Study Report of RDSO for Check Rails/Restraining Rails for Metro Systems in India

1. Introduction:

Check rails/guard rails were apparently introduced on curves and special layouts to facilitate the operation of multi-axle rigid frame vehicles with long axle base, since these vehicles had a tendency of outer wheel climbing the rail. The objective behind providing check rails was to:

(i) Prevent derailment due to flange climbing.

(ii) Reduce rail wear of high rail.

(iii) Improve vehicle curving performance

Later, the use of checkrail on majority of curves was discontinued over many railroad systems with the advent of bogie vehicles having better suspensions and smaller axle bases, but, continued over transit systems world over because of following factors:

(i) Presence of sharp curves

(ii) High traffic densities; very limited time for track maintenance and worn rail replacement

(iii) Narrow wheel treads; many transit systems have narrower wheel making them much more sensitive to gauge widening effect of rail wear

1.2 Provision of check rail has been legislated for Indian metro systems in “Technical Standard of Track Structure for Metro/MRTS Systems”, which under Para 4(iv) stipulates that;

“Check rail should be provided on curves where radius is 218m or less on BG and 190m or less on SC”.

2. Functional Requirement of check rail on Indian Metro Systems:

The check/restraining rail provides additional steering action using the flange of the wheel that is riding on inside rail of a curve. The working face of the restraining rail bears against the back side of the inside wheel, guiding it towards the center of the curve and reducing the lateral contact force of the opposite outside wheel flange against the high wheel. This essentially divides the lateral force between two contact surfaces and greatly reduces the rate of lateral wear on the high rail. By doing so, the lateral to vertical force (L/V) ratio at the outer wheel can be reduced, which will reduce risk of flange climb. It also reduces the tendency of the truck to assume the shape of parallelogram, thereby reducing the angle of attack between the wheel flange and the rail. In all cases, the use of restraining rail will reduce the tendency of the leading outside wheel to climb the high rail.

Some transit agencies use “double guard” on extremely sharp curves by placing a guard / restraining rail adjacent to the low rail as well as the high rail. These installations are designed
to counter the tendency of the second axle on a truck to drift towards the center of a curve, thus increasing the angle of attack. In a double restraining rail installation, the restraining rail along the inner rail shifts the leading axle of the truck towards the center of the curve. The outer restraining rail then guides the trailing axle away from the center, helping to ensure that the truck is reasonably square to the track, that both axles are in a nearly radial orientation and that the truck frame is rectilinear rather than parallelogrammed.

Since metro systems in India are being designed for small axle loads (17T max) with 1080 grade head hardened 60kg rails, the problem of wear on high rail in sharp curves is not considered to be a prime concern. Thus, the main function envisaged for check/restraining rails is to control wheel wear and to provide a mechanism against derailment caused due to wheel climbing on sharp curves. The flangeway clearance for check rails/restraining rails should, therefore be designed in such a manner to make check rail an effective mechanism against wheel climb phenomenon without causing any other problem for the system.

3. **Restraining Rail / Guard Rail Layout**

Survey of various transit systems conducted under TCRP indicated that most commonly used guard/restraining are as shown in figure 1 & figure 2 below. These guard/restraining rails are installed in a vertical or horizontal position according to design practice that have been standardized by individual transit properties.

The most common type of a guard rail is a vertically mounted tee rail as shown in figure 1, with about a 70-80 degree contact angle on the wheel flange back. The horizontally mounted tee rail, shown in figure 2, makes contact with the wheel flange back at 90 degree.

![Figure 1: W/R contact with guard rail.](image-url)
4. **Salient International stipulations regarding Guard/Restraining Rail Installation Curve Radius:**

4.1 U.S. Transit Track Restraining Rail-Volume II: Guidelines

- All mainline curves of a 500 ft radius or less; except where cars are operated at or below balanced speed and periodic inspection show that the wheel do not have tendency to climb the high rail

- Mainline curves above 500 ft radius where periodic inspections indicate the car wheels have tendencies to climb the high rails

4.2 TCRP report -71 recommendations:

- Guard rails should be installed on curves with radii less than or equal to 500 ft (152.4m) for type 1 light rail vehicles running at 4 inch cant deficiency speed with level 2 track perturbations.

- Guard rails should be installed on curves with radii greater than or equal to 955 ft for Type 2 light rail vehicles running at a 4 in. cant deficiency speed with Level 2 track perturbations.

4.3 Stipulation in Indian Railways:

Indian Railway Schedule of Dimensions stipulates that check rails should be provided on curves having radius 218 m or less on Broad Gauge (1676mm) and radius 125 m or less on Meter Gauge(1000mm).

4.4 Practice at some U.S. Transit Systems:

4.4.1 **Southeastern Pennsylvania Transportation Authority (SEPTA) rail line** - Guard/Restraining rail is installed on curves with a radius less than 750 ft

4.4.2 **Washington Metropolitan Area Transport Authority (WMATA) rail line** - Guard/Restraining rail is installed on curves with a radius less than 775 ft
Chicago Transit Authority (CTA) rail line - Guard/Restraining rail is installed on curves with a radius less than 500 ft

5. Optimal Flangeway Width

5.1 Flangeway width is the most important parameter in the design of a check/restraining rail system as it has most prominent effect on wheel/rail forces and wear.

5.2 Research Results of TCRP:

5.2.1 Studies conducted through NUCARS simulation under TCRP Project D-7/Task-12 concluded that:

i. The optimal restraining rail/check rail installation can be achieved through the control of flangeway width and wheel/rail friction coefficient.

ii. The optimal Flangeway width depends upon wheel profile shape, wheel gauge, track gauge, restraining rail profile shape, installation height and the track curvature or wheelset angle of attack (AOA).

iii. The optimal Flangeway width makes the flange front clearance between the wheel flange face and high rail equal to the flange back clearance between the wheel flange back and the guard rail. The Flangeway width should increase by approximately the same amount as the track gauge to keep the flange front clearance equal to the flange back clearance.

iv. A wide Flangeway leads to high lateral force and wear on high rail and increase of high rail climb derailment risk while narrow Flangeway leads to high lateral force and wear on restraining rail and increases restraining rail climb derailment risk.

v. To ensure safety, the guideline for check rail installation on curves as proposed in TCRP Report 71: Track Related Research-Vol-5 w.r.t. wheel lateral to vertical (L/V) ratio and flange climb distance criteria shall be followed. Either test or simulations can provide the L/V ratio and climb distance.

The above study for a particular set of W/R parameters indicates that, as the Flangeway width reaches to 1.55 inch, the left and right W/R contact point share the total lateral force equally, and the guard rail and high rail also wear equally, thus making it the optimal width. With the increase in the flange way width to 1.7 inch, the right wheel flange tip contacts on the high rail while the left wheel flange back contacts the guard rail at the same time and causes a situation of wheel climb. The study, thus, indicates that Flangeway width to be designed very carefully to achieve the desired objective. The tight flange way clearance will result into high lateral force and wear of check rail and excessive flange way clearance will result into high lateral force and wear of high rail.

5.2.2 The flange climb derailment studies conducted and discussed under TCRP report No. 71, Vol-7 indicates that 3 most critical factors governing the Flange way clearance are:

i. Wheel Flange angle
ii. Wheel-Rail friction coefficient

iii. Track perturbation limits

5.3 U.S. Transit Track Restraining Rail-Volume II: Guidelines

i. In an installation designed for the restraining rail to wear at the approximate rate of lubricated high rail, the guard distance from the guard face of the restraining rail to the gauge side of high rail should equal the back to back distance between wheels plus one flange thickness.

ii. In an installation designed for the restraining rail to prevent wear on the high rail, the guard distance should be 0.6 inch more than the back to back of wheels distance plus flange thickness.

5.3 STIPULATION OF UIC 710 (OCTOBER’ 2004):

Stipulations regarding gauge widening and installation of check rail (if track is laid with check rail) at sharp curves are as under:

<table>
<thead>
<tr>
<th>Radius of Curve</th>
<th>Track Gauge</th>
<th>Flangeway width</th>
</tr>
</thead>
<tbody>
<tr>
<td>175&gt;R&gt;150m</td>
<td>1435 mm</td>
<td>45 mm</td>
</tr>
<tr>
<td>150&gt;R&gt;125m</td>
<td>1440 mm</td>
<td>50 mm</td>
</tr>
<tr>
<td>125&gt;R&gt;100m</td>
<td>1445 mm</td>
<td>55 mm</td>
</tr>
</tbody>
</table>

5.4 INDIAN RAILWAY STIPULATIONS:

Check rails are provided on Indian Railway at curves having radius 218m or less on BG and 125m or less on MG. The minimum flange way clearance stipulated for BG is 44mm while that for MG is 41mm. However, the Flangeway has been kept as 75mm in 60kg sleepers designed with 1682mm gauge (+9 mm slack gauge) for use in curves.

6.0 Recommendations given by BMRCL

BMRCL, based on recommendation given by their consultant and TCRP study reports, have submitted following recommendations:

i) Check rail can be dispensed with on main lines if the following conditions are fulfilled:
   a) 1080 grade HH rails are used on mainlines
   b) Derailment up-stands are provided, and
   c) Rail grinding using rail grinding Machine and wheel grinding using Wheel Grinding Machine is done

ii) Check rails need not be provided in Depots with speeds limited to 25kmph

The consultant of BMRCL have cited example of Bangkok BTS where check rails were removed due to problem of wheel flange climb over check rail. Examples of few transit systems have
also been sighted where check rails are said to have not been provided. However, details of system and technical reasons have not been provided in this regard to draw a conclusion. Further, no studies have been conducted to assess the effect of rail and wheel grinding.

