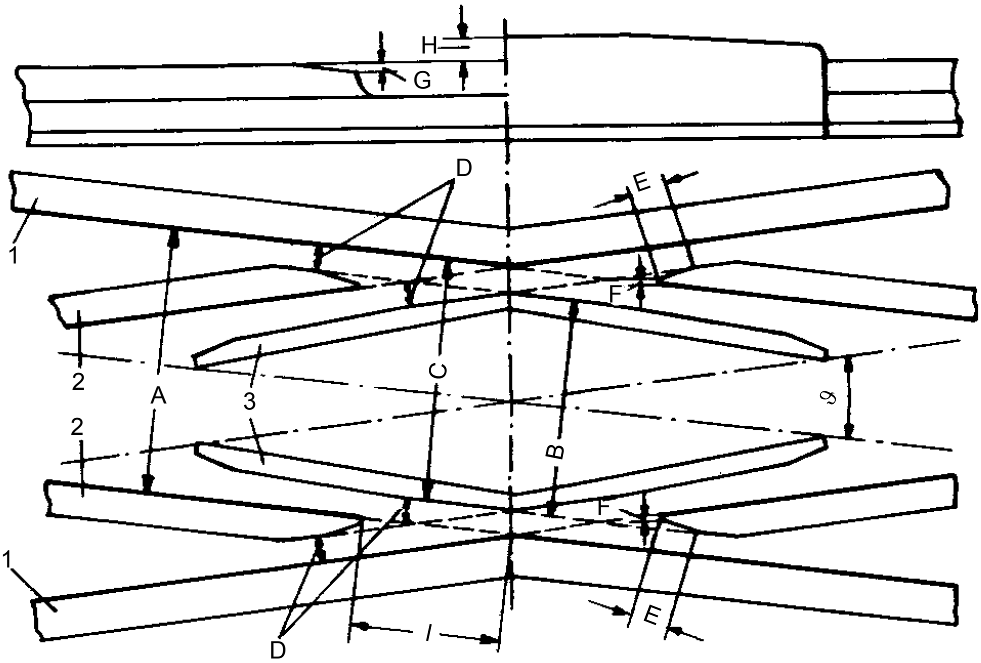


Fig. 37 -

Table 4 : French description

1	Obtuse wing rail
2	Nose
3	Check rail
ϑ	Crossing angle
A	Track gauge of the crossing
B	Running clearance measurement
C	Check-rail gauge
D	Width of the flangeways
E	Nose easement
F	Width of the actual nose
G	Lowering of the actual nose
H	Extra height of the check rail
I	Gap

Glossary

Angle of attack	Angle formed by the centre line of the axle with the normal in the main running direction.

List of abbreviations

ERRI	European Railway Research Institute (formerly ORE)

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Warning

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