CHAPTER
14

Points and Crossings

Introduction

Points and crossings are provided to help transfer railway vehicles from one track to another. The tracks may be parallel to, diverging from, or converging with each other. Points and crossings are necessary because the wheels of railway vehicles are provided with inside flanges and, therefore, they require this special arrangement in order to navigate their way on the rails. The points or switches aid in diverting the vehicles and the crossings provide gaps in the rails so as to help the flanged wheels to roll over them. A complete set of points and crossings, along with lead rails, is called a *turnout*.

14.1 Important Terms

The following terms are often used in the design of points and crossings.

Turnout It is an arrangement of points and crossings with lead rails by means of which the rolling stock may be diverted from one track to another. Figure 14.1(a) shows the various constituents of a turnout. The details of these constituents are given in Table 14.1.

Direction of a turnout A turnout is designated as a right-hand or a left-hand turnout depending on whether it diverts the traffic to the right or to the left. In Fig. 14.1(a), the turnout is a right-hand turnout because it diverts as the traffic towards the right side. Figure 14.1(b) shows a left-hand turnout. The direction of a point (or turnout) is known as the *facing direction* if a vehicle approaching the turnout or a point has to first face the thin end of the switch. The direction is *trailing direction* if the vehicle has to negotiate a switch in the trailing direction i.e., the vehicle first negotiates the crossing and then finally traverses on the switch from its thick end to its thin end. Therefore, when standing at the toe of a switch, if one looks in the direction of the crossing, it is called the *facing direction* and the opposite direction is called the *trailing direction*.

Tongue rail It is a tapered movable rail, made of high-carbon or -manganese steel to withstand wear. At its thicker end, it is attached to a running rail. A tongue rail is also called a *switch rail*.

Stock rail It is the running rail against which a tongue rail operates.

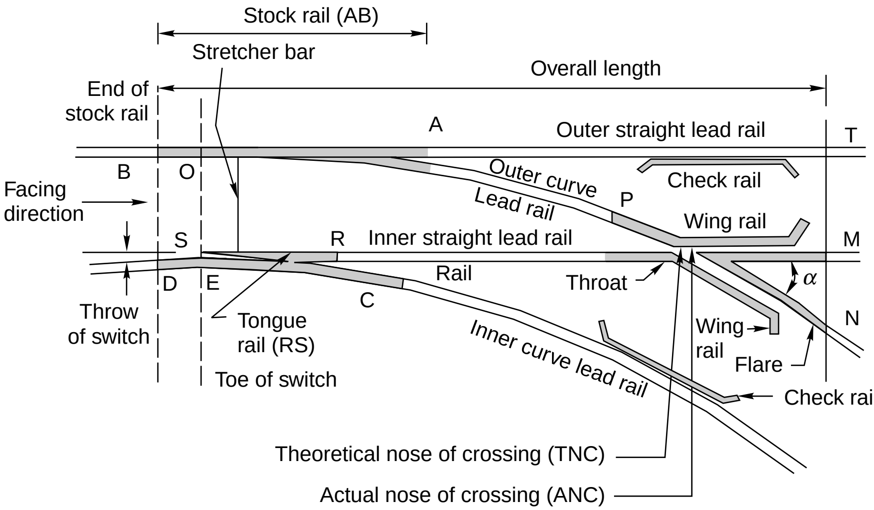

Fig. 14.1 (a) Constituents of a turnout

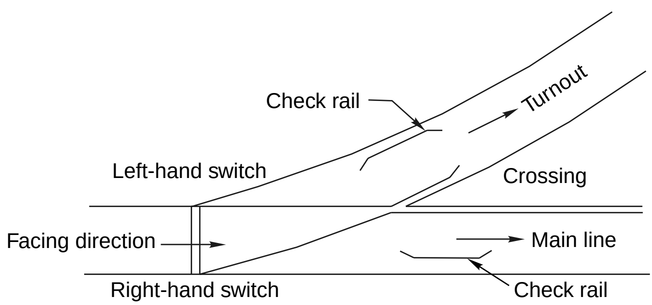

Fig. 14.1 (b) Left-hand turnout

Table 14.1 Parts of a turnout

Name of the main assembly	*Various constituents of the assembly*
Set of switches (Figs 14.1 and 14.2)	A pair of stock rails, a pair of tongue rails, a pair of heel blocks, several slide chairs, two or more stretcher bars, and a gauge tie plate
Crossing	A nose consisting of a point rail and splice rails, two wind rails, and two check rails
Lead rails (Fig. 14.1)	Four sets of lead rails

Points or switch A pair of tongue and stock rails with the necessary connections and fittings forms a switch.

Crossing A crossing is a device introduced at the junction where two rails cross each other to permit the wheel flange of a railway vehicle to pass from one track to another.

14.2 Switches

A set of points or switches consists of the following main constituents (Fig. 14.2).

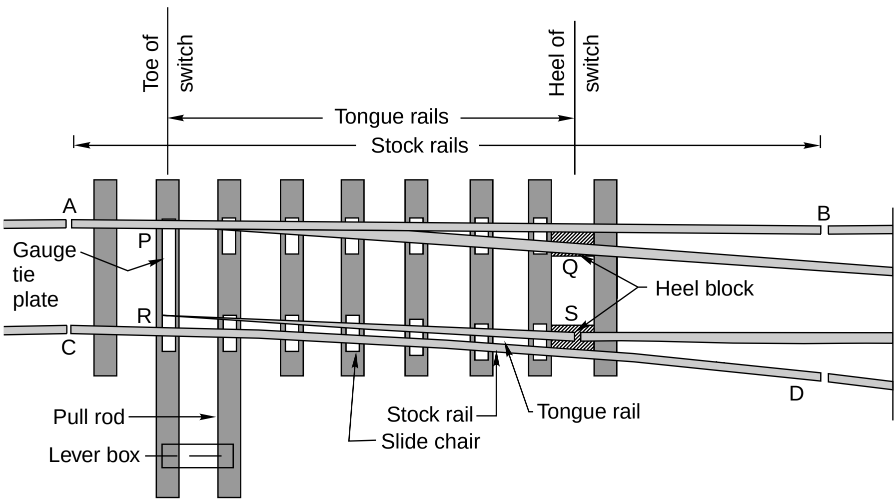

Fig. 14.2 Details of a switch

(a) A pair of stock rails, AB and CD, made of medium-manganese steel.
(b) A pair of tongue rails, PQ and RS, also known as switch rails, made of medium-manganese steel to withstand wear. The tongue rails are machined to a very thin section to obtain a snug fit with the stock rail. The tapered end of the tongue rail is called the *toe* and the thicker end is called the *heel*.
(c) A pair of heel blocks which hold the heel of the tongue rails is held at the standard clearance or distance from the stock rails.
(d) A number of slide chairs to support the tongue rail and enable its movement towards or away from the stock rail.
(e) Two or more stretcher bars connecting both the tongue rails close to the toe, for the purpose of holding them at a fixed distance from each other.
(f) A gauge tie plate to fix gauges and ensure correct gauge at the points.

14.2.1 Types of Switches

Switches are of two types, namely, *stud switch* and *split switch*. In a stud type of switch, no separate tongue rail is provided and some portion of the track is moved from one side to the other side. Stud switches are no more in use on Indian Railways. They have been replaced by split switches. These consist of a pair of stock rails and a pair of tongue rails. Split switches may again be of two types—loose heel type and fixed heel type. These are discussed below.

Loose heel type In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of the tongue rail. The fish plates holding the tongue rail may be straight or slightly bent. The tongue rail is fastened to the stock rail with the help of a fishing fit block and four bolts. All the fish bolts in the lead rail are tightened while those in the tongue rail are kept loose or snug to allow free movement of the tongue. As the discontinuity of the track at the heel is a weakness in the structure, the use of these switches is not preferred.

Fixed heel type In this type of split switch, the tongue rail does not end at the heel of the switch but extends further and is rigidly connected. The movement at the toe of the switch is made possible on account of the flexibility of the tongue rail.

Toe of switches

The toe of the switches may be of the following types.

Undercut switch In this switch the foot of the stock rail is planed to accommodate the tongue rail (Fig. 14.3).

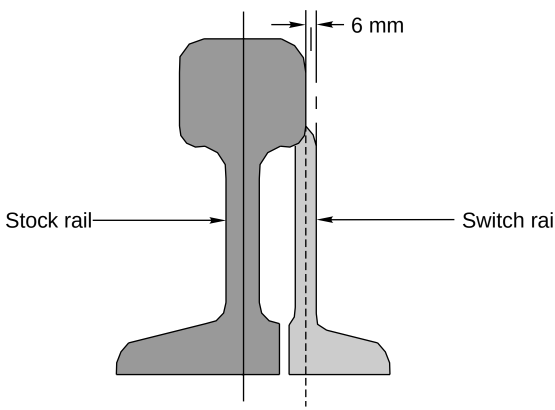

Fig. 14.3 Undercut switch

Overriding switch In this case, the stock rail occupies the full section and the tongue rail is planed to a 6-mm (0.25") -thick edge, which overrides the foot of the stock rail (Fig. 14.4). The switch rail is kept 6 mm (0.25") higher than the stock rail from the heel to the point towards the toe where the planing starts. This is done to eliminate the possibility of splitting caused by any false flange moving in the trailing direction. This design is considered to be an economical and superior design due to the reasons given below.

(a) Since the stock rail is uncut, it is much stronger.
(b) Manufacturing work is confined only to the tongue rail, which is very economical.
(c) Although the tongue rail has a thin edge of only 6 mm (0.25″), it is supported by the stock rail for the entire weakened portion of its length. As such, the combined strength of the rails between the sleepers is greater than that of the tongue rail alone in the undercut switch.

Overriding switches have been standardized on the Indian Railways.

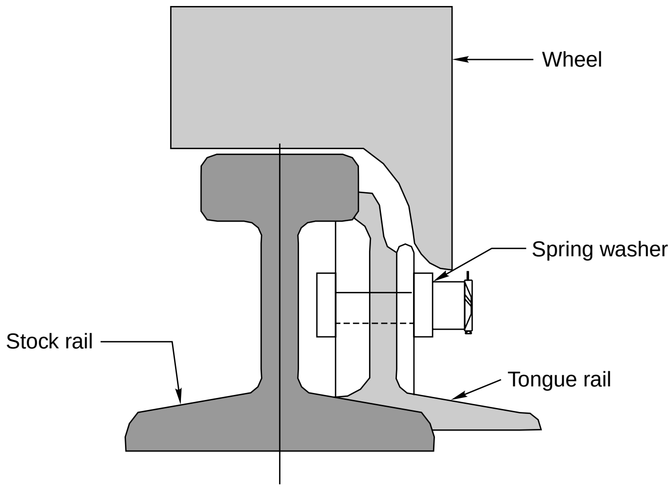

Fig. 14.4 Overriding switch

14.2.2 Important Terms Pertaining to Switches

The following terms are common when discussing the design of switches.

Switch angle This is the angle between the gauge face of the stock rail and that of the tongue rail at the theoretical toe of the switch in its closed position. It is a function of the heel divergence and the length of the tongue rail.

Flangeway clearance This is the distance between the adjoining faces of the running rail and the check rail/wing rail at the nose of the crossing. It is meant for providing a free passage to wheel flanges. Table 14.2 gives the minimum and maximum values of flangeway clearance for BG and MG tracks.

Table 14.2 Flangeway clearance

	Flangeway clearance	
Gauge	*Maximum value (mm)*	*Minimum value (mm)*
BG	48	44
MG	44	41

Heel divergence This is the distance between the gauge faces of the stock rail and the tongue rail at the heel of the switch. It is made up of the flangeway clearance and the width of the tongue rail head that lies at the heel.

Throw of the switch This is the distance through which the tongue rail moves laterally at the toe of the switch to allow movement of the trains. Its limiting values are 95–115 mm for BG routes and 89–100 mm for MG routes.

14.3 Design of Tongue Rails

A tongue rail may be either straight or curved. Straight tongue rails have the advantage that they are easily manufactured and can be used for right-hand as well as left-hand turnouts. However, get jolted trains while negotiating with straight tongue rails turnouts because of the abrupt change in the alignment. Straight tongue rails are normally used for 1 in 8.5 and 1 in 12 turnouts on Indian Railways.

Curved tongue rails are shaped according to the curvature of the turnout from the toe to the heel of the switch. Curved tongue rails allow for smooth turning of trains, but can only be used for the specific curvature for which they are designed. Curved switches are normally used for 1 in 16 and 1 in 20 IRS (Indian Railway Standard) turnouts on Indian Railways. Recently Indian Railways has also started laying 1 in 8.5 and 1 in 12 turnouts with curved switches on important lines.

14.3.1 Length of Tongue Rails

The length of a tongue rail from heel to toe varies with the gauge and angle of the switch. The longer the length of the tongue rail, the smoother the entry to the switch because of the smaller angle the switch rail would make with the fixed heel divergence. The longer length of the tongue rail, however, occupies too much layout space in station yards where a number of turnouts have to be laid in limited space. The length of the tongue rail should be more than the rigid wheel base of a four-wheeled wagon to preclude the possibility of derailment in case the points move from their position when a train is running on the switch. Table 14.3 gives the standard lengths of switches (tongue rails) for BG and MG tracks.

Table 14.3 Length of tongue rail

Gauge and type	*Length of tongue rail*				
	1 in 8.5 straight (mm)	*1 in 12 straight (mm)*	*1 in 12 curved (mm)*	*1 in 16 curved (mm)*	*1 in 20 curved (mm)*
BG (90 R)	4725	6400	7730	9750	1,1150
MG (75 R)	4116*	5485*	6700	7420	

* These dimensions hold good for NG tracks also.

14.4 Crossing

A crossing or *frog* is a device introduced at the point where two gauge faces cross each other to permit the flanges of a railway vehicle to pass from one track to another (Fig. 14.5). To achieve this objective, a gap is provided from the throw to the nose of the crossing, over which the flanged wheel glides or jumps. In order to ensure that this flanged wheel negotiates the gap properly and does not strike the nose, the other wheel is guided with the help of check rails. A crossing consists of the following components, shown in Fig. 14.6.

(a) Two rails, the *point rail* and *splice rail*, which are machined to form a nose. The point rail ends at the nose, whereas the splice rail joins it a little behind the nose. Theoretically, the points rail should end in a point and be made as thin as possible, but such a knife edge of the point rail would break off under the movement of traffic. The point rail, therefore, has its fine end slightly cut off to form a blunt nose, with a thickness of 6 mm (1/4"). The toe of the blunt nose is called the *actual nose of crossing* (ANC) and the theoretical point where gauge faces from both sides intersect is called the *theoretical nose of crossing* (TNC). The 'V' rail is planed to a depth of 6 mm (1/4") at the nose and runs out in 89 mm to stop a wheel running in the facing direction from hitting the nose.

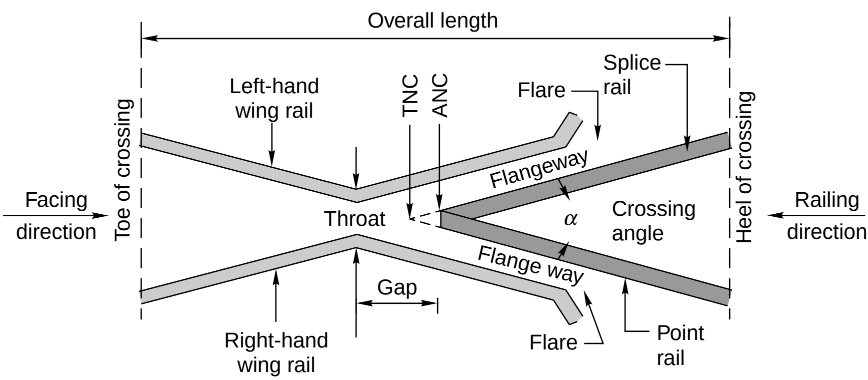

Fig. 14.5 Details of a crossing

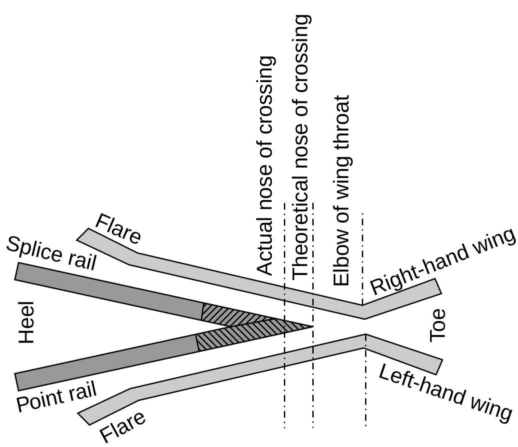

Fig. 14.6 Point rail and splice rail

(b) Two wing rails consisting of a right-hand and a left-hand wing rail that converge to form a throat and diverge again on either side of the nose. Wing rails are flared at the ends to facilitate the entry and exit of the flanged wheel in the gap.

(c) A pair of check rails to guide the wheel flanges and provide a path for them, thereby preventing them from moving sideways, which would otherwise may result in the wheel hitting the nose of the crossing as it moves in the facing direction.

14.4.1 Types of Crossings

A crossing may be of the following types.

(a) An *acute angle crossing* or 'V' crossing in which the intersection of the two gauge faces forms an acute angle. For example, when a right rail crosses a left rail, it makes an acute crossing. Thus, unlike rail crossings form an acute crossing (A and C of Fig. 15.9).

(b) An *obtuse or diamond crossing* in which the two gauge faces meet at an obtuse angle. When a right or left rail crosses a similar rail, it makes an obtuse crossing (B and D of Fig. 15.9).

(c) A *square crossing* in which two tracks cross at right angles. Such crossings are rarely used in actual practice (Fig. 14.7).

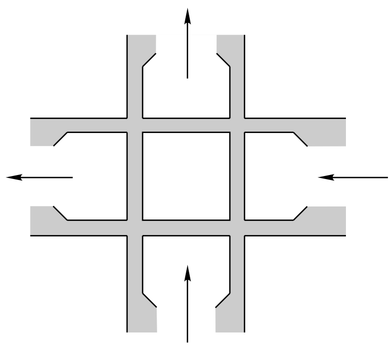

Fig. 14.7 Square crossing

For manufacturing purposes, crossings can also be classified as follows.

Built up crossing In a built-up crossing, two wing rails and a V section consisting of splice and point rails are assembled together by means of bolts and distance blocks to form a crossing. This type of crossing is commonly used on Indian Railways. Such crossings have the advantage that their initial cost is low and that repairs can be carried out simply by welding or replacing each constituent separately. A crossing becomes unserviceable when wear is more than 10 mm (3/8"). A built-up crossing, however, lacks rigidity. The bolts require frequent checking and sometimes break under fast and heavy traffic.

Cast steel crossing This is a one-piece crossing with no bolts and, therefore, requiring very little maintenance. Comparatively, it is a more rigid crossing since it consists of one complete mass. The initial cost of such a crossing is, however, quite high and its repair and maintenance pose a number of problems. Recently cast manganese steel (CMS) crossings, which have longer life, have also been adopted.

Combined rail and cast crossing This is a combination of a built-up and cast steel crossing and consists of a cast steel nose finished to ordinary rail faces to form the two legs of the crossing. Though it allows the welding of worn out wing rails, the nose is still liable to fracture suddenly.

14.4.2 CMS Crossing

Due to increase in traffic and the use of heavier axle loads, the ordinary built-up crossings manufactured from medium-manganese rails are subjected to very heavy wear and tear, specially in fast lines and suburban sections with electric traction. Past experience has shown that the life of such crossings varies from 6 months to 2 years, depending on their location and the service conditions. CMS crossings possess higher strength, offer more resistance to wear, and consequently have a longer life. The following are the main advantages of CMS crossings.

(a) Less wear and tear.
(b) Longer life: The average life of a CMS crossing is about four times more than that of an ordinary built-up crossing.
(c) CMS crossings are free from bolts as well as other components that normally tend to get loose as a result of the movement of traffic.

These days CMS crossings are preferred on Indian Railways. Though their initial cost is high, their maintenance cost is relatively less and they last longer. However, special care must be taken in their laying and maintenance. Keeping this in view, CMS crossings have been standardized on Indian Railways. On account of the limited availability of CMS crossings in the country, their use has, however, been restricted for the time being to group A routes and those lines of other routes on which traffic density is over 20 GMT. These should also be reserved for use on heavily worked lines of all the groups in busy yards.

14.4.3 Spring or Movable Crossing

In a spring crossing, one wing rail is movable and is held against the V of the crossing with a strong helical spring while the other wing rail is fixed (Fig. 14.8). When a vehicle passes on the main track, the movable wing rail is snug with the

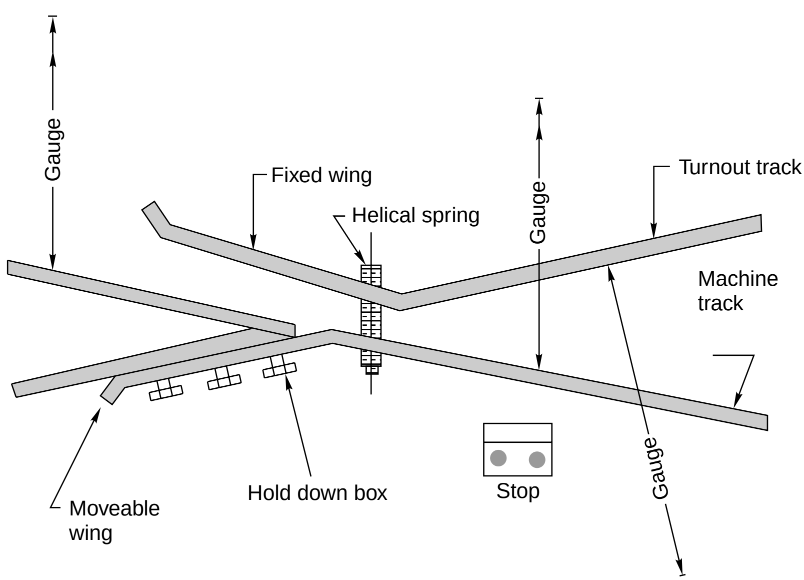

Fig. 14.8 Spring or movable crossing

crossing and the vehicle does not need to negotiate any gap at the crossing. In case the vehicle has to pass over a turnout track, the movable wing is forced out by the wheel flanges and the vehicle has to negotiate a gap as in a normal turnout.

This type of crossing is useful when there is high-speed traffic on the main track and slow-speed traffic on the turnout track.

14.4.4 Raised Check Rails for Obtuse Crossings

In order to provide a guided pathway in the throat portion of a 1 in 8.5 BG obtuse diamond crossing, the check rails are raised by welding a 25-mm-thick MS plate. This arrangement is considered satisfactory for BG as well as MG routes.

14.4.5 Position of Sleepers at Points and Crossings

Sleepers are normally perpendicular to the track. At points and crossings, a situation arises where the sleepers have to cater to the main line as well as to the turnout portion of the track. For this purpose, longer sleepers are used for some length of the track as shown in Fig. 14.9.

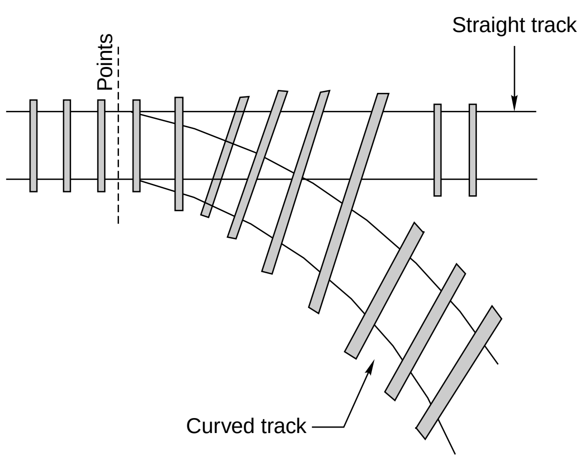

Fig. 14.9 Sleepers for points and crossings

14.5 Number and Angle of Crossing

A crossing is designated either by the angle the gauge faces make with each other or, more commonly, by the number of the crossing, represented by *N*. There are three methods of measuring the number of a crossing, and the value of *N* also depends upon the method adopted. All these methods are illustrated in Fig. 14.10.

Centre line method

This method is used in Britain and the USA. In this method, *N* is measured along the centre line of the crossing.

$$\cot\frac{\alpha}{2} = N \div \frac{1}{2}$$

or

$$N = \frac{1}{2}\cot\frac{\alpha}{2}$$

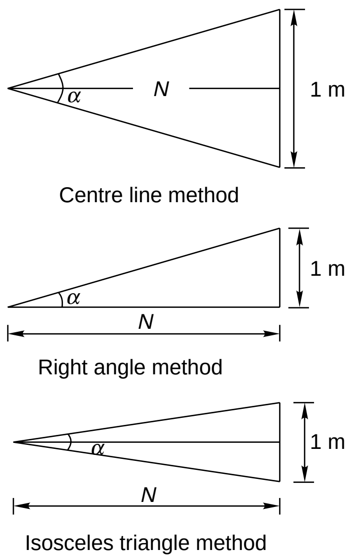

Fig. 14.10 Different methods of measuring number (*N*) and angle of crossing

Right angle method

This method is used on Indian Railways. In this method, *N* is measured along the base of a right-angled triangle. This method is also called *Coles method*.

$$\cot\alpha = \frac{N}{1}$$

or

$$N = \cot\alpha$$

Isosceles triangle method

In this method, *N* is taken as one of the equal sides of an isosceles triangle.

$$\sin\frac{\alpha}{2} = \frac{1/2}{N} = \frac{1}{2N}$$

or

$$\operatorname{cosec}\frac{\alpha}{2} = 2N$$

$$N = \frac{1}{2}\operatorname{cosec}\frac{\alpha}{2}$$

The right angle method used by Indian Railways, in which *N* is the cotangent of the angle formed by two gauge faces, gives the smallest angle for the same value of *N*.

To determine the number of a crossing (*N*) on site, the point where the offset gauge face of the turnout track is 1 m is marked. The distance of this point (in metres) from the theoretical nose of crossing gives *N*.

14.6 Reconditioning of Worn Out Crossings

Generally, noses of crossings and wing rails ungergo the maximum amount of wear in a turnout. The limiting wear for a crossing is 10 mm, after which it is required to be replaced. A worn out crossing is generally reconditioned at the stage when the wear is only 6 mm (1/4"). In the case of tongue rails, the limit of vertical wear for 52-kg and 90 R rails is 6 mm (1/4") and that of lateral wear is 8 mm. Similarly, the limit of vertical wear for 60 R and 75 R rails is 6 mm and that of lateral wear is 5 mm. Normally gas welding is adopted to recondition crossings at the site itself. The sequence of operation is as follows.

1. An advance party carries out the preliminary work in which complete and detailed attention is paid to the turnout including through packing, replacement of worn out fittings, tightening of fittings, squaring, spacing of sleepers, etc.
2. Both the vertical and side wear are measured with the help of an 1.8-m straight edge. The area where welding is to be done is cleaned, and burns, etc., are removed using chalk.
3. The surfaces to be welded are also cleaned, and burns, etc. are removed using chisels.
4. Welding is done with the help of an oxyacetylene flame using suitable welding rods after pre-heating the surface for about 5 minutes. When the section is built up to the thickness required, the deposit metal is hammered to make a uniform level surface. The prepared surface is then checked with the help of a straight edge.
5. A caution order is sent out while the work is in progress and no speed restriction is necessary.
6. One welding party consisting of one permanent way mistry (craftsman), two welders, and six khalasis (labourers) including lookout men can weld one crossing or two pairs of switches every working day. The consumable items required for reconditioning work are ilsted in Table 14.4.

Table 14.4 Consumables required for reconditioning of crossings

Component	*Requirement of oxygen (m^3)*	*Requirement of acetylene (m^3)*	*Requirement of welding rods (kg)*
One crossing	5.7	6.5	1.60
One pair of switches	2.3	3.0	0.75

14.7 Turnouts

The simplest arrangement of points and crossing can be found on a turnout taking off from a straight track. There are two standard methods prevalent for designing a turnout**.** These are the (a) Coles method and the (b) IRS method.

These methods are described in detail in the following sections.

The important terms used in describing the design of turnouts are defined as follows.

Curve lead (CL) This is the distance from the tangent point (T) to the theoretical nose of crossing (TNC) measured along the length of the main track.

Switch lead (SL) This is the distance from the tangent point (T) to the heel of the switch (TL) measured along the length of the main track.

Lead of crossing (L) This is the distance measured along the length of the main track as follows:

Lead of crossing (L) = curve lead (CL) – switch lead (SL)

Gauge (G) This is the gauge of the track.

Heel divergence (D) This is the distance between the main line and the turnout side at the heel.

Angle of crossing (α) This is the angle between the main line and the tangent of the turnout line.

Radius of turnout (R) This is the radius of the turnout. It may be clarified that the radius of the turnout is equal to the radius of the centre line of the turnout (R_1) plus half the gauge width.

$$R = R_1 + 0.5G$$

As the radius of a curve is quite large, for practical purposes, R may be taken to be equal to R_1.

Special fittings with turnouts

Some of the special fittings required for use with turnouts are enumerated below.

Distance blocks Special types of distance blocks with fishing fit surfaces are provided at the nose of the crossing to prevent any vertical movement between the wing rail and the nose of the crossing.

Flat bearing plates As turnouts do not have any cant, flat bearing plates are provided under the sleepers.

Spherical washers These are special types of washers and consist of two pieces with a spherical point of contact between them. This permits the two surfaces to lie at any angle to each other. These washers are used for connecting two surfaces that are not parallel to one another. Normally, tapered washers are necessary for connecting such surfaces. Spherical washers can adjust to the uneven bearings of the head or nut of a bolt and so are used on all bolts in the heel and the distance blocks behind the heel on the left-hand side of the track.

Slide chairs These are provided under tongue rails to allow them to move laterally. These are different for ordinary switches and overriding switches.

Grade off chairs These are special chairs provided behind the heel of the switches to give a suitable ramp to the tongue rail, which is raised by 6 mm at the heel.

Gauge tie plates These are provided over the sleepers directly under the toe of the switches, and under the nose of the crossing to ensure proper gauge at these locations.

Stretcher bars These are provided to maintain the two tongue rails at an exact distance.

Coles method

This is a method used for designing a turnout taking off from a straight track (Fig. 14.11). The curvature begins from a point on the straight main track ahead of the toe of the switch at the theoretical toe of switch (TTS) and ends at the theoretical nose of crossing (TNC). The heel of the switch is located at the point where the offset of the curve is equal to the heel divergence. Theoretically, there would be no kinks in this layout, had the tongue rail been curved as also the wing rail up to the TNC. Since tongue rails and wing rails are not curved generally, there are the following three kinks in this layout.

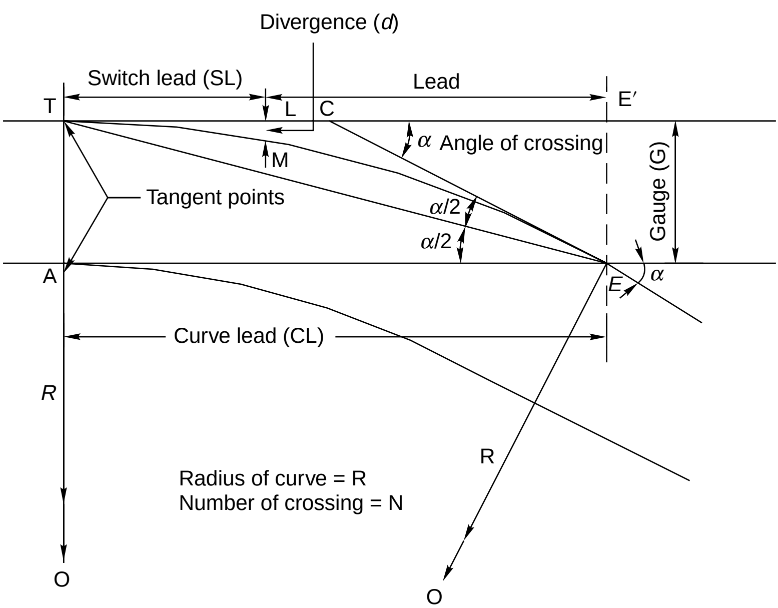

Fig. 14.11 Turnout from a straight track (Coles method)

(a) The first kink is formed at the actual toe of the switch.
(b) The second kink is formed at the heel of the switch.
(c) The third kink is formed at the first distance block of the crossing.

The notations used in Fig. 14.11 are the following.

Curve lead (CL) = AE = TE′

Switch lead (SL) = TL

Lead of crossing (L) = LE′
Gauge of track (G) = AT = EE′
Angle of the crossing $(\alpha) = \angle CEA = \angle ECE'$
Heel of divergence (d) = LM
Number of the crossing (N) = $\cot\alpha$
Radius of outer rail of turnout curve (R) = OE = OT
(O is the centre of the turnout curve)

Calculations

Curve lead (CL) In ΔATE,

$$AT = G \text{ and } \angle AET = \frac{\alpha}{2}$$

$$\tan\frac{\alpha}{2} = \frac{AT}{AE} = \frac{G}{\text{curve lead}}$$

or

$$\text{Curve lead} = G\cot\frac{\alpha}{2}$$

Also,

Curve lead = E′C + CT
= E′C + CE (as CT = CE)

$$= G\cot\alpha + G\,\text{cosec}\,\alpha$$

$$= GN + G\sqrt{1+N^2} \quad (as \cot\alpha = N)$$

or

= 2GN (approximately)

Switch lead (SL) TL is the length of the tangent with an offset LM = D = heel divergence.

From the properties of triangles,

SL × SL = d(2R – d)

or

$$\text{Switch lead} = \sqrt{2Rd - d^2}$$

Lead of crossing (L)

L = curve lead – switch lead

$$= G\cot\frac{\alpha}{2} - \sqrt{2Rd - d^2}$$

Radius of curve (R) In ΔAOE,

OE = OT = R, OA = $R - G$
$OE^2 = OA^2 + AE^2$
$OE^2 = (R - G)^2 + (\text{curve lead})^2$

or,

$$R^2 = (R - G)^2 + (GN + G\sqrt{1 + N^2})$$
$$= R^2 - 2RG + G^2 + G^2N + G^2(1 + N^2) + 2\,G^2N\sqrt{1 + N^2}$$
$$2RG = 2G^2(1 + N^2) + 2G^2N\sqrt{1 + N^2}$$

or

$$R = G(1 + N^2) + GN\sqrt{1 + N^2}$$
$$= 1.5G + 2GN^2 \text{ (approximately)}$$

Summarizing the formulae derived,

$$\text{Curve lead (CL)} = G\cot\frac{\alpha}{2} \text{ or } 2GN \text{ approx.} \quad (14.1)$$

$$\text{Switch lead (SL)} = \sqrt{2Rd - d^2} \quad (14.2)$$

$$\text{Lead of crossing } (L) = G\cot\frac{\alpha}{2} - \sqrt{2Rd - d^2}$$
$$= 2GN - \sqrt{2Rd - d^2} \quad (14.3)$$

$$\text{Radius of curve } (R) = 1.5G + 2GN^2 \quad (14.4)$$

$$\text{Heel divergence } (d) = \frac{(SL)^2}{2\left(R + \frac{G}{2}\right)} \quad (14.5)$$

Example 14.1 Calculate the lead and radius of a 1 in 8.5 BG turnout for 90 R rails using Coles method.

Solution

$G = 1.676$ m $\quad d = 120$ mm

$\alpha = 6° 42' 35''$ $\quad N = 8.5$

(i) Curve lead (CL) = $\sqrt{1 + N^2}$

$$= 1.676 \times 8.5 + 1.676\sqrt{1 + 8.5^2}$$
$$= 28.6 \text{ m}$$

(ii) Radius of turnout curve $(R) = 1.5G + 2GN^2$

$$= 1.5 \times 1.676 + 2 \times 1.676 \times 8.5$$
$$= 245 \text{ m}$$

(iii) Switch lead (SL) $= \sqrt{2Rd - d^2}$

$$= \sqrt{2 \times 2.45 \times 0.12 - 0.12^2}$$
$$= 7.67 \text{ m}$$

(iv) Lead = CL – SL = 20.6 – 7.7 = 20.9 m

IRS method

In this layout (Fig. 14.12), the curve begins from the heel of the switch and ends at the toe of the crossing, which is at the centre of the first distance block. The crossing is straight and no kink is experienced at this point. The only kink occurs at the toe of the switch. This is the standard layout used on Indian Railways. The calculations involved in this method are somewhat complicated and hence this method is used only when precision is required.

