Health and Safety Executive

Rail track and associated equipment for use underground in mines

Guidance on selection, installation and maintenance

Contents

Status of document

This guidance was prepared by the Health and Safety Executive (HSE). It has been agreed by the Mining Industry Committee.

Following the guidance is not compulsory and you are free to take other action. If you do follow this guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Introduction

Some basic principles

1 Good rail track standards are fundamental to the safe and efficient operation of rail transport systems underground in mines.

2 The design and layout of rail track needs to be incorporated into the overall planning of the mine to ensure that practical payloads and acceptable journey times are achievable. In particular, the mine roadways should be designed to have adequate clearances, suitable gradients and the largest practical radii on curves.

3 Careful selection of rail track components, the use of competent tracklayers and installing the track to a suitable specification will enhance safety and significantly reduce future maintenance needs.

What the guidance covers

4 This guidance covers rail track used underground in mines by locomotive and rope-haulage systems, to transport people, equipment, material supplies and minerals. It does not apply to temporary trackwork, or to light-duty trackwork used solely for mineral or material transport at speeds below 5 km/hour. However, for these systems a suitable risk assessment should be performed to ensure that the standards and control measures adopted are appropriate for the hazards.

5 This guidance gives technical advice on the selection of rail track components, recommends standards for installation and maintenance and gives background information on the design of turnouts and curves. The guidance principally deals with conventional rail track, including high-speed (16 km/hour and over) track and, where appropriate, makes specific reference to captive rail track, rack locomotive track and rope-hauled systems. It also gives advice on the safety of track workers and on track-mounted vehicle retarders.

Who the guidance is for

6 This guidance is aimed at engineers, technicians and purpose-trained personnel who have duties to select, install, maintain, inspect and deal with trackwork at mines. It is not intended to provide guidance for manufacturers of rail track.

7 The guidance is relevant to underground rail track in coal mines, miscellaneous mines and tourist mines.

8 The guidance may be of use to other sectors outside the mining industry that use narrow-gauge rail track, such as the tunnelling sector and narrow-gauge railway operators.

The legal framework

9 The principal legislation associated with the selection, installation and maintenance of rail track and associated equipment for use underground in mines is listed in the Appendix.

Components of rail track

10 Rail track not only supports the train weight, it also resists the longitudinal forces resulting from tractive and braking effort and the lateral forces resulting from guiding the wheels. Those designing and maintaining track should therefore select and use only those components that are suitable for the proposed duty and fit for purpose.

Rails

Determining the correct rail size

11 Rails are described and specified by their weight per unit length. The minimum weight per metre of rail required depends on the maximum axle load of the heaviest vehicle that will run on the track and the quality of vehicle suspension. Without sprung suspension even minor changes in track cross level will cause full axle loads to be carried on one wheel. For locomotive systems, the minimum weight of rail allowable is specified in regulations.[1]

12 However, dutyholders should take note that when selecting heavier-duty rail than the minimum required, there will be a significant reduction in maintenance costs and improved running qualities.

13 Generally, steel tyred locomotives have been designed around a maximum axle load of 7.5 tonnes. To contend with modern demands for heavier loads and heavier locomotives, yet retain the maximum axle loading within the 7.5 tonnes, multiple axle wheel sets have been used. Rubber tyred locomotives are designed with much lower axle loads than this to avoid undue compression of tyres.

14 When axle loads occasionally exceed those for which the track is designed, special arrangements should be made to ensure that the transport is carried out safely, eg by reducing speeds and improving track maintenance.

Sleeper spacing

15 The method of selecting rail size according to axle loading assumes that suitable sleeper spacing is specified and used. Increasing the sleeper spacing beyond that specified in paragraph 232 will significantly reduce the margin of safety against rail failure.

Minimum rail size

16 The minimum weight of rail recommended for any new installation underground in mines is 17.36 kg/m (35 lb/yd). Provided that sleepers are suitably spaced and properly ballasted, this size of rail gives a good general-purpose track in a typical mining environment.

Common rail sizes

17 The three sizes of rail most commonly used are 17.36 kg/m (35 lb/yd), 24.8 kg/m (50 lb/yd), and 30.54 kg/m (60 lb/yd). Figure 1 shows the principal dimensions for each rail size. The rail sections are referred to by section numbers in British Standards and the designations are BS 248[2] 35M(FB), where M is for mining and FB is for flat bottom, BS 11[3] 50 ‘O’ and BS 11 60 ‘A’ (‘O’ and ‘A’ are alphabetic designations), usually abbreviated to 35M, 50, and 60A.

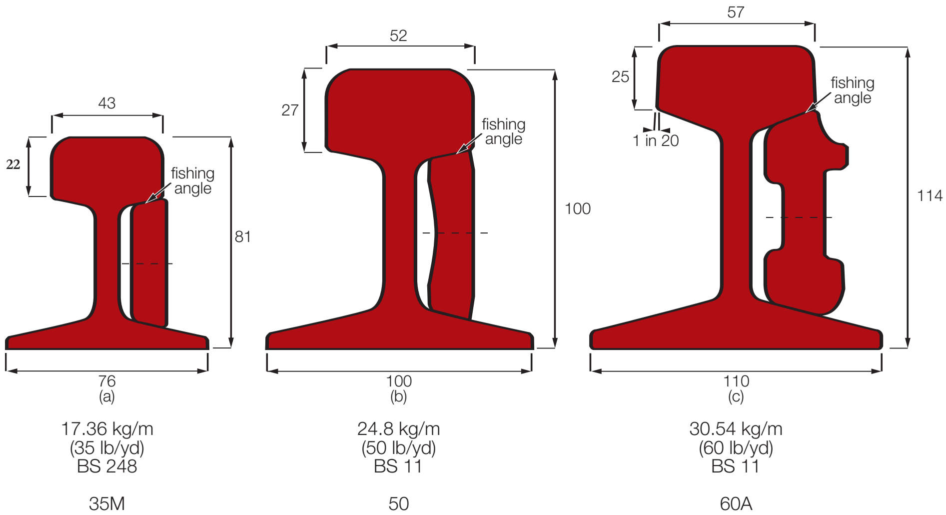


Figure 1 Common rail sizes and principal dimensions

18 The length of rails used in mines varies from 3 m to 7 m. The size chosen at a particular mine often depends on the limitations imposed by the shaft and transport arrangements. The aim should be to select the longest length of rail, which reduces the number of joints needed when it is installed. This will also result in a reduction in supply and maintenance costs. