Design Principles
Applicable to the Guidance of Rail Vehicles
for use on UK Tramways

Adapted from the

Regulations
on the Guidance of Rail Vehicles
in accordance with the
German Federal Regulations on the Construction and
Operation of Light Rail Transit Systems (BOStrab)

- Guidance Regulations (SpR) -
(March 2004)

Re-translated from the original translation and adapted to the UK tramway & light railway environment

by J Snowdon, I.Eng, FIET, FIMechE

September 2008
Regulations on the Guidance of Rail Vehicles
in accordance with the German Federal Regulations
on the Construction and Operation of
Light Rail Transit Systems (BOStrab)

Guidance Regulations (SpR).

Table of Contents

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Definitions and Dimension Designations</td>
<td>6</td>
</tr>
<tr>
<td>2.1</td>
<td>Definitions</td>
<td>7</td>
</tr>
<tr>
<td>2.1.1</td>
<td>Wheel/Rail Profile Characteristics</td>
<td>7</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Gauge Clearance</td>
<td>8</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Angle of Attack (α)</td>
<td>8</td>
</tr>
<tr>
<td>2.1.4</td>
<td>Derailment</td>
<td>8</td>
</tr>
<tr>
<td>2.1.5</td>
<td>Climbing</td>
<td>8</td>
</tr>
<tr>
<td>2.1.6</td>
<td>Mounting</td>
<td>8</td>
</tr>
<tr>
<td>2.2</td>
<td>Technical Guidance Systems</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>Dimension Designations on Track, Switches, Crossings</td>
<td>16</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Track Gauge (S)</td>
<td>16</td>
</tr>
<tr>
<td>2.3.2</td>
<td>Distance between Groove Back Face Lines or Guiding Lines (K)</td>
<td>16</td>
</tr>
<tr>
<td>2.3.3</td>
<td>Check-Rail Gauges (L_H, L_R)</td>
<td>16</td>
</tr>
<tr>
<td>2.3.4</td>
<td>Groove Width (W, W_H, W_R)</td>
<td>16</td>
</tr>
<tr>
<td>2.3.5</td>
<td>Groove Depth (T)</td>
<td>16</td>
</tr>
<tr>
<td>2.4</td>
<td>Dimension Designations on the Wheelset</td>
<td>16</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Tread</td>
<td>16</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Tread Distance (m)</td>
<td>17</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Active Face Dimension (s)</td>
<td>17</td>
</tr>
<tr>
<td>2.4.4</td>
<td>Flange Back Distance (k) and Wheel Back Distance (r)</td>
<td>17</td>
</tr>
<tr>
<td>2.4.5</td>
<td>Guiding Dimension (I)</td>
<td>17</td>
</tr>
<tr>
<td>2.4.6</td>
<td>Flange Thickness (d)</td>
<td>18</td>
</tr>
<tr>
<td>2.4.7</td>
<td>Flange Width (e)</td>
<td>18</td>
</tr>
<tr>
<td>2.4.8</td>
<td>Lateral Flange Back Dimension (f)</td>
<td>18</td>
</tr>
<tr>
<td>2.4.9</td>
<td>Flange Height (h)</td>
<td>18</td>
</tr>
<tr>
<td>2.4.10</td>
<td>Flange Cross Dimension (q_R)</td>
<td>18</td>
</tr>
<tr>
<td>2.4.11</td>
<td>Flange Angle (P_s)</td>
<td>19</td>
</tr>
<tr>
<td>2.4.12</td>
<td>Angle of Flange Back Blend (P_R)</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>Guidance</td>
<td>20</td>
</tr>
<tr>
<td>3.1</td>
<td>General</td>
<td>20</td>
</tr>
<tr>
<td>3.2</td>
<td>Safety against Derailment due to Climbing</td>
<td>21</td>
</tr>
<tr>
<td>3.3</td>
<td>Track Gauge and Active Face Dimension</td>
<td>22</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Basic Criteria</td>
<td>22</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Limit Values</td>
<td>23</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Track Gauge Adaptations in Curved Tracks</td>
<td>23</td>
</tr>
<tr>
<td>3.4</td>
<td>Distance between Gauge Lines or Groove Back Face Lines and Flange Back or Wheel Back Distance</td>
<td>24</td>
</tr>
<tr>
<td>3.5</td>
<td>Check-Rail Gauge and Guiding Dimension</td>
<td>24</td>
</tr>
<tr>
<td>3.6</td>
<td>Wheel Width</td>
<td>24</td>
</tr>
<tr>
<td>3.7</td>
<td>Groove Width, Flange Width and Flange Thickness</td>
<td>25</td>
</tr>
<tr>
<td>3.8</td>
<td>Adaptations of the Guidance Specific to the Vehicle</td>
<td>25</td>
</tr>
</tbody>
</table>
3.9 Groove Depth and Flange Height 26
3.10 Switches and Crossings 26
3.10.1 Designations and Specific Features 26
3.10.2 Switch Tongue Zone 31
3.10.3 Crossing Area 34

4 Cross Dimension Proof 36
4.1 General 35
4.2 Single Proofs 38
4.2.1 Line Track 38
4.2.2 Switches and Crossings within the Zone of Common Crossings (EH) 41
4.2.3 Switches and Crossings within the Zone of Obtuse Crossings (DH) 46
4.2.4 Minimum Contact Width of the Wheel 50
4.3 Single Values 52
4.3.1 Wheelset 52
4.3.2 Main Line 53
4.3.3 Crossing Area 54
4.4 Need for Additional Space for Wheel Flanges in Curved Tracks 57
4.5 Representation of the Cross Dimension Proof 57

5 Mixed Operation according to BOSstrab and EBO 58
6 Compilation of Symbols and Abbreviations 59
7 Reasons for the Revision of the Guidance Regulations in Accordance with BOSstrab (SpR) as well as Explanations 67
8 Literature 71

Appendices

1 Determination of the additional space needed for the wheel flanges in curved tracks (analytical and graphical methods)
2 Representation of the cross dimension proof
3 Example for a typical running gear:
   - Determination of the numerical values for the cross dimension table
   - Representation of the cross dimensions
   - Proof of the gaping dimension at the switch tip
4 Minimum stand-up width of the wheel or minimum width of the flange tip
1. General

1. Introduction

Sections 17 and 35 of the German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab) of 11.12.1987 (German Federal Law Gazette I, p. 2648) set out the regulations applicable to the guidance of tramway and light rail vehicles for use within that country. The basis for this document is the “Technical Rules for Guidance” (“Technischen Regeln Spurführung”, usually abbreviated to “TR Sp”), which sets out to codify the Regulations contained within BOStrab.

These apply to traction systems with guidance equipment designed in a conventional way; i.e., double-rail traction systems in which the vehicles are guided by wheels with inside flanges.

These Regulations are not mandatory and deviation is permitted provided that this does not result in a reduction in safety. They consider only the geometric relationships involved in wheel/rail guidance, not the forces that occur.

As is appropriate for regulations originating in a country with a long and unbroken history of tramway and light railway operation, the TR Sp recognises the existence of three distinct classes of operation, each with distinct characteristics. These are:-

Operating system S (tramway / light rail transit operation) – applicable to systems which predominantly employ grooved rails on “in-street” track formations.

Operating system E (light rail transit / metro operation) – applicable to systems, the vehicles and tracks of which are similar to or meet the German Regulations Governing the Construction and Operation of Railways (EBO)\(^1\) in respect of guidance.

Operating system M (mixed operation within the limits of BOStrab and EBO – applicable to systems, the vehicles and tracks of which are within the limits of the operating system S or E and meet the EBO in respect of guidance.

\(^1\) Or, for narrow gauge systems, the German Regulations Governing the Construction and Operation of Narrow-Gauge Railways (ESBO)
In practice, these systems can be broadly described as:

System S – traditional street tramway systems, operating on grooved rails with a small gauge corner radius, usually around 10mm, with wheel profiles having shallow flanges

System E – systems which, either through expansion and/or conversion, often as U-bahn, operate predominantly on off street tracks built to railway standards and laid with Vignole rail, with rails having a gauge corner radius of 13mm and flange profiles intermediate between those of System S and full railway operation.

System M – systems whose vehicles operate on both tramways and railways, and thus have to comply with the guidance standards for both operations. Typically, this is termed “tram/train” operation.

These definitions do not readily align with the path which tramway development has followed since the inauguration of the so-called “second generation” systems in the UK. These essentially align with the German System E standards, even though some of them employ considerable proportions of on-street track. The only systems which fall within the System S standards are the various heritage and the remaining first generation systems.

Within the British Isles (i.e. the UK, Ireland and the Isle of Man), examples of systems conforming to Group S are:
- Blackpool Tramways (as the only remaining UK First generation system)
- The National Tramway Museum (Crich)
- Great Orme Tramway
- Birkenhead Tramway and several other museum type operations.

The new, or Second Generation, tramways, currently represented by Metrolink (Manchester), Supertram (Sheffield), Midland Metro (Birmingham), NET (Nottingham) and Tramlink (Croydon), LUAS (Dublin) all fall within Group E, with Metrolink having the distinction of being the only UK system to have vehicles capable of tram/train operation, ie able to operate on both tramway and railway track dimensions (although there is in practice no shared operation, the composite wheel profiles having been adopted for other reasons).

The true Light Rail / Light Metro systems such as the Docklands Light Railway and the Tyne & Wear Metro, which are built to the same track and guidance standards as applicable to Network Rail, or equivalents thereof, fall outside the scope of this document.

As it is unlikely that any new tramway systems will be built using the characteristics of Group S, only the Group E dimension system is considered in detail in this document. However, the same principles apply to each Group in terms of the determination of the critical dimensions, so that those for a Group S system can be logically deduced.

---

2 Tramway systems built prior to 1925 and utilising the engineering standards appropriate to the 1870 Tramways Act.
2. Definitions and Dimension Designations

The definitions and dimension designations listed below are the basis for characterisation of features having relevance to technical guidance.

Characteristics relating to wheels or running gears are marked by lower-case letters and characteristics relating to rails or tracks by upper-case letters.

As regards the characteristics relating to wheels or running gears it has to be born in mind that

- a wheelset consists of two parallel wheels interconnected by a shaft at their axial centre line,

- a wheelpair consists of two wheels that are aligned in parallel to one another on a straight track and not interconnected by a continuous shaft,

- the definitions and dimensions for the wheelset also apply logically to the wheelpair.

As far as possible, the dimensions referring to the track include the word “gauge” or “width” and the dimensions referring to the wheelset the word “dimension”.