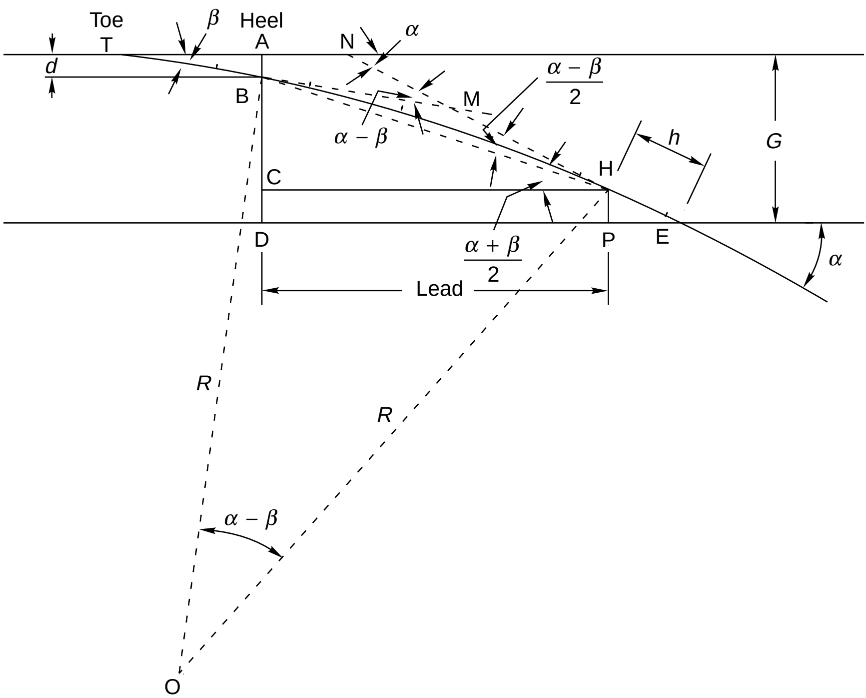

Fig. 14.12 Turnout from a straight track (IRS method)

Lead of crossing (L) In ΔBMH,

BM = MH (as both are tangents)

$$\angle \text{MHB} = \angle \text{MBH} = \frac{\alpha - \beta}{2}$$

$$\text{BC} = \text{AD} - (\text{AB} + \text{CD}) = G - (d + h \sin\alpha)$$

Therefore, crossing lead

$$L = (G - d - h \sin\alpha) \cot\frac{\alpha - \beta}{2} + h \cos\alpha \tag{14.6}$$

Radius of curve (R) ΔOBH,

$$\angle \text{BOH} = \alpha - \beta$$

$$\text{BH} = 2R \sin\frac{\alpha - \beta}{2} \tag{14.7}$$

In ΔBHC,

$$\text{BH} = \frac{\text{BC}}{\sin\frac{\alpha+\beta}{2}} = \frac{G - d - h\sin\alpha}{\sin\frac{\alpha+B}{2}} \tag{14.8}$$

Equating Eqns (14.7) and (14.8)

$$2R\sin\frac{\alpha-\beta}{2} = \frac{G - d - h\sin\alpha}{\sin\frac{\alpha+\beta}{2}}$$

or

$$R = \frac{G - d - h\sin\alpha}{2\sin\frac{\alpha+\beta}{2}\times\sin\frac{\alpha-\beta}{2}}$$

$$= \frac{G - d - h\sin\alpha}{\cos\beta - \cos\alpha} \tag{14.9}$$

Example 14.2 Calculate the lead and radius of a 1 in 8.5 BG turnout with straight switches. Use the IRS method.

Solution

G = 1676 mm, d = 136 mm, h = 864 mm

α = 6° 42′ 35″, β = 1° 34′ 27″

(i) Lead = $(G - d - h\sin\alpha)\cot\frac{\alpha+\beta}{2} + h\cos\alpha$

= (1676 – 136 – 864 × 0.1168) × 13.8089 + 864 × 0.993

= 20,729.89 mm or approx. 20,730 mm

(ii) Radius = $\frac{G - d - h\sin\alpha}{2\sin\frac{\alpha+\beta}{2}\times\sin\frac{\alpha-\beta}{2}}$

$$= \frac{1676 - 136 - 864\times 0.1168}{2\times 0.7223\times 0.0448} = 222{,}360 \text{ mm}$$

Example 14.3 A turnout is to be laid off a straight BG track with a 1 in 12 crossing. Determine the lead and radius of the turnout with the help of the following data: heel divergence (d) = 133 mm, crossing angle (α) = 4° 45′ 49″, switch angle (β) = 1° 8′ 00″, straight length between the theoretical nose of crossing and the tangent point of crossing (h) = 1.418 m.

Solution

α = 4° 45′ 49″, β = 1° 8′ 0″

G = 1.676 m, d = 0.133 m

N = 12, h = 1.418 m

(i) Radius $R = \dfrac{G - d - h\sin\alpha}{\cos\beta - \cos\alpha}$

$$= \frac{1.676 - 0.133 - 1.418\sin 4°45'49''}{\cos 1°8'0'' - \cos 4°45'49''}$$

$= 437.38$ m

(ii) Crossing lead (L) = $h\cos\alpha + (G - d - h\sin\alpha)\cot\dfrac{\alpha+\beta}{2}$

$= 1.418 \cos 4° 45' 49'' + (1.676 - 0.133 - 1.418 \sin 4° 45' 49'') \times \cot 2° 56' 54''$

$= 1.418 \times 0.9965 + 1.425 \times 19.415$

$= 29.084$ m

Standard turnouts and permissible speeds

On Indian Railways, normally 1 in 8.5 turnouts are used for goods trains while 1 in 12 and 1 in 16 turnouts are used for passenger trains. Recently 1 in 20 and 1 in 24 turnouts have also been designed by the RDSO, to be used to permit higher speeds for fast trains on the turnout side. The maximum speeds permitted on these turnouts are given in Table 14.5.

Table 14.5 Permissible speeds on turnouts

Gauge	*Type of turnout*	*Switch angle*	*Permissible speed (km/h)*
BG	1 in 8.5	1° 34′ 27″	10* for straight switch and 15 for curved switch for 52/60 kg on PSC sleepers
BG†	1 in 8.5	Symmetrical split (SS) 0° 27′ 35″	30 for curved switch as well as SS with 52/60 kg on PSC sleepers; 15* for curved switch for 52/60 kg on PSC sleepers‡
BG	1 in 16	1° 8′ 0″ 0° 24′ 27″	50 or 60¶
MG	1 in 8.5	1° 35′ 30″ 0° 29′ 14″	10 for straight as well as curved switch
MG	1 in 12	1° 09′ 38″ 0° 24′ 27″	15 for straight switch and 15 for partly curved switch
MG	1 in 16	0° 24′ 27″	30

Source: Indian Railway Permanent Way Manual (IRPWM)—Correction slip no. 94 dated 1 June 2004.

* As per the Indian Railway way and works (IRWW) manual, a speed of 15 km/h was originally permitted on 1 in 8.5 turnouts. However, due to a subsequent number of derailments of passenger trains on turn-in curves, the speeds on these turnouts have row been reduced to 10 km/h only.

† The figures in the second row correspond to curved switches.

‡ A speed of 30 km/h is also permitted on 1 in 12 turnouts on those interlocked sections where all turnouts over which a running train may pass are 1 in 12 throughout the section and the locomotives are fitted with speedometers. In all other cases, speed is restricted to 15 km/h only.

¶ 60 km/h permitted only for high-speed turnouts to Drg. No. RDST/T-403.

14.8 Turnout with Curved Switches

The following formulae are used for the calculation of turnouts with curved switches

$$R = \frac{G - t - h\sin\alpha}{2\sin\frac{\alpha+\beta}{2} \times \sin\frac{\alpha-\beta}{2}} = \frac{G - t - h\sin\alpha}{\cos\beta - \cos\alpha} \tag{14.10}$$

$$I = R\sin\alpha - (G - t - h\sin\alpha)\cot\frac{\alpha+\beta}{2} \tag{14.11}$$

$$V = G - \{h\sin\alpha + R(1 - \cos\alpha)\} \tag{14.12}$$

$$\text{Switch lead} = \sqrt{2R(d - y) - (d - y)^2 - 1} \tag{14.13}$$

$$\text{Lead} = (G - t - h\sin\alpha)\cot\frac{\alpha+\beta}{2} - \text{SL} - h\cos\alpha \tag{14.14}$$

where R is the radius of the outer lead rail, G is the gauge, h is the lead of the straight leg of the crossing ahead of TNC up to the TP of the lead curve, t is the thickness of the switch at the toe, I is the distance from the toe of the switch to the point where the tangent drawn to the extended lead curve is parallel to the main line gauge face, V is the distance between the main line gauge face and the tangent drawn to the lead curve from a distance l from the toe, y is the vertical ordinate along the Y-axis, α is the crossing angle, and β is the switch angle.

14.9 Layout of Turnout

To lay out a turnout in the field, the values of offsets from the gauge face of the straight track to the gauge face of the turnout may be adopted from Table 14.6.

Table 14.6 Laying turnouts in the field*

Distance from heel	*Offset from gauge face of straight track to gauge face of turnout*					
	1 in 8.5 4725-mm straight (ST) switch	*1 in 12 6400-mm ST switch*	*1 in 12 7730-mm curved switch*	*1 in 8.5 4115-m ST switch*	*1 in 12 5485-mm ST switch*	*1 in 12 6700-mm curved switch*
3000	–	–	–	241	–	–
4500	–	–	–	330	–	–
6000	382	293	322	437	313	362
7500	469	365	381	564	386	445
9000	565	403	445	709	468	537
10,500	672	466	515	–	559	638
12,000	790	512	589	–	659	747
13,500	917	606	668	–	769	–
15,000	1055	685	752	–	–	–
16,500	1202	767	841	–	–	–

(*contd*)

Table 14.6 (*contd*)

Distance from heel	*Offset from gauge face of straight track to gauge face of turnout*					
	1 in 8.5 4725-mm ST switch	*1 in 12 6400-mm ST switch*	*1 in 12 7730-mm curved switch*	*1 in 8.5 4115-m ST switch*	*1 in 12 5485-mm ST switch*	*1 in 12 6700-mm curved switch*
18,000	–	856	935	–	–	–
19,500	–	950	1033	–	–	–
21,000	–	1047	1137	–	–	–
22,500	–	1151	1246	–	–	–
24,000	–	1260	1359	–	–	–
Total number of sleepers	51	70	70	37	47	47
Switch angle	1°34′27″	1°8′0″	0°27′35″	1°35′30″	1°9′38″	0°24′27″
Crossing angle	6°42′35″	4°45′49″	4°45′49″	6°42′49″	4°45′49″	4°45′49″
Drg. no.	TA 20,104 and 20,804	TA 5268(M) and 20,801	TA 20,171 and 21,831	TA 20,171 and 21,004	TA 20,401 and 20,001	TA 20,484

* All dimensions are in millimetres.

14.10 Trends in Turnout Design on Indian Railways

The main factors responsible for low speeds over turnouts on Indian Railways are as follows.

(a) A sudden change in the direction of the running edge upon entry onto the switch from a straight track
(b) Absence of a transition between the curved lead and the straight crossing
(c) Non-transitioned entry from the curved lead to the straight crossing
(d) Absence of superelevation over the turnout curve
(e) Gaps in the gauge face and the running table at the crossing
(f) Variation in cross level caused by raised switch rails

In order to achieve higher speeds on turnouts, it is necessary that all the limitations of the design of a turnout be overcome as far as possible. In European countries, the design of turnouts has been greatly improved and speeds of more than 100 km/h are permitted on turnout curves. The main features of the design of these turnouts are the following.

(a) Long curved switches are provided to avoid the abrupt change in the direction of the vehicle at the entry to the switch.
(b) Switches and crossings are curved to the same radius as the lead curve or, alternatively, a transition curve is provided between the toe of the switch and the nose of the crossing. This provides a smooth passage to the trains on the turnout curve.

(c) Higher cant deficiency is permitted so that the disadvantage of not providing superelevation on the turnout curve is duly compensated.

In keeping with the trend in the railways of the world to permit higher speeds on turnouts, Indian Railways is considering standardization of high-speed turnouts for the following conditions of the track.

(a) For goods yards for a maximum permissible speed of 25 km/h and for passenger yards for maximum permissible speed of 50 km/h.
(b) In peripheries of big yards for bypass lines for a maximum permissible speed of 75 km/h.
(c) At junction joints of single-line and double-line sections for a maximum permissible speed of 100 km/h.

A design of 1 in 12 turnouts for passenger yards with thick web tongue rails and CMS crossings (RDSO Drg. no. T-2733) has already been finalized for enabling a maximum permissible speed of 50 km/h. Similarly, a new design of 1 in 24 turn outs for BG routes with curved switches and thick web tongue rails with a speed potential of 160 km/h is being finalized by Indian Railways.

14.11 Inspection and Maintenance of Points and Crossings

Points and crossings should be inspected in detail, as the quality of a train ride greatly depends on their maintenance. The following important points should be checked.

Condition of tongue rails and stock rails There should be no wear on the top as well as the gauge face side of the tongue rail. Badly worn out rails should be replaced. It should be ensured that the turnout side stock rail is provided with the requisite bend ahead of the toe of the switch; otherwise the alignment at this spot is bound to be kinky.

Condition of fittings of tongue and stock rails The fittings should be tight and the spherical washers must be placed at their correct locations. The slide chairs should be cleaned and greased with graphite for smooth operation of the points. The fish plates should be provided with the correct amount of bend at the loose heel joint. A gauge tie plate should be added if provisions for the same have not been made.

Gauge and cross level at switch assembly The gauge and cross levels should be checked for correctness at the following locations: (i) the stock joint, (ii) 150 mm (6") behind the toe of the switch, (iii) the mid-switch for the straight track and for the turnout side, and (iv) the heel of the switch for the straight track and for the turnout side.

Clearance between stock and tongue rails at the heel of the switch The correct divergence to be provided at heel of the switch should be as follows:

1 in 16 or 1 in 12	*1 in 8.5*
BG—133 mm (5.25")	120 mm (4.25")
MG—117 mm (4.65")	120 mm (4.75")

Throw of the switch The throw of the switch should be as follows

	Recommended	*Minimum*
BG	115 mm (4.5")	95 mm (3.25")
MG	100 mm (4")	89 mm (3.5")

Condition of crossing and tongue rail The condition of the crossings and of the fittings should be checked. The maximum vertical wear permitted on a point or wing rail is 10 mm and these should be reconditioned when the wear is 6 mm. The burn burrs should also be removed and the fittings should be tightened. The maximum vertical wear permitted on a tongue rail is 6 mm, whereas the permitted lateral wear is 8 mm for 90 R and 52-kg rails and 5 mm for 60 R and 75 R rails. The tongue rail should be replaced or reconditioned before this value is reached. The Railway Board has recently decided that the maximum vertical wear on wing rails and the nose of the crossings should be limited to 4 mm on the Rajdhani and Shatabdi routes and 6 mm on all other routes. The wear limits for CMS crossings are, however, 5.5 mm for Rajdhani and Shatabdi routes and 7.5 mm for all other routes.

Gauge and cross level of crossing assembly The gauge and cross level should be checked at the following locations and should always be correct: (i) 1 m ahead of the nose on straight tracks and on turnouts, (ii) 150 mm (6") behind the ANC on straight tracks and on turnouts, and (iii) 1 m behind the ANC on straight tracks and on turnouts.

Check rails The condition of check rails should be ascertained. Check rail clearances should be as follows:

	Maximum	*Minimum*
BG	48 mm	44 mm
MG	44 mm	41 mm

Lead curvature The curvature should be checked either by the offset method or by the versine method. The curvature should be correct and uniform.

Cross levels on straight tracks and turnouts The cross levels on straight tracks and turnouts should be checked to see that they are correct at all places.

Sleepers The condition of the sleepers and their fittings should be checked and unserviceable sleepers should be replaced. The squaring and spacing of sleepers should be proper and they should be well packed.

Ballast and drainage Enough quantity of ballast should be available so as to provide an adequate cushion. The drainage should be proper.

Any other defects If there are any other defects in the layout, these should be checked and corrected.

Special attention is required to ensure that the sleepers are well packed, all fittings are tightened, gauge and cross levels are properly maintained, and the wear on the tongue rail as well as on the crossing is within permissible limits. It should also be ensured that proper distance blocks are provided at correct locations. The schedule of inspection followed on Indian Railways is given in Table 14.7.

Table 14.7 Schedule of inspection

PWI (permanent way inspector) III and PWI (in charge)	Once in 3 months in rotation for passenger lines and once in 6 months in rotation for other lines. The interval between two inspections for passenger lines of the same turnout should not exceed 4 months
AEN (assistant engineer)	Once in 12 months for all passenger lines and test checking of 10% of other points and crossings
DEN (divisional engineer)	Test checking of certain number of points and crossings, particularly in running lines and those recommended for renewals.

Summary

A turnout is an integral part of a railway track. It is a combination of lead rails and points and crossings. These are provided when two tracks are to be connected or when a branch line is to be introduced. The various features and designs of a turnout have been discussed in this chapter. Design examples have also been included. It is possible to have various types of track junctions with different combinations of points and crossings. These are described in Chapter 15.

Review Questions

1. Design a turnout for a BG track if the number of the crossing is 12 and the heel divergence is 114 mm. Assume a simple circular curve from the toe of the switch to the TNC.
2. Draw a neat sketch of a right-hand turnout taking off from a straight broad gauge track and name thereon the various component parts and important terms connected with the layout. Show the disposition of the sleepers.
3. A turnout is to be laid off a straight broad gauge track with a 1 in 12 crossing. Determine the lead and radius for the turnout given the following data heel divergence d = 133 mm, the straight length between the TNC and the tangent point of the crossing curve, h = 1.418 m, crossing angle $\alpha = 4°45'49''$, and switch angle $\beta = 1°9'00''$.
4. Draw a neat sketch of a left-hand turnout and name its various components. Describe any one method of designing a turnout and give the detailed procedure for calculating the (a) lead, (b) radius, and (c) heel divergence.
5. Calculate the elements required to set out a 1 in 8.5 turnout taking off from a straight BG track, with its curve starting from the heel of the switch and ending at a distance of 864 mm from the TNC, given that the heel divergence is 136 mm and the switch angle is $1° 34' 27''$. Make a freehand sketch showing the values of the calculated elements.
6. Explain with the help of neat sketches the points and crossings used in railways, indicating the precautions to be taken while laying the same.
7. On a straight broad gauge track a turnout takes off at an angle of $6° 42' 35''$. Design the turnout when it is given that the switch angle is equal to $1° 34' 27''$ and the length of the switch rails is 4.73 m. The heel divergence is 11.43 cm.

The straight arm is 0.85 m long.

8. Draw a neat sketch of a crossover between two parallel straight MG tracks spaced at 5 m centre-to-centre distance. Show the position of the switches as they would be when trains would be diverted from one track to the other. Also show the following particulars on the sketch of the crossover: (a) overall length of turnout, (b) overall length of the crossover, (c) any two wing rails, (d) any two check rails, (e) any two stock rails, (f) any two switch rails, (g) two heel blocks, (h) one pull rod.
9. Calculate all the necessary elements for a 1 in 12 turnout taking off from a straight BG track, with its curve starting from the toe of the switch, i.e., tangential to the gauge face of the outer main rail and passing through the TNC, given that the heel divergence is 11.4 cm.
   (a) Find the crossing angles of the 1 in 12 crossing using the right angle method.
   (b) Draw a labelled section for the points at the toe of the switch.
10. A crossover is to be laid connecting two BG parallel tracks spaced 4.5 m apart. Assuming that 1 in 8.5 crossings are to be used, work out the various details required for setting out the crossover.
11. Calculate the principal dimensions required to connect a parallel siding to a main line with the help of a 1 in 8.5 turnout, the spacing between these BG parallel tracks being 6 m c/c. For a 1 in 8.5 crossing the detailed dimensions are as follows: theoretical length of switch rail = 4950 mm, actual length of switch rail = 4725 mm, heel divergence = 136 mm, distance between the ends of the switch and stock rails = 840 mm, distance between TNC and the first distance block (tangent point) at the toe of the crossing = 864 mm. Draw a detailed dimensioned sketch for this turnout connecting two parallel tracks and label therein the various parts of the turnout.
12. Find the crossing angles for a 1 in 12 crossing using the centre line method.
13. What are the standard turnouts prescribed on Indian Railways? What are the special fittings that are provided with turnouts and what are their functions?
14. When is it necessary to recondition worn out crossings? Describe in detail one of the methods of reconditioning a crossing.
15. What are the various points required to be checked during the inspection of points and crossings? Give the schedule laid down by Indian Railways for the inspection of these points and crossings.
16. Describe the main constituents of a crossing. Draw neat sketches to show a point rail and a splice rail.
17. What is a CMS crossing? Describe its advantages.
18. Differentiate between the following.
   (a) Stud switch and split switch
   (b) Stock rail and tongue rail
   (c) Flangeway clearance and heel divergence
   (d) Flat bearing plate and anticreep bearing plate
   (e) Slide chairs and grade-off chairs