It is opined that Transit Systems word over have large variations in design, loading and operating conditions and systems adopted by a metro can be considered for other one only after detailed studies and justifications. The practices in this regard on major metro systems having sizeable network needs to be studied.

7.0 Conclusion and Recommendation:

The wheel flange climb is a complex phenomenon and depends upon large number of factors. Any decision in this regard shall be based on detailed studies and supported by sound technical justification.

It can be concluded from the practices adopted by the various transit systems and as per studies conducted under TCRP, that, check rail/restraining rail installation at sharp curves with a judiciously designed Flangeway width is required to keep the W/R forces and wear under control. The control over W/R forces under all the conditions of operations is very much desired from safety point of view. The existing stipulations in this regard under “Technical Standard of Track Structure for Metro/MRTS Systems” are considered to be essential.

The check rail distance (Flangeway width) however may be decided by metros considering the requirement with respect to wear of check rail or high rail. The design width shall also depend upon relevant factors mentioned under Para 5.2.2 above and control exercised by metro over these factors. Stipulations under UIC 710 in this regard may be considered while designing the Flangeway. However, the Flangeway width, in any case, should satisfy that it will work as an effective mechanism against rail wheel climb derailment as envisaged in Railway Board’s letter no.2010/Proj/Bangalore/3014(Vol.II) dated 15.02.2012.

In case of Depots, the installation of check rail can be dispensed with if the speeds are not exceeding 25kmph.

8.0 Way Ahead:

To have a better clarity in the matter so as to make a review at latter stage, it is considered that following shall be required:

i) Details from large and established world metro systems along with technical justification.

ii) The oscillation trials over Indian Metro systems covering measurement of lateral force with measuring wheel and estimation of derailment coefficient, particularly on sharp curves where check rails are provided.

iii) Study of effect of rail and wheel grinding, measure suggested by BMRCL, on lateral force and derailment coefficient

The issue can be reviewed subsequently once adequate information is available on above.
Figure 1  W/R contact with guard rail.

Figure 2  Wheel and horizontal restraining rail geometry.

Figure 3  Wheel and horizontal guard/restraining rail installed at low position.
Figure 5  Strap guard rail.

Figure 4  Gird rail.

Figure 6  W/R contact geometry in two point flange back contact.
Table 1  Examples of guard/restraining rail installation practices

<table>
<thead>
<tr>
<th>Transit System</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBTA (Light Rail Line)</td>
<td>Guard/restraining rail is installed on curves with a radius less than 1,000 ft.</td>
</tr>
<tr>
<td>Newark City Subway (Light Rail Line)</td>
<td>Guard/restraining rail is installed on curves with a radius less than 600 ft.</td>
</tr>
<tr>
<td>SEPTA (Heavy Rail Line)</td>
<td>Guard/restraining rail is installed on curves with a radius less than 750 ft.</td>
</tr>
<tr>
<td>WMATA (Heavy Rail Line)</td>
<td>Guard/restraining rail is installed on switches corresponding to less than 500 ft in radius and curves with a radius less than 775 ft.</td>
</tr>
<tr>
<td>CTA (Heavy Rail Line)</td>
<td>Guard/restraining rail is installed on curves with a radius less than 500 ft.</td>
</tr>
</tbody>
</table>

NOTE: MBTA = Massachusetts Bay Transportation Authority. SEPTA = Southeastern Pennsylvania Transportation Authority. WMATA = Washington Metropolitan Area Transit Authority. CTA = Chicago Transit Authority.

Table 2  Guard/restraining rail geometry dimensions on 700-ft radius curves from three transit systems

<table>
<thead>
<tr>
<th>Geometry Parameters</th>
<th>Transit A (Light Rail) (in)</th>
<th>Transit B (Heavy Rail) (in)</th>
<th>Transit C (Heavy Rail) (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track gage</td>
<td>56.75</td>
<td>56.5</td>
<td>56.5</td>
</tr>
<tr>
<td>Back-to-back distance</td>
<td>54.19</td>
<td>53.31</td>
<td>53.38</td>
</tr>
<tr>
<td>Flange thickness</td>
<td>1.12</td>
<td>1.42</td>
<td>1.16</td>
</tr>
<tr>
<td>Flange front clearance</td>
<td>0.33</td>
<td>0.35</td>
<td>0.81</td>
</tr>
<tr>
<td>Flangeway width based on Guideline 1</td>
<td>0.85</td>
<td>1.17</td>
<td>1.37</td>
</tr>
<tr>
<td>Flangeway width based on Guideline 2</td>
<td>1.45</td>
<td>1.77</td>
<td>1.97</td>
</tr>
<tr>
<td>Design flangeway width</td>
<td>1.75</td>
<td>1.88</td>
<td>2</td>
</tr>
<tr>
<td>Flangeway width tolerance for maintenance</td>
<td>1.75-2</td>
<td>1.75-2.25</td>
<td>*</td>
</tr>
</tbody>
</table>

*No data available.