Special designations for switches and crossings are listed in Section 3.10.
2.1 Definitions

2.1.1 Wheel/Rail Profile Characteristics

The sections of the wheel profile and the rail profile having relevance to guidance and the terms used for their designations appear from Fig. 1 onwards.

Figure 1: Designations on the cross section of wheel and rail
2.1.2 Flangeway Clearance

The flangeway clearance is the distance by which a wheelset, whose axle is horizontally perpendicular to the longitudinal axis of the track (angle of attack $\alpha = 0^\circ$), can be pushed transversely in the track from the contact of the wheel flange of the one wheel with the head of rail of the appertaining rail to the contact of the wheel flange of the other wheel with the head of rail of the other rail (see Figs. 2a and 2b).

In general, this approximates to:-

\[
\text{flangeway clearance} = \text{track gauge} - \text{wheelset gauge}
\]

2.1.3 Angle of Attack ($\alpha$)

The angle of attack $\alpha$ is at the horizontal sectional plane through the wheel flange / rail contact point. It is the angle between the tangent at the rail in the contact point and the right angle to the axle (Fig. 3).

2.1.4 Derailment

In the context of this standard, derailment is when one wheel is lifted so much that the flange tip reaches the running surface of the rail or the head of the guidance equipment and then leaves the rail.

Derailment can be provoked by climbing or mounting.

2.1.5 Climbing

Climbing is when a wheel that runs with the face or back of its wheel flange at the gauge face or the guiding face, or the back face of groove rolls up onto the running surface of the rail or onto the head of the guidance equipment under adhesion by lateral guidance forces.

2.1.6 Mounting

Mounting is when a wheel drives up onto an obstacle on its route.
Figure 2a: Dimension designations on the wheelset and the track (grooved rails)
Figure 2b: Dimension designations on the wheelset and the track (non-grooved rails)
2.2 Technical Guidance Systems

A technical guidance system is harmonised with the existing operational conditions (e.g., new dimensions and wear limits as well as vehicle characteristics) and includes track and wheelset dimensions that are determined on the basis of these operational conditions. This harmonisation is to be proved in the form of a cross dimension proof. As regards the guidance, distinction is to be made between three operating systems:

Operating system S (tramway / light rail transit operation):

The operating system S applies to traction systems, the vehicles of which mainly drive on grooved rails on “in-street” track formations.

Operating system E (light rail transit / metro operation):

The operating system E applies to traction systems, the vehicles and tracks of which are similar to or meet the German Regulations Governing the Construction and Operation of Railways (EBO) or the German Regulations Governing the Construction and Operation of Narrow-Gauge Railways (ESBO) in respect of guidance.
Operating system M (mixed operation within the limits of BOStrab and EBO or ESBO): The operating system M applies to traction systems, the vehicles and tracks of which are within the limits of the operating system S or E and meet the EBO or the ESBO in respect of guidance.

As referred to in Section 1, the UK’s Second Generation tramway systems employ the standards corresponding to System E, irrespective of the fact that they have relatively low proportions of street track mileage with grooved rail. System E does, therefore, constitute the base standard for future UK tramways, other than specifically heritage operations.

Comment 1
As against the operational conditions of the railway, the application of the technical guidance principles of the EBO or the ESBO, respectively, is extended to curved tracks with radii of less than 180m or 50m, respectively, for the operating system E.

In order to determine the dimensions of the technical guidance system, the following levels or lines are to be defined and their positions determined.

The reference plane for the track is the joint rail surface tangent (GFT) of the two rails.

The track gauge measuring level is a level in parallel to the GFT at the distance A below the GFT. The distance A is determined as a function of the rail head corner radii and the depth of the flat grooves. The intersection lines of the track gauge measuring level with the gauge faces, guiding faces and back faces of grooves are called gauge lines, guiding lines and groove back face lines, respectively.

The reference line for a wheelset is the connecting line of the tread datum points.

The active face reference line of a wheelset is a parallel at the distance a from the connecting line of the tread datum points through the wheel flanges.

Comment 2
The track gauge measuring level is determined by the gauge corner radius of the rail, so as not to be influenced by the curvature of the rail surface. For UK systems conforming to System E and using rails with a 13mm gauge corner radius, e.g. S49, Ri59N/60N, the value for A is normally set at 14mm.

For heritage and other systems using rails with a 10mm gauge corner, e.g. BS 80A, Se35, GP41 etc., it is more appropriate to set the value of A as 10mm.

If rails with different profiles (with different rail head corner radii) have been laid in the same traction systems, it is recommended a uniform measuring level is determined that also considers the depth of the flat grooves and that this level is used as the basis for the cross dimension table (Section 4).

With a view to the continued development of new wheel and rail profiles a distance of 14 mm is recommended for the distance A.
Joint Geometric Level (GGE)

A joint geometric level (GGE) of track and wheelset is to be determined for the required cross dimension proof. This joint geometric level is to lie within the levels within which the gauge faces of the rails and the flange faces can actually touch one another; here the new condition, the worn condition, the straight track and the curved track are to be taken into consideration. Ideally, they are to match the track gauge measuring level and the active face reference line (if possible, at the same height).

Examples of the dimension designations on a wheelset and a track (with grooved rails / non-grooved rails) are illustrated in Figs. 2a and 2b, and in Figs. 4a and 4b examples of the dimension designations on a wheelset and the crossing area of a switch (having grooved rails / non-grooved rails) are illustrated.

Comment 2a

*For consistency with the track dimensions, the distance at which the GGE line lies below that of the GFT datum is also taken as being 14mm for rails with a 13mm gauge corner radius, and 10mm for rails with a 10mm gauge corner radius.*
Figure 4a: Dimension designations on a wheelset and a single turnout (grooved rails)
Figure 4b: Dimension designations on a wheelset and a single turnout (non-grooved rails)
2.3 Dimension Designations on Track, Switches, Crossings

(see Figs. 2a, 2b, 4a and 4b)

2.3.1 Track Gauge (S)

The track gauge $S$ is the distance between the two gauge lines of a track.

*Comment 3*
*If the track gauge cannot be measured at the height of the track gauge measuring level e.g. due to wear, the smallest distance between the inner lateral surfaces of the heads of rails (gauge lines) above the track gauge measuring level is regarded as the track gauge.*

2.3.2 Distance between Groove Back Face Lines or between Guiding Lines (K)

The distance between groove back face lines or between guiding lines $K$ is the distance between the groove back face lines or between the guiding lines of a track.

2.3.3 Check-Rail Gauges ($L_{H}, L_{R}$)

The check-rail gauge above the crossing flangeway $L_{H}$ is the distance between the guiding line of the check rail and the gauge line at the crossing.

The check-rail gauge above the check-rail groove $L_{R}$ is the distance between the groove back face line at the crossing and the gauge line within the zone of the check rail.

2.3.4 Groove width ($W$, $W_{H}$, $W_{R}$)

The groove width of the grooved rail $W$, the crossing flangeway $W_{H}$ and the check-rail groove $W_{R}$ is the distance between the gauge line and the groove back face line of the grooved rail or the guiding line of the check rail.

2.3.5 Groove Depth (T)

The groove depth $T$ is the distance between the joint rail surface tangent of a track and the deepest point of the rail groove (groove bottom).

2.4 Dimension Designations on the Wheelset

2.4.1 Tread

The tread is a line of intersection in parallel to the back of wheel through the rail surface. The two tread levels of a wheelset are symmetrical to the vertical level in the middle of the wheelset. The tread datum points MKF are the deepest points of the two treads.
2.4.2 Tread Distance (m)

The distance \( m \) between the tread levels of a wheelset is equivalent to the basic dimension of the track gauge + 65 mm.

\[ m = S + 65 \text{ mm} \]

2.4.3 Active Face Dimension (s)

The active face dimension \( s \) is the distance between the flange faces of the two wheels of a wheelset at the active face reference line, It can be determined by adding up the wheel back distance and the flange widths, ie:

\[ s = k + 2(d) = r + 2(e) \]

2.4.4 Flange Back Distance (k) and Wheel Back Distance (r)

Dependent on the position at which the wheel is in contact with the guidance equipment of the track (guiding lines or check rails), either the flange back distance \( k \) is important in respect of guidance as the distance between the flange back blends of the two wheels of a wheelset at the active face reference line and the respective guidance equipment or the wheel back distance \( r \) is important in respect of guidance as the distance between the wheel back surfaces in the contact zone and the respective guidance equipment.

\[ \text{Comment 4} \]

*The zone of contact depends on the type of check rail used, particularly where raised check rails are used on off-street (ballasted) track with Vignole rail.*

2.4.5 Wheelset Check Gauge (l)

At crossings, where the gauge face of one running rail is interrupted, guidance of the wheelset (wheelpair) is provided through contact between the back of the opposite wheel and a check rail, which may be formed as part of the rail groove, or by an additional rail which may, particularly on off-street tracks, be raised above the level of the GFT.

Depending upon the point of contact between the wheel and the check rail, the wheelset check gauge dimension \( l \) is either:

\[ l = k + d \]

if the check rail contact is below the GFT, otherwise

\[ l = r + e \]

if the check rail contact is at or above the GFT.
2.4.6 Flange Thickness (d)

The flange thickness \( d \) is the distance between the flange face and the flange back blend at the active face reference line.

2.4.7 Flange Thickness (e)

The flange width \( e \) is the horizontal distance between the flange face and the wheel back level at the height of the active face reference line.

2.4.8 Lateral Flange Back Dimension (f)

The lateral flange back dimension \( f \) is the difference between the flange width and the flange thickness. Reference positions for the measurement are the back of wheel, and the tread datum point, from which the position of the active face reference line is determined, at the height of which the lateral flange back dimension \( f \) is registered.

2.4.9 Flange Height (h)

The flange height \( h \) is the vertical distance between the flange tip and the tread datum point of the wheel.

2.4.10 Flange Cross Dimension (\( q_R \))

The flange cross dimension \( q_R \) is the horizontal distance between the intersection point of the joint geometric level (GGE) with the flange face and the intersection point of a reference line at a distance of 2 mm from the flange tip with the flange face (see Figs. 5a and 5b).

The smallest permissible flange cross dimension is to be determined with regard to determination of the maximum gaping dimension permitted (see Section 3.10.2 and Figs. 9a/b).

---

**Comment 5**

*The flange cross dimension characterises the steepness of the flange face.*

In the operating systems M and E the dimension \( a \) amounts to 10 mm and in operating system S the dimension \( a \) or \( a^* \) is to be oriented by the position of the mean contact level (GGE), which is to be determined in consideration of the most unfavourable wear states.

In the case of the EBO wheel profile, the tangent forms an angle of approx. 28° to the horizontal at the lower measuring point 2 mm above the flange tip. The friction coefficients possible at this position for operational reasons are below 0.53 (tangent of 28°) which means that a wheel flange that touches at this point slips to the intended side. As the wheel profiles of the operating systems S and M mostly have larger tangential angles than the EBO profile at the 2 mm point, it is justified to use this measuring point generally.
2.4.11 Flange Angle ($\beta_s$)

The flange angle $\beta_s$ is the angle between the flange face and the connecting line of the tread datum points. It has to be at least 60°.

2.4.12 Angle of Flange Back Blend ($\beta_R$)

The angle of flange back blend $\beta_R$ is the angle between the flange back blend and the connecting line of the tread datum points. If the proportion of grooved rails is high, the angle of flange back blend is to match the steepness of the back face of the groove of the rail.
3 Guidance

3.1 General

“Track and vehicle dimensions must be so matched that for the permitted speeds, there is no risk of derailment even when wearing parts are in the fully worn condition, and also so as to achieve the quietest possible running” [Section 17(2) BOStrab].

As regards the wear state, the limit values of the wheel/rail dimensions that are relevant for reasons of guidance are to be determined as a function of the operational conditions.

---

Comment 6
The wheel and the rail head adjust to one another during operation so that the following wear state profiles emerge, which are more or less out of the advance calculation:

- A rounding with a bigger radius than that of the rounding of the rail surface is formed in the running surface of the wheel.
- The flange face and the gauge face of the head of rail adjust to one another.
- Material on the wheel and the rail is overstressed and burrs are formed.

Further modifications of the profiles depend on operational management and maintenance:
- The flange back blends and the guiding faces of grooved rails are worn if the wheel is often guided on the back of wheel. This happens particularly if the wear of the gauge face of the opposite rail is not corrected by welding on new material.
- In curved tracks a “step” is formed at the gauge face in accordance with the mean wear flange profile.
- Material is worn and crushed at the flange tip if wheels are often run on flat grooves or on the bottom of grooved rails.

Usually the following modifications are observed:
- A rounding with a bigger radius than that of the rounding of the rail surface is formed in the running surface of the wheel.
- The flange face and the gauge face of the head of rail adjust to one another.
- Material on the wheel and the rail is overstressed and burrs are formed.

New profiles or wear limit profiles are to be documented. If both wheel profiles (new / worn) are compatible with both rail head profiles (new / worn) and if the fixed wear limit...
dimensions are observed, the requirements according to Section 3.1 can be regarded as fulfilled. As the new profile of the wheel is modified gradually, it is possible to adapt it to the wear profile and thus to optimise the service life of the wheels and rails. However, these profile modifications shall only be carried out if the braking characteristics - and especially the profile modifications developing during operation as well as the formation of “steps” at the gauge face - are observed thoroughly.

3.2 Safety against Derailment due to Climbing

The safety against derailment due to climbing is to be seen in the interaction between vehicle and track and is much influenced by the -

- track position (ramping)
- running speed
- flange height
- flange shape
- rail head corner
- curve negotiability and torsional softness of the running gears
- suspension behaviour of wheel and rail
- adhesion coefficients between wheel and rail

The flange height has to be matched with the groove depth, particularly in the case of -

- flat grooves
- rail head corner
- rounding of the flange tip
- smallest wheel diameter
- switch tongue design (Section 3.10.2)

It shall not be less than
- 18 mm in case of the operating system S
- 26 mm in case of the operating systems E and M

Comment 7

Guidance on the back of flange is to be avoided in curved tracks because load is transferred if a wheel is guided in that way due to the tilting moments of the centrifugal force. To ensure that this is avoided, welding new material to the gauge face at the correct time is recommended, to reconstruct the gauge face shape of the rail. If (derailment) guard rails have to be fitted, they are to be placed so far from the inner rail that they are not touched by the back of wheel even in case of maximum wear on the outer rail and the flange face. (see VDV Directive on Permanent Way for particulars)

In curved track the contact point between the gauge face and the flange face is shifted to the front or the back, respectively, seen from the meridian level of the wheel as well as upwards at the gauge face within the zone of the rounding of the flange tip. In case of curves with small radii (with big angles of attack) this contact point may only shift so far into the zone of the rounding of the flange tip that the safety against derailment due to
climbing is still ensured. If the contact point shifts into this zone, measures have to be taken to increase the running safety. The vehicle design (e.g. wheel base, wheel diameter, wheelset guidance), the gauge clearance, the maximum flange height and the maximum permissible flange angle are to be considered correspondingly. The flange angle $\beta_s$ is limited upwards by the smallest permissible $q_R$ dimension (Figs. 5a and 5b).

Comment 8

The radius of the curved track at which contact between the rail and the wheel flange occurs at the transition point from the flange flank to the rounding of the flange tip is the limit radius of the curved track as regards additional measures to be taken to increase the running safety. Based on operational experience, it is recommended that protection against derailment, e.g. check or guard rails, is provided in tracks that have non-grooved rails and curves with $R < 50m$.

3.3 Track Gauge and Active Face Dimension

3.3.1 Basic Criteria

In consideration of the manufacturing tolerances and the wear limit values of track and wheelset, the deflection of the wheelset and the gauge clearance, the track gauge and the active face dimension have to be so matched that there is no forcing between the gauge faces (Section 3.8), and so that the smallest permissible stand-up width of the wheel (Section 3.6) is still observed. Moreover, the check-rail gauges and the guiding dimensions are to be harmonised (Section 3.5).

The basic dimension of the track gauge amounts to

- 1435 mm for standard gauge and
- 1000 mm for metre gauge

at the measuring level determined (Section 2.2).

Deviation from the basic dimensions of the track gauge is permissible for existing networks.

The nominal active face dimension has to be derived from the basic dimension of the track gauge in accordance with the selected gauge clearance and checked via the limit value consideration according to Section 3.3.2.

Comment 9

In consideration of Sections 3.3.2 and 3.3.3 the gauge clearance is to be so selected that

- the running behaviour is as smooth as possible
- the wear is as low as possible.
For traction systems according to operating system E or M a minimum flangeway clearance of 9 mm is required between the nominal track gauge and the maximum value of the active face dimension.

For traction systems according to operating system S a mean flangeway clearance of at least 5 mm is recommended in the new state.

The variations in the active face dimension due to flexure of the axle (or wheelpair suspension) between the empty and fully loaded states for the vehicle has to be stated by the vehicle manufacturer and considered in the preparation of the cross dimension table. Similarly, variations due to the lateral flexibility of resilient wheels have also to be considered.

Values based on experience can be used for existing vehicles.

3.3.2 Limit Values

The maximum track gauge shall not be bigger and the smallest active face dimension not smaller than permitted for the smallest stand-up width of the wheel in harmonisation with the track and wheelset dimensions (Section 3.6). In that connection first and foremost the deep grooves in the crossing area are to be considered.

In consideration of the criteria mentioned in Section 3.3.1 the following applies to the maximum permissible active face dimension:

\[ s_{\text{max}} < s_{\text{min}} \] (smallest track gauge)

3.3.3 Alterations to Track Gauge in Curves

Any widening (or reduction) of the track gauge in curved track is to be determined as a function of the -

- minimum gauge clearance
- curve radius
- distance between the rigidly coupled axles
- wheel diameter
- tyre width
- flange angle
- flange height

Comment 10

The extent of and/or need for gauge widening can be reduced if the active face dimension is reduced on vehicles with longer fixed wheel bases. This can be useful, in particular, for maintenance and heritage vehicles, especially for operation on grooved rail tracks and where the running speeds are low.
It is sometimes considered useful (and is permissible) to reduce the track gauge in curved tracks, reducing the flangeway clearance in order to force a reduction in the Attack Angle (α).

3.4 Distance between Gauge Lines or Groove Back Face Lines and Flange Back or Wheel Back Distance

The distance between the groove back face lines (K) and the flange or wheel back to back distances (k or r) have to be so matched that the wheelsets do not become wedged between the guiding lines or the back faces of grooves, i.e.

\[ K_{max} < k_{min} \quad \text{or} \quad K_{max} < r_{min} \]

as appropriate (Section 3.8)

The minimum values for the flange back distance \( k_{min} \), or the wheel back distance \( r_{min} \), are determined by the manufacturing tolerances for the wheelset (or wheelpair) and the effects of flexure of the axle (wheelsets), distortion of the wheel mountings (wheelpairs) and the transverse elasticity of the wheels.

3.5 Check-Rail Gauge and Wheelset Check Gauge

The check-rail gauge and the wheelset check gauge dimensions are to be so matched in consideration of

- the running gears, the wheels of which have transverse dimension distances that are modified as a function of the curved track,
- the effects of tyres fitted in a transversely flexible way

that the wheels are guided on the flange faces as far as possible and only on the flange back blends at guidance equipment.

3.6 Wheel Width

The wheel width has to be so dimensioned that the wheels, particularly when passing through crossings, retain a sufficient area of contact with the rail, even after allowing for wear on both components and the maximum lateral displacement of both the wheelset (or wheelpair) and the wheel tyres, where these are flexibly mounted on the wheel centre.

The wheel width shall not be below -

- 95mm for operating system S
- 105mm for operating system S where deep groove crossings are employed
- 130mm for the operating systems E and M
Comment 11

The minimum contact width of the wheel can be proved as a function of the wheel diameter in the worn state, the maximum load on the wheel and the permissible stress levels in the material of the rail and the wheel (Annex 4).

The minimum supported width of the wheel is to be maintained at all times, even in case of the wheel being in contact with the back face of groove or to the wing rail of the crossing.

Where it is not possible to support the minimum width of the wheel on the running surface of the rails through the crossing area, the use of crossings where shallow depth grooves are used to ensure the wheel is supported on the flange tip (ie flange running) becomes unavoidable.

3.7 Groove Width, Flange Width and Flange Thickness

The groove width and the flange width have to be so matched that forcing of the wheel flanges is avoided in the rail grooves. Dependent on the wheel diameter and the running gear design, special attention has to be paid to this factor especially in curved tracks (Section 3.8).

On public roads the groove width shall not exceed 45 mm in case of straight tracks laid in these roads and 60 mm in case of curves and within the zones of the switch tips.

In the worn state the wheel flange still has to be sufficiently thick that it can reliably withstand the lateral forces encountered during operation without risk of damage.

The flange thickness shall be at least 11 mm for the operating systems S and M and 20 mm for the operating system E.

The values for the flange width according to EBO (in which it is called “flange thickness”) also have to be observed when the vehicles are operated in EBO networks.

Comment 12

Where flange running is employed through crossings and the like, the minimum width of the flange tip can be determined by reference to the wheel diameter in the fully worn state, the maximum vertical load on the wheel and the maximum permissible stress in the tyre material (Annex 4).

3.8 Adaptations of the Guidance Specific to the Vehicle

If there are a few vehicles in a network that have much bigger wheel bases and/or wheel diameters than the majority of vehicles and if they are usually operated over short distances (e.g. work cars and museum trains), the flange thickness on these vehicles should be reduced on the face for operation without forcing on curved tracks with small radii and on the back blend for operation without forcing in narrow grooves in consideration of the basic technical rules on guidance.
3.9 Groove Depth and Flange Height

The groove depth and the flange height have to be matched. In case of deep grooves wear of the height of the head of rail is permitted till the wheel flange touches the groove bottom. If it develops so far that the wheel runs on the groove bottom, the reduced stopping power of the vehicles has to be taken into consideration.

Elastically flexible equipment covering the rail grooves shall not impair the safe guidance of the wheels of the rail vehicles.

In case of flat grooves the maximum groove depth must be less than the minimum flange height in order to ensure that the wheel is supported on the flange tip.

3.10 Switches and Crossings

3.10.1 Designations and Specific Features

The designation of components and features in a turnout is defined with the viewer standing at the switch tip and looking towards the crossing. At crossings (Figs. 6 and 7) the viewer is defined as standing at the intersection point of the two tracks and looking towards either of the crossings.

Crossings are defined as being either common crossings (EH) or obtuse crossings (DH) for design and dimensioning reasons.

At common crossings (Fig. 6, zones I and IV), and in normal turnouts a check rail with narrowed groove width is usually fitted opposite the crossing.

This case, which is the simplest from a guidance point of view, the guidance is provided completely by the check rail, even in its worn condition, bearing on the back of the wheel flange. In curved tracks, especially with small radii (resulting in a high angle of attack $\alpha$) the contact point at the flange back blend shall only shift so much within the zone of the flange tip rounding that safety against derailment due to climbing is maintained.

In case of obtuse crossings (Fig. 6, zones II and III), two crossings lie so close opposite to one another within one track in the longitudinal direction that the groove width of one crossing becomes the check rail for the other crossing. Therefore, the two grooves of the track have to have the same groove width within this zone. The groove widths are to be minimised in consideration of the manufacturing tolerances and for avoidance of forcing. A significant element of guidance is provided by the length of the flange that is below the level of the rail head being greater than the oblique length of the intersecting groove.

It must be noted that, provided the two intersecting tracks have the same gauge, it is a geometrical necessity that the two obtuse crossing noses are offset longitudinally from each other. However, the value of this offset decreases in proportion to the crossing angle, and at very small angles it becomes necessary to substitute crossings with movable switches.

There are, in addition, certain other track formations, particularly crossovers and double junctions (Fig. 8), in which pairs of common crossings may lie nearly opposite each other. In this case, as with the opposed pairs of obtuse crossings in crossings, guidance of the wheel through one crossing is provided by the groove in the other crossing. The wear state
of the wheelset decides what proportion of guidance is provided by the gauge face and what proportion by the guiding face.

The crossing nose is the intersection point of two guiding lines crossing one another.

The point of groove back face line is the intersection point of two groove back face lines crossing one another.

The point of guiding line is the intersection point of two guiding lines crossing one another.

In case of switches with grooved rails based on the “common crossing” design principle the point of groove back face line, which has not got a guiding function, is opposite the crossing nose.

If the “obtuse crossing” design principle is applied, which is, for example, the case in crossings, a point of guiding line is opposite the crossing nose as the two groove back face lines take over the check-rail functions as guidance equipment in this case. The two other edge intersection points within the crossing area besides the crossing nose and the point of groove back face line or guiding line are secondary points. A secondary point is characterised in that a gauge line and a groove back face line or a guiding line cut themselves in these secondary points. If the view goes from the point of groove face line or guiding line to the crossing nose, distinction is made between the right secondary point and the left secondary point.
**Figure 6:** Designations on the crossing
(example: diamond crossing with deep grooves in a grooved rail design)
Figure 7: Designations on the crossing
(example: 90° crossing with flat grooves in a grooved rail design)
Figure 8: Dimensioning of crossings
3.10.2 Switch Tongue Zone

The switch tongue can be housed under the stock rail (undercut switch) or be set in to a rebate in the gauge face of the stock rail, formed either by machining or joggling the latter (Figs. 9a and 9b).

From a theoretical point of view, the undercut switch is to be preferred as it allows the through gauge line of the stock rail to be maintained unbroken.

However, for small flange heights, and where the switch is set into a curve where $< 100$ m (in and/or directly in front of the switches) the joggled switch is to be used in order to avoid the wheel climbing onto the switch tip if the gaping dimension $Q$ occurs.

**Figure 9a:** Gaping dimension for undercut switches
In order to ensure that contact between the flange face and the front of the switch rail is maintained as even as possible, after allowing for the differential wear on the flange face, the vertical slope on the face of the switch tongue should be at least 1:6 (measured vertically).
In order to minimise the risk of the flange tip striking and/or mounting the tip of an imperfectly closed switch tongue, the value of H (fig. 9a) should be maintained as small as is practicable. In any case,

\[ H < h - 4 \text{ mm} \]

in order to ensure sufficient overlap to provide positive guidance with minimal risk of derailment.

**Comment 13**

The distance between the open switch and the adjacent stock rail is to be so dimensioned that the tongue is not touched by the back of flange, if possible, when the stock rail is crossed.

If there are switches that are used mainly for one route, a step will develop either across the head of the stock rail, or between the head of the tongue and stock rail. This shall not impair the safe running.

The gaping dimension \( Q \) is a practically unavoidable dimension, the maximum size of which has to be determined.

The following applies to **undercut switches**:

To be able to observe the maximum permissible gaping dimension, the tongues have to be shaped additionally within the switch tip zone at the upper edge. In that way the potential surface of contact with the flange face is reduced. The maximum permissible lowering of the switch tip (due to the shaping of the gauge face of the tongue) has to be such that, with the smallest flange height, there is at least 2 mm overlap between the flange tip and the lowest part of the switch tongue in all operational states (see also comment 5):

\[ H_{\text{max}} \leq h_{\text{min}} - 2 \text{ mm} \]

The following applies to **joggled switches**:

In accordance with the smallest permissible flange cross dimension (\( q_R \) dimension) gaping of the tongue tip beyond the gauge face profile of the unmachined outline of the stock rail can be allowed. The difference to the maximum gaping dimension has to be realised via an additional inset into the stock rail. This additional inset amounts to:

\[ Q' = Q - q_R \]

Switch face angle\(^3\) - conventionally, this has been set at 1:6 for grooved rail tramway switches, but 1:4 for railway-type switches manufactured from Vignole rail and used in ballasted track. With the wear characteristics of some tram wheels, particularly those with independent rotation, this leads to the situation where first contact between the flange and the switch occurs at the corner of the flange tip. This in turn, especially if the switch is partially open, significantly increases the risk of derailment as a result of the flange tip either mounting the switch tip, or climbing the side face of the switch.

---

\(^3\) This requirement is additional to the Guidance Regulations as published.
3.10.3 Crossing Area

In no operational state of the wheels or the track shall the wheel flanges strike or climb on to either the crossing noses or the knuckles formed by the intersecting groove back face lines.

In case of common crossings the crossing flanges shall not be negotiated.

---

Comment 14

As a means of avoiding contact with the crossing noses in case of lateral wear on the check rails, it is permissible to provide taper relief to the gauge faces of the crossing nose in the normal direction of travel at a nominal rate of 2 mm per 100 mm (1:50).

In general, this also applies to obtuse crossings.

In case of the operating system S it can be necessary, if deep groove crossings are being used, to reduce the flangeways through the crossing by reducing the gauge clearance. For dimensioning with minimal groove widths and the avoidance of forcing, rail head profiling is recommended that leads to two-point contact if the wheel flange is negotiated laterally. This is in contrast to the plain line track.

It is recommended that the parallel guidance length of the check rails or guiding lines is equivalent to double the nominal bogie wheel base. Where this cannot be achieved, the parallel length should be at least that of the nominal bogie wheel base.

Check-rail entries are to be designed with a suitably gradual lead in (see VDV Directive on Permanent Way, Section 14).

---

Use shall only be made of crossings with flat grooves if the minimum contact area of the wheel (Section 3.6) is not above the minimum value for all operational states.

If the minimum contact area of the wheel is insufficient, or if the flange flanks overlap the gauge faces or back faces of grooves of the crossings, the dimensioning according to the principles of obtuse crossings (Section 3.10.1) can be followed for common crossings for realisation of the deep groove. In that connection lateral wear on the flanks of the crossing flangeway has to be taken into consideration.

In consideration of the operational influence (wear, deflection of the wheelset, transverse elasticity of the wheels) the maximum or minimum guiding dimension, respectively, for the wheelset is considered to be the biggest or smallest guiding dimension of the wheelset ($l_{\text{max}}$ or $l_{\text{min}}$).

In consideration of the manufacturing tolerances there shall be no forcing of the wheel flange in the most narrow check-rail groove with the biggest flange thickness.

Where crossings with movable switches are used to close the crossing gap, the requirements for switch tongues set out in Section 3.10.2 are applicable.
If, in designing the layout of the switches and crossings, it is not possible to avoid interruptions of the gauge line during which both wheels of a wheelset are not positively guided, special measures have to be taken to ensure the guidance.

Limit values are to be determined for the wear on the wheel flanges, the running rails and the guidance equipment in consideration of the above points.

Comment 15

The following measures are some of the possibilities for ensuring guidance if the gauge line is interrupted:

a) on the vehicle
   - increase in the wheel diameter
   - increase in the minimum flange height
   - decrease in the permissible flange face angle (higher $q_R$ value which allows for resistance to a larger gap between switch and stock rails)
   - rigid connection between several wheelsets

   all of which measures act to lengthen the part of the wheel flange that is lying below the rail head and/or gauge line

b) on the track

   - equipping the switch with movable crossing noses
   - decrease in the groove width
   - reduction of the crossing noses and the points of guiding lines
   - employing raised check rails (applies to obtuse crossings), provided that the arrangement of the rail brake and the wheel design allow this.
4 Cross Dimension Proof

4.1 General

Each transport undertaking has to document the new dimensions and the wear limit dimensions with tolerances for the wheels and the tracks that are valid for its zone. For this purpose a cross dimension representation is recommended (in the form of a table and a drawing). This representation is to consider all the vehicles being operated in the network and all the existing kinds of tracks. The basis for the cross dimension representation is the cross dimension proof, which has to be made by way of suitable mathematical or graphical procedures in consideration of the operational experience.

Generally, the new state and wear limit state differ. In between there are several wear states.

Theoretically, the following four extreme-case combinations result:

- New state of the track/new state of the wheelset
- New state of the track I wear limit state of the wheelset
- Wear limit state of the track / new state of the wheelset
- Wear limit state of the track / wear limit state of the wheelset

The single proofs, which are used as functional proofs, only need to be made for the most unfavourable combinations. From practical experience it can be derived that the wear of the flange face is usually bigger than the wear of the flange back blend because there is less guidance on the flange back blend, which is to be avoided, if possible (i.e. the guiding dimension does not grow). This was taken as a basis for the listed single proofs below.

Comment 16

The dimensions having relevance to the guidance (if applicable, new dimensions with manufacturing tolerances and wear limit dimensions) are to be documented in the cross dimension proof. The dimensions are particularly:

a) for the **wheels and running gears** of all the empty vehicles ready for operation on the tracks

- wheelbases
- nominal active face dimension
- changes of the dimensions in case of loading (e.g. due to deflection of the axles, lateral movement of the tyres relative to the wheel centre)
- special running gear features (e.g. independent wheels, wheelpairs, steerable axles, inside journal axles, outside journal axles)
- position of the active face reference line
- wheel profiles with the characteristics:
  - wheel diameter
  - wheel profile width
  - flange height
  - flange thickness
  - flange cross dimension ($q_R$ dimension)
  - flange root radius
  - angle of flange face
• angle of flange back blend
• running surface outlines

b) for the tracks

• track gauge
• tightest radius of curvature (line, switch systems)
• rail profiles
• inclination of the rail profile
• position of the track gauge measuring level of the track to the GFT

c) flangeway clearance

d) in addition for switches and crossings, dependent on the radius and perhaps dependent on the pairings deep groove / deep groove, flat groove / flat groove and deep groove / flat groove:

• track gauge in the crossing area
• check-rail gauge over the check-rail groove
• check-rail gauge over the crossing flangeway
• minimum stand-up width of the wheel in the crossing area
• area in which crossings with deep grooves are to be fitted
• groove width on the crossing
• groove width on the check rail
• height of the check rail over GFT (only in systems with non-grooved rails)
• maximum permissible gaping dimension of the switch tip
• special features (e.g. at obtuse crossings)
• other assumptions and determinations

Calculations for determination of dimensions are always to be made with the required accuracy; final dimensions are to be so rounded off in millimetres for practical use that the guidance safety is not diminished. The (general) conditions and the calculation itself are to be represented in an understandable way.

The cross dimension representation can be made in accordance with Annex 2 or following the example of calculation in Annex 3.

When the cross dimensions are calculated for the cross dimension proof, a manufacturing tolerance of usually ± 2 mm is to be considered for the track gauge, a manufacturing tolerance of usually + 1 mm is to be considered for the groove width and a manufacturing tolerance of usually - 1 mm is to be considered for wheelsets for the active face dimension and the flange thickness.

When the dimensions listed in the cross dimension table, the manufacturing tolerances and the wear limit dimensions for switches and crossings are being compiled, the following procedure is recommended:

For determination of the dimensions the minimum track gauge and the minimum groove width required for the non-forcing run-through of wheels with new wheel flanges are to be determined first. This happens by way of a model in which the gauge faces and the back faces of grooves or the guiding faces are moved till they touch the wheelset or the rigidly interconnected wheelsets of a running gear. In that connection it has to be taken into
consideration that the wheel flange needs more space at a wheel bevelled to the centre of the track. Then the gauge faces and the back faces of grooves or the guiding faces are to be drawn so far from one another that the contact proportions are safe for all wear and tolerance states and so that the gauge clearance that emerges between the track and the wheelset is not over or below the limit dimensions.

Thus, the following single proofs are to be made within the scope of a cross dimension proof:

4.2 Single Proofs

The single considerations are for the straight track, differentiated in accordance with the track sections and with reference to the GGE (Section 2.2). The single considerations made for the straight track are to be supplemented with regard to the need for additional space in curved tracks.

4.2.1 Line Track

(see also Figs. 10a and 10b)

- Proof: No forcing between the gauge faces

\[ S_{\text{min}} - S_{\text{max}} > 0 \]

(track and wheelset in the new state)

- Proof: No forcing between the back faces of grooves and the guiding faces

\[ k_{\text{min}} - K_{\text{max}} > 0 \] (in case of EBO: \( r_{\text{min}} - K_{\text{max}} > 0 \))

(wheelset and track in the new state)

- Recommendation: If possible, no guidance on the flange back blend

\[ l_{\text{min}} - L_{\text{max}} > 0 \]

(wheelset and track in the wear limit state)
Figure 10a: Cross dimensional relations on the wheelset in the line track (grooved rails)
Figure 10b: Cross dimensional relations on the wheelset in the line track (non-grooved rails)
4.2.2 Switches and Crossings within the Zone of Common Crossings (EH)
(see also Figs. 11a -13)

Proofs required:
- No forcing in the check-rail groove
  \[ W_{R,\text{min}} - d_{\text{max}} > 0 \quad \text{(check rail and wheel in the new state)} \]
- Observance of the minimum stand-up width of the wheel at the crossing noses at crossings with deep grooves in accordance with Section 4.2.4
  (track and wheelset in the wear limit state)

Objective: No wear on the crossing noses
- Recommendation: If possible, guidance on the flange face or the gauge face of the check-rail and no overlapping of the flange back (blend) or the flank of the crossing flangeway (see Figs. 11a and 11b bottom)
  \[ l_{\text{min}} - L_{R,\text{max}} > 0 \]
  (wheelset and track in the wear limit state)
- Recommendation: If possible, guidance on the flange back (blend) or the guiding face of the check rail and no overlapping of the flange face or the gauge face of the crossing (see Figs.11a and 11b top)
  \[ L_{H,\text{min}} - l_{\text{max}} > 0 \]
  (track: wear limit state / wheelset: new state)

Comment 17

“Overlapping” means that the profiles of the wheel flange and the crossing nose overlap one another mathematically, which is also called “displacement.”
Figure 11a: Cross dimensional relations on the common crossing (grooved rails, deep groove / deep groove)
Figure 11b: Cross dimensional relations on the common crossing (non-grooved rails)
Figure 12: Cross dimensional relations on the common crossing (grooved rails, deep groove / flat groove)
Figure 13: Cross dimensional relations on the common crossing (grooved rails, flat groove / flat groove)
4.2.3 Switches and Crossings within the Zone of Obtuse Crossings (DH) 
(see also Figs. 14a-15)

- Proof: No forcing between the gauge faces in consideration of the tolerances
  \[ S_{DH,\text{min}} - S_{\text{max}} > 0 \]
  (track and wheelset in the new state)

- Proof: No forcing between the back faces of grooves and the guiding faces in consideration of the tolerances
  \[ k_{\text{min}} - K_{DH,\text{max}} > 0 \]
  (wheelset and track in the new state)

- Proof: Observance of the minimum contact area width of the wheel at crossing noses at crossings with deep grooves in accordance with Section 4.2.4
  (track and wheelset in the wear limit state)
Figure 14a: Cross dimensional relations on the obtuse crossing (grooved rails, deep groove / deep groove)
Figure 14b: Cross dimensional relations on the obtuse crossing (non-grooved rails)
Figure 15: Cross dimensional relations on the obtuse crossing (grooved rails, flat groove / flat groove)
4.2.4 Minimum Contact Width of the Wheel

The proof of sufficient contact width of the wheel is to be made for the most unfavourable case (wear limit state of wheelset / wear limit state of track) and shall always be made at the measuring level of the track gauge in accordance with the purpose, also if it does not correspond to the joint geometric level.

According to Fig. 16 the following applies:

\[ b_p - f_{\text{max}} - W_{H,S;\text{max}} - 0.5 \, b_{R,H} - \left[ \frac{(0.5 \, b_{R,H} + W_{H,Z;\text{max}})}{\cos \beta_H} \right] - b_{R,F} \geq 0 \]

where:

- \( b_p \) Wheel profile width (not considering any front bevel)
- \( f_{\text{max}} \) Lateral flange back dimension (measured at the distance \( a \) from the tread datum point) in consideration of the maximum wear on the back of flange
- \( W_{H,S;\text{max}} \) Maximum permissible groove width of the groove of the main line in the crossing
- \( W_{H,Z;\text{max}} \) Maximum permissible groove width of the groove of the diverted track in the crossing
- \( b_{R,H} \) Smallest permissible crossing nose width that can carry the wheel load
- \( b_{R,F} \) Smallest permissible wing rail width that can carry the wheel load
- \( \beta_H \) Crossing angle
- \( a \) Vertical distance between the measuring level of the track gauge and the tread datum point

Comment 18

To increase the available width of the wheel when traversing crossings, it is possible to do without the front bevel.

The minimum values of the permissible carrying width of the crossing nose and the wing rail (measured at the measuring level of the track gauge) are to be determined as a function of the wheel load, the smallest wheel diameter and the material quality of the crossing or the wing rail (Annex 4). For that purpose typical figures can be taken as a basis.
Figure 16: Stand-up width of the wheel
4.3 Single Values

The single values can be determined as follows:
(All dimensions are to be stated at the height of the GGE!)

4.3.1 Wheelset

Gauge – The largest wheelset gauge dimension (s max ) is given by :-

\[ s_{\text{max}} = r_{\text{max}} + (2 \times e_{\text{max}}) \]

This normally applies only to wheelsets in the new state.

Flange back distance – The smallest flange back distance (k min ) is given by:-

\[ k_{\text{min}} = r_{\text{min}} + (2 \times f_{\text{min}}) \]

This normally applies only to wheelsets in the new state and, depending upon the design of the running gear, may be increased or decreased by any flexing of the axle under the weight of the load.

Smallest guiding dimension – The smallest wheelset guiding dimension (or check gauge) (l min ) is given by:-

\[ l_{\text{min}} = r_{\text{min}} + e_{\text{min}} + f \text{ (in the new state or the wear limit state)} \]

Depending upon the design of the running gear, this may be increased or decreased by any flexing of the axle under the weight of the load, and by any lateral movement of the wheel tyre relative to the wheel centre (if resilient wheels are employed).

(nominal value of the lateral flange back dimension less the absolute value of the negative manufacturing tolerance or plus the maximum permissible wear of the flange back blend or less the biggest increase with decreasing tread diameter)

Largest guiding dimension – The largest wheelset guiding dimension (or check gauge) (l max ) is given by:-

\[ l_{\text{max}} = r_{\text{max}} + e_{\text{max}} + f_{\text{max}} \text{ (in the new state or the wear limit state)} \]

Depending upon the design of the running gear, this may be increased or decreased by any flexing of the axle under the weight of the load, and by any lateral movement of the wheel tyre relative to the wheel centre (if resilient wheels are employed).
4.3.2 Track
(see also Figs. 14a-15)

**Gauge** – The smallest track gauge ($S_{\text{min}}$) is given by:

$$S_{\text{min}} = S_{\text{nom}} - \delta S$$

This normally applies only to track in the new state.

**Width over groove back face lines (or guiding lines)** - The largest width over the groove back faces ($K_{\text{max}}$) is given by:

$$K_{\text{max}} = S_{\text{max}} - (2 \times W_{\text{min}})$$

(usually only occurs in the new state)

**Check-rail gauge** – The largest check-rail gauge ($L_{\text{max}}$) is given by:

$$L_{\text{max}} = S_{\text{max}} - W_{\text{min}}$$

(usually only occurs in the wear limit state)
4.3.3 Crossing Area

Common crossing (EH):

When new (recommended preferential variant):

Smallest check-rail gauge over the crossing flangeway

\[ L_{H,\text{min}} = S_{EH,\text{min}} - W_{R,\text{max}} \]
Largest check-rail gauge over the check-rail groove

\[ L_{R,\text{max}} = S_{EH,\text{max}} - W_{EH,\text{min}} \]

When worn:

Check-rail gauge over the crossing flangeway

\[ L_{H,v} = S_{EH,v} - W_{R,v} \]

Check-rail gauge over the check-rail groove

\[ L_{R,v} = S_{EH,v} - W_{EH,v} \]
Obtuse crossing (DH):

**Smallest track gauge** (usually occurs in the new state)

\[ S_{DH,min} = S_{nom} - \delta S \]

**Largest guiding line distance** (usually occurs in the new state)

\[ K_{DH,max} = S_{DH,max} - (2 \times W_{DH,min}) \]
4.4 Need for Additional Space for Wheel Flanges in Curved Tracks

With conventional, i.e., non-steering, bogies or trucks, the wheelsets cannot take up a position that is radial to the curve. Consequently, each wheel takes up an angle to the rail – the angle of attack (α). On the leading wheels in each bogie, this is increased by the way in which the bogie will “crab”, with the leading outer and trailing inner flanges in contact with the rail. Consequently, the effective width of the wheel flange increases, in turn requiring more space in the groove both on the flange face side and on the flange back side (Annex 1).

The widening on the flange face side affects the track gauge required, and the widenings on the flange face and flange back sides affect the check-rail gauge and the groove width required. Moreover, characteristics specific to the vehicle (wheel base, transversely flexible wheels, transversely movable independent wheels etc.) have to be included when the single values for curved tracks are determined. Thus, some independent self-steering wheel designs might not need more space for the wheel flanges, but the effective wheel back distance might decrease.

The values for the need for additional space are to be taken into consideration over and above the values for the straight track from the cross dimension proof.

---

**Comment 19**

*In that connection the maximum dimension of the transverse displacement of the flexibly suspended tyre can come to the nose in a graduated way:*

- *in case of big curve radii proportionately*

- *in case of small curve radii completely or in case of effectiveness against the centrifugal force also only proportionately*

---

4.5 Representation of the Cross Dimension Proof

The representation of the cross dimension proof includes both the data of characteristics specific to the vehicles, which are to be examined in respect of their operational dimensions, i.e., particularly the characteristics of the wheel profile features in the new state and the wear limit state together with the running gear geometry, and the data about the tracks with a table of the track gauges and the groove widths as a function of the curve radius for main lines and for switch/crossing systems, inclusive of the building or manufacturing tolerances as well as the limit values having relevance to safety (Annex 2).
5 Mixed Operation according to BOSTrab and EBO

The profiles of the rails and the tyres are to be determined on the basis of the following aspects and are to be harmonised:

a) for a new BOSTrab network to be set up

If a new BOSTrab network is being set up and if this network is to be linked to an existing railway network, the tracks in the BOSTrab zone are to be so designed from the outset that the EBO wheel profile can be operated on them. If grooved rails are used, care has to be taken that they have sufficient groove width and depth.

b) for an existing BOSTrab network

If the BOSTrab network already exists and if its tracks and switches cannot be adapted in respect of guidance at reasonable cost, the wheel profile geometry has to meet the BOSTrab and EBQ requirements for guidance.

Figure 17: Wheel profile for mixed operation within an existing BOSTrab network; example from Karlsruhe
6 Compilation of Symbols and Abbreviations
(Regulations and Annexes)

The references to figures are only examples and not always complete!

A  Vertical distance from the track gauge measuring level to the GFT (Figs. 2a / 2b / 4a / 4b / 1.7)

a  Vertical distance from the active face reference line to the connecting line of the tread datum points (Figs. 2a, 2b, 4a, 4b)

a* Vertical distance from the GGE to the GFT or the connecting line of the tread datum points (e.g. Figs. 2a, 2b, 4a, 4b, 1.7)

a_{Ell,R} Big elliptical axis of the ellipse on the flange back side in the sectional surface of the wheel flange (Figs. 1.1, 1.4, 1.6)

a_{Ell,S} Big elliptical axis of the ellipse on the flange face side in the sectional surface of the wheel flange (Figs. 1.1, 1.4, 1.6)

a_F Distance between the two axles of the running gear (Figs. 1.2 -1.6, 1.9 -1.12)

b  Wheel width (Figs. 2a, 2b, 4a, 4b)

b_p Wheel profile width (not considering any front bevel) (Fig. 16)

b_{Ell,R} Small elliptical axis of the ellipse on the flange back side in the sectional surface of the wheel flange (Figs. 1.1, 11.4, 11.6)

b_{Ell,S} Small elliptical axis of the ellipse on the flange face side in the sectional surface of the wheel flange (Figs. 1.1, 1.4, 1.6)

b_R Stand-up width of the wheel

b_{R,H} Minimum width of the crossing nose that can carry alone (Fig. 16)

b_{R,F} Minimum width of the wing rail that can carry alone (Fig. 16)

δ  Variation due to tolerance

d  Flange thickness in the active face reference line (Figs. 2d, 4a, 4b)

d_K Length of the flange tip lines to the extended flange face or flange back blend (Fig. 1.1)

d_{K,G} Length of the straight flange tip (Figs. 1.1, 1.4, 1.6)

d_{K,R} Extension of the flange tip lines on the flange back side till the intersection point with the extended flange back blend (Figs. 1.1, 1.4, 1.6)
**d_{K,S}**  Extension of the flange tip lines on the flange face side till the intersection point with the extended flange face (Figs. 1.1, 1.4, 1.6)

**d_{M}**  Tread diameter (Fig. 1.1)

**d_{R}**  Horizontal reduction of d* on the flange back side between GGE and the non-rounded flange tip (Figs. 1.1, 1.4, 1.6)

**d_{S}**  Horizontal reduction of d* on the flange face side between GGE and the non-rounded flange tip (Figs. 1.1, 1.4, 1.6)

**d_{U,R}**  Size of the arrow of the hyperbola on the back side in the sectional surface of the wheel flange at the GGE (Fig. 1.1)

**d_{U,S}**  Size of the arrow of the hyperbola on the face side in the sectional surface of the wheel flange at the GGE (Fig. 1.1)

**E**  Elasticity module of the wheel and rail material

**e**  Flange width in the active face reference line (Figs. 2a/2b/4a/14b)

**F_{N}**  Stand-up force of the wheel with a vehicle full to capacity

**f**  Lateral flange back dimension in the active face reference line [Figs. 2a, 4a)

**GFT**  Joint rail surface tangent (Figs. 2a/12b/14a/14b)

**GGE**  Joint geometric level (Figs. 2a/12b/14a/14b)

**g_{1}**  Line connecting the midpoints of the radii replacing the hyperbolas at the sectional surfaces of the wheel flanges r_{A,R} for wheel 1 (on the back side) and r_{A,S} for wheel 2 (on the face side) (Fig. 1.5)

**g_{2}**  Connecting line from the point of attack in the sectional surface of the wheel flange at wheel 1 to the midpoint of the radius replacing the hyperbola of the sectional surface of the wheel flange on the face side on wheel 2 r_{A,S} (Fig. 1.5)

**g_{3}**  Horizontal connecting line from the point of attack in the sectional surface of the wheel flange at wheel 2 to the midpoint of the curve radius R_1 with the gauge face (Fig. 1.6)

**g_{3,x}**  x-coordinate of g_3 (Fig. 1.6)

**g_{3,y}**  y-coordinate of g_3 (Fig. 1.6)

**H**  Vertical distance between the GFT and the switch tip (Figs. 9a/b)

**h**  Flange height, vertical distance between the connecting line of the tread datum points and the flange tip (Figs. 9a/b, 1.1)

**h_{U,R}**  Vertical distance from the GGE to the transition point of the hyperbola/ellipse at the flange back blend (Fig. 1.1)
h_{U,S}^* \quad \text{Vertical distance from the GGE to the transition point of the hyperbola/ellipse at the flange face (Fig. 1.1)}

K \quad \text{Distance between guiding lines or groove back face lines at the measuring level of the track gauge (Figs. 2a, 4a, 4b)}

K_{F/F} \quad \text{Distance between guiding lines or groove back face lines for flat groove}

Y \quad \text{flat groove at the measuring level of the track gauge (Fig. 1.7)}

K_{B^*} \quad \text{Distance between guiding lines in a curved track at the GGE}

K_{G^*} \quad \text{Distance between guiding lines on a straight track at the GGE}

K_{T/F} \quad \text{Distance between guiding lines or groove back face lines for deep groove/flat groove at the measuring level of the track gauge}

k \quad \text{Flange back distance at the active face reference line (Figs. 2a, 4a)}

L \quad \text{Check-rail gauge at the measuring level of the track gauge (Fig. 4b)}

L_{F/F} \quad \text{Check-rail gauge at flat groove/flat groove at the measuring level of the track gauge (Fig. 1.7)}

L_H \quad \text{Check-rail gauge over the crossing flangeway at the measuring level of the track gauge (Fig. 4a)}

L_{H^*} \quad \text{Check-rail gauge over the crossing flangeway at deep groove/flat groove at the measuring level of the track gauge}

L_{H,T/F} \quad \text{Check-rail gauge over the check-rail groove at the measuring level of the track gauge (Fig. 4a)}

L_{R^*} \quad \text{Preliminary check-rail gauge over the check-rail groove at the GGE}

L_R \quad \text{Check-rail gauge over the check-rail groove at deep groove/flat groove at the measuring level of the track gauge}

l \quad \text{Guiding dimension (wheelset check gauge) at the active face reference line (Figs. 2a, 4a, 4b)}

l_a \quad \text{Length of the sectional surface of the wheel flange at the GGE (Figs. 1.1 -1.6)}

MKF \quad \text{Tread datum point (Figs. 2a, 2b, 4a, 4b)}

m \quad \text{Distance between the tread levels of the two wheels of one axle (Figs.2a, 2b, 4a, 4b)}

...max \quad \text{Maximum value}

...min \quad \text{Minimum value}
... N Value in the new state

... nom Nominal value

n_R Canting value of the flange back blend (Fig. 1.1)

n_S Canting value of the flange face (Fig. 1.1)

p Hertz-calculated stresses

p_{lim} Limit value of the Hertz-calculated stresses

Q Gaping dimension at the switch tip (Figs. 9a/b)

Q_i Transverse elasticity acting into the curve as a function of the curved track and the centrifugal force

q_R Horizontal distance between the two intersection points of the dimension h_1 with the flange face (Figs. 5a/b)

R_m Mean curve radius (Fig. 1.3)

R_{m,x} x-coordinate of R_m (Fig. 1.4)

R_{m,y} y-coordinate of R_m (Fig. 1.4)

R_{p0,2} Yield point of the wheel or rail material

R_{1...n} Curve radius at the point of attack of the wheel 1...n on the sectional surface of the wheel flange (Figs. 1.4-1.6)

R_{1...n,x} x-coordinate of the curve radius R_{1...n} (Figs. 1.3/1.4)

R_{1...n,y} y-coordinate of the curve radius R_{1...n} (Figs. 1.3/1.4)

R_{E,S} Curve radius in the face-side hyperbola/flange tip corner point of the sectional surface of the wheel flange (Fig. 1.2)

R_{E,R} Curve radius in the back-side hyperbola/flange tip corner point of the sectional surface of the wheel flange (Fig. 1.2)

R_{E,R,m} Mean curve radius belonging to R_{E,R} (Fig. 1.2)

R_{E,S,m} Mean curve radius belonging to R_{E,S} (Fig. 1.2)

(R_R-r_{A,R})_y y-coordinate of (R_R –r_{A,R})

(R_S-r_{A,S})_y y-coordinate of (R_S –r_{A,S})

R_{U,S} Curve radius in the face-side hyperbola/ellipse transition point of the sectional surface of the wheel flange (Fig. 1.2)
$R_{U,R}$ Curve radius in the back-side hyperbola/ellipse transition point of the sectional surface of the wheel flange (Fig. 1,2)

$R_{U,R,m}$ Mean curve radius belonging to $R_{U,R}$ (Figs. 1.2)

$R_{U,S,m}$ Mean curve radius belonging to $R_{U,S}$ (Fig. 1,2)

$R_{1\ldots n}$ Curve radius at the point of attack of the wheel 1...n (Figs. 1.3 -1.6, 1.10 -1.14)

$(R_{1\ldots 4} + r_{A,S})_x$ x-coordinate of $(R_{1\ldots 4} + r_{A,S})$

$(R_{1\ldots 4} + r_{A,S})_y$ y-coordinate of $(R_{1\ldots 4} + r_{A,S})$

$R_{1\ldots 4,x}$ x-coordinate of $R_{1\ldots 4}$ (Figs. 1.4, 1.6)

$R_{1\ldots 4,y}$ y-coordinate of $R_{1\ldots 4}$ (Figs. 1.4, 1.6, 1.11)

$r$ Wheel back distance (figs. 2a/2b/4a/4b)

$R_{A,R}$ Radius at the flange back blend in the sectional surface of the wheel flange (replaces a hyperbola) (Figs. 1.2/1.3/1.5)

$R_{A,S}$ Radius at the flange face in the sectional surface of the wheel flange (replaces a hyperbola) (Figs. 1.2/1.3/1 -5)

$R_{K,R}$ Inside flange tip rounding radius (Fig. 1.1)

$R_{K,S}$ Outside flange tip rounding radius (Fig. 1.1)

$S$ Track gauge at the measuring level of the track gauge (Figs. 2a/2b/4a/4b)

$S_{DH,B}^*$ Track gauge in the obtuse crossing in the curved track at the GGE

$S_{DH,G}^*$ Track gauge in the obtuse crossing in the straight track at the GGE

$S_{EH}$ Track gauge in the common crossing at the measuring level of the track gauge (Fig. 1.22)

$S_{F/F}^*$ Track gauge at flat groove /flat groove at the measuring level of the track gauge (Fig. 1.7)

$S_B^*$ Track gauge in the curved track at the GGE

$S_G^*$ Track gauge in the straight track at the GGE

$S_{T/F}$ Track gauge at deep groove /flat groove at the measuring level of the track gauge

$s$ Active face dimension at active face reference line (Figs. 2a/2b/4a/4b)

$T$ Groove depth (Fig. 2a/4a)

$t$ Flat groove depth (Fig. 1.7)
...v Dimension in the wear limit state

W Groove width at the measuring level of the track gauge (Fig. 2a)

WDH,B* Groove width in the obtuse crossing in the curved track at the GGE

WDH,G* Groove width in the obtuse crossing in the straight track at the GGE

WEH Groove width in the common crossing at the measuring level of the track gauge (Fig. 1.22)

WF Groove width at flat groove at the measuring level of the track gauge (Fig. 1.7)

WH Groove width in the crossing at the measuring level of the track gauge (Fig. 4a)

WH,F Groove width in the crossing at a flat groove at the measuring level of the track gauge

WH,S Groove width of the groove of the main line in the crossing at the measuring level of the track gauge (Fig. 1.6)

WH,Z Groove width of the groove of the diverted track in the crossing at the measuring level of the track gauge (Fig. 16)

WR Groove width in the check rail at the measuring level of the track gauge (Fig. 4a)

WR,x x-coordinate of WR

WR,y y-coordinate of WR

WR,G* Groove width in the check rail in the straight track at the GGE

x-direction Assumed horizontal coordinate system, direction in parallel to the longitudinal axle of the running gear

xEll,R' Distance in the x-direction of the axle from the midpoint of the back-side ellipse in the sectional surface of the wheel flange (Figs. 1.1 /1.4)

xEll,S' Distance in the x-direction of the axle from the midpoint of the face-side ellipse in the sectional surface of the wheel flange (Figs. 1.1/1.4)

xEll,1...n Distance in the x-direction of the point of attack of the wheel I ...n from the midpoint of the ellipse in the sectional surface of the wheel flange (figs. 1.4, 1.6)

xEll,R Distance in the x-direction of the transverse axle of the running gear from the midpoint of the back-side ellipse in the sectional surface of the wheel flange (Fig. 1.4)

xEll,S Distance in the x-direction of the transverse axle of the running gear from the midpoint of the face-side ellipse in the sectional surface of the wheel flange (Fig. 1.4)
\(x_{0,R}\) Distance in the x-direction from the wheel centre to the back-side hyperbola/ellipse transition point in the sectional surface of the wheel flange (Figs. 1.1/1.6)

\(x_{0,S}\) Distance in the x-direction from the wheel centre to the face-side hyperbola/ellipse transition point in the sectional surface of the wheel flange (Figs. 1.1/1.6)

\(x_{1...n}\) Distance in the x-direction of the point of attack of the wheel 1…n from the axle in the sectional surface of the wheel flange (Fig. 1.6)

y-direction Assumed horizontal coordinate system, direction in parallel to the transverse axle of the running gear

\(y_{Eli,1...n}\) Distance in the y-direction of the point of attack of the wheel 1…n from the midpoint of the ellipse in the sectional surface of the wheel flange (Figs. 1.4/1.6)

\(\alpha_{E,S}\) Angle of attack in the face-side hyperbola/flange tip corner point of the sectional surface of the wheel flange (Fig. 1.2)

\(\alpha_{E,R}\) Angle of attack in the back-side hyperbola/flange tip corner point of the sectional surface of the wheel flange (Fig. 1.2)

\(\alpha_{0,S}\) Angle of attack in the face-side hyperbola/ellipse transition point of the sectional surface of the wheel flange (Fig. 1.2)

\(\alpha_{0,R}\) Angle of attack in the back-side hyperbola/ellipse transition point of the sectional surface of the wheel flange (Fig. 1.2)

\(\alpha_{1...n}\) Horizontal angle of attack in the point of attack of the wheel 1:n (Figs. 1.4 - 1.6)

\(\beta_{H}\) Crossing angle (Fig. 16)

\(\beta_{S}\) Vertical angle between the flange face and the horizontal line (Fig. 9a)

\(\beta_{Z,R}\) Angle of flange back blend at the switch tongue (Fig. 9a)

\(\beta_{Z,S}\) Angle of flange face at the switch tongue (Fig. 9a)

\(\gamma\) Horizontal angle between g1 and g2(Fig. 1.5)

\(\Delta d^*\) Total expansion of the groove in the curved track opposite the straight line at the GGE

\(\Delta d_{R}^*\) Back-side expansion of the grooves of the check rails of common crossings in the curved track opposite the straight line at the GGE

\(\Delta d_{S}^*\) Face-side expansion of the grooves of the check rails of common crossings in the curved track opposite the straight line at the GGE

\(\Delta F/\bar{U}_F\) Free space or overlapping at the gauge face of the crossing

\(\Delta F/\bar{U}_R\) Free space or overlapping at the back face of groove of the crossing

\(\Delta S\) Positive building tolerance of the track gauge
\[ |\Delta S| \] Absolute value of the negative building tolerance

\[ \Delta s_D \] Change in the active face dimension due to deflection of the axle

\[ \Delta W \] Positive manufacturing tolerance of the groove width

\[ |\Delta W| \] Absolute value of the negative manufacturing tolerance of the groove width

\[ \delta \] Horizontal angle between the curve radius R1 at the point of attack of wheel 1 and the connecting line g2 (Fig. 1.5)

\[ \epsilon \] Horizontal angle between the connecting line g3 and the x-direction (Fig. 1.6)

\[ \Phi \] Horizontal angle between the connecting line g7 and the y-direction (Fig. 1.5)

\[ \nu \] Poisson’s ratio of the wheel and rail material

\[ \sigma_{vs} \] Effective stress according to the shearing stress hypothesis

\[ \ldots^* \] Dimension measured at the GGE or referring to the GGE
7 Reasons for the Revision of the Guidance Regulations in Accordance with BOStrab (SpR) as well as Explanations

The new edition of the “German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab)”, which was published at the end of 1987, gave rise to the need to revise the Guidance Regulations for BOStrab traction systems. In the official reason for Section 1.7 “Permanent Way” of the BOStrab it says: “The correlations to be considered are extremely complex and also very different for the various guidance systems and traction systems. Consequently, the new law does not standardise details, which were included in the law valid till now, but instead it comprises a requirement for harmonisation, which is worded as a general clause. This basic requirement is expressed in concrete terms in regulations for the various guidance systems.”

On the basis of this principle the “Regulations on the Guidance of Rail Vehicles in accordance with the German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab) -Guidance Regulations (SpR)” were published already in 1984, i.e., even before the revised BOStrab was published. Before the Guidance Regulations were published, the profile relations between wheel and rail were listed thoroughly by the transport undertakings in the Federal Republic of Germany of that time. On the basis of the result the experts defined the dimension systems A, B and C, and many users now believed that they could use the tables in the Guidance Regulations without further examination when they purchased switches. However, this led to many disappointments and wrong assessments as the existing traction systems are very different. After all, millimetres decide in this field of rail engineering. Thus, the practical application of the Guidance Regulations was not without difficulties; there were many questions and uncertainties.

Without wanting to belittle the outstanding merits of the Guidance Regulations developed for the first time in 1984 in that form, the Association of German Transport Undertakings (VDV) tried to clarify the Guidance Regulations in 1994 with its “Supplementary Comments” to the Regulations and to answer the questions that had arisen.

However, this solution did not solve all the practical problems satisfactorily, and by mutual agreement with the Federal Ministry of Transport (later: Federal Ministry of Transport, Building and Housing) the VDV therefore finally decided to revise the Guidance Regulations completely.

Another reason for this initiative was the new scientific knowledge of the optimal design of tracks that comprise different kinds of rails (non-grooved rail and grooved‘ rail) and of the optimisation of the wheel profiles to be operated on these rails. In particular, this knowledge led to development of modified grooved rail profiles, the head shape of which is adapted to that of the (non-grooved) railway rails and the inclination of these rails. In that way it became possible for the first time to offer the same rail head profile to the vehicle within the complete network.

It was realised that the ride quality and the advantage of a wheel/rail pairing optimised like a railway in respect of wear can also be reached for tramways and light rail transit systems in that way. It is the intention to avoid “two-point contact” and to have as much “one-point contact” between the wheel and the rail as at all possible. Whereas there were not many different typical wheel diameters before the low-floor vehicles were introduced, there are now many different wheel diameters as the low-floor vehicles have been designed very differently. Moreover, the guidance relations in switches
and crossings had to be reconsidered in connection with the introduction of mixed operation of different traction systems.

Another important experience was that hardly any completely new tramway or light rail transit systems have emerged in the last few years in Germany, whereas existing networks are being extended everywhere. This means that the respective general conditions of the existing networks have to be considered in respect of track gauge, check-rail gauges and guiding dimensions.

The advanced development of the tramways to light rail transit systems within the last 15 years - and thus especially to higher operating speeds - showed that it is also possible to operate safely on railway tracks up to a speed of 80 km/h with wheel profiles of “dimension system A. The application of the “dimension system B” remained limited to the Cologne - Bonn area.

As light rail vehicles were to be operated on EBO tracks, other solutions became necessary, i.e. solutions that had been introduced already many years ago on the Taunusbahn lines of the Verkehrsbetriebe Frankfurt am Main and that are practised today e.g. within the “Karlsruhe system”.

It might be regrettable that it is not possible to decide on standardised dimension systems for the tramways, light rail transit systems and metros in accordance with BOStrab, but the reality of the existing networks does not allow this. If the existing differences in the wheel/rail geometries were to be overcome and standardised dimension systems to be introduced, there would be very big problems as regards the practicability, the necessary periods and the costs for the measures.

As this had been realised, it was decided not to use the term of “dimension systems” in the revised Guidance Regulations, but to define “operating systems” instead in accordance with the wheel/rail geometry of the single traction systems.

In that connection distinction has to be made between three typical operating systems:

Operating system S (“tramway / light rail transit system”) - The wheel/rail geometry is characterised by grooved rails on “in-street” track formations. Such systems are tramways and light rail transit systems close to tramways.

* Operating system E (“railway-similar” or “railway-like” according to EBO) The wheel/rail geometry is characterised by non-grooved rails on independent track formations. Such systems are metro systems and light rail transit systems close to metro systems.

Operating system M (“mixed operation”) The wheel/rail geometry is characterised by the transition of the vehicles from the BOStrab network to the EBO network. Such systems are e.g. the systems in Karlsruhe and Kassel.

With this procedure the objective of extensive standardisation is not dropped, but the variety of existing traction systems is taken into account. Now the principles for determination of the profile and dimensional relations of wheel and rail are standardised instead.

The revised Guidance Regulations frees itself of the idea of being able to create a standardised cross dimension table for the wheel/rail geometries of all BOStrab traction systems. Instead it develops a standardised approach as to how safe guidance and maximum ride quality can be achieved on the basis of today’s scientific knowledge and practical operational experience.
In this connection special attention has to be paid to curved tracks with very small radii and grooved rails; these tracks have to be examined thoroughly in respect of the wheel/rail contact relations. For that purpose deepening examination and calculation methods have been developed.

On the other hand, the traction systems that have railway-like or railway-similar wheel/rail relations can follow the EBO regulations partly or fully. The future development will show whether the application of the present findings about safety and ride quality will lead to standardisation of the geometries and dimensional relations by themselves in combination with the present rail profiles within the above mentioned operating systems because these findings are logical. In that connection it is very important that the present knowledge about the intended ride quality of the BOStrab traction systems is based on that of the railway and that only scientific research in the 1980s and 1990s led to the realisation that it can also be applied to the public transport systems.

The Guidance Regulations cover geometric questions about the guidance, not the problem of running safety as a whole.

In some places the described method of calculation goes deeper than earlier. However, the requirements made in the revised Guidance Regulations are not stricter than the requirements made in the Guidance Regulations valid so far. Consequently, the operational safety on the existing traction systems is not questioned with the revised version of the Guidance Regulations.

In consideration of the facts about the network and the vehicles it finally has to be decided what method of calculation is to be applied, in what cases simplified assumptions are possible and can be answered for and whether special conditions require other or further examinations. Modifications of the dimensional relations in the network shall only be made in small steps.

Each transport undertaking has to determine the dimensional relations required for its traction system - for the new state and the worn state - and to document this in a cross dimension table. If the networks of several transport undertakings are interconnected, this also applies to them as a whole.

As regards the contents of the Guidance Regulations, the actual Regulations are followed by four Annexes, in which the Guidance Regulations are explained in detail. The actual Regulations include the definitions of the important terms and designations, by way of which the guidance-relevant characteristics of the track and the vehicle are to be described. As regards the grooved rails, the term of “groove head” is introduced instead of “guiding rail”. The relations at the switch tips and the “wheel cross dimension” q~ on the wheel profile (following the definition of the , railway) are described in detail.

Thereafter, the principles of safe guidance are discussed. It is described how a cross dimension proof is prepared in principle; it can be prepared both analytically and graphically. The actual Regulations conclude with comments on the mixed operation according to BOStrab and EBO.

The single statements in the actual Regulations are supplemented with comments and explanations, which are written in italics and separated clearly from the actual Regulations with horizontal lines before and after the comments and explanations. Appendix 1 discusses the mathematical bases for determination of the need of the wheel flanges for additional space in curved tracks in the form of a detailed variant and a
simplified variant. The basic formulae are listed and detailed distinctions made between
the cases in respect of the position of the point of contact of the wheel flange and the rail.
Moreover, a graphical CAD procedure for determination of the numerical values for the
need of the wheel flanges for additional space in the curved track is presented.

Appendix 2 shows the procedure for representation of the cross dimension proof with the
appertaining formulae of calculation and lists the data needed.

Appendix 3 includes an exemplary calculation for determination of the numerical values for
the cross dimension table and a representation of the cross dimensions for a typical
running gear. In that way the applicability of the procedure for preparation of a cross
dimension, which was only described theoretically beforehand, is described by way of a
practical example.

Appendix 4 delivers a simplified method of calculation, by way of which it is possible to
correctly estimate the minimum stand-up width of the wheel or the minimum width of the
flange tip as a function of the yield point of the material, the wheel diameter and the stand-
up width of the wheel.
8 Literature

German Federal Regulations on the Construction and Operation of the Light Rail Transit Systems, 11 Dec. 1987 (BOStrab)
[Verordnung über den Bau und Betrieb der Straßenbahnen vom 11.12.1987 (Straßenbahn-Bau-und Betriebsordnung -BOStrab)]

Kurz / Bosch / Kurek / Braitsch / Weber - Regulations on the Guidance of Rail Vehicles in accordance with the German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab) -Guidance Regulations (SpR) [Richtlinien für die Spurführung von Schienenbahnen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab) -Spurfuhrungs-Richtlinien(SpR) -]
Published - Erich Schmidt, 1986, Volume 75

Kurz / Bosch / Kurek / Braitsch / Weber - Regulations on the Guidance of Rail Vehicles in accordance with the German Federal Regulations on the Construction and Operation of Light Rail Transit Systems (BOStrab) -Guidance Regulations (SpR) - 2nd supplemented edition [Richtlinien fur die Spurführung von Schienenbahnen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BO Strab) -Spurführungs-Richtlinien (SpR) ]
Published - Erich Schmidt Verlag, 1994, Volume 75

Prof. Dr.-Ing. H. Heumann
Characteristic Features for Guidance of Rail Vehicles
Off-print from “Elektrische Bahnen”, years 1950 -1953 [Grundzüge der Fuhrung der Schienenfahrzeuge]
Published - R. Oldenbourg, Munich

Hans-Ludwig Krugmann
What Wheel Flange Shape is to be discussed as not safe in Operation? [Wetche Spurkranzform ist als nicht betriebssicher anzusprechen?]
Glasers Annalen, November 1960

Prof. Dr.-Ing. Fritz Frederich, Dr.-Ing.Dietmar Kraft
Der Nahverkehr, 415 1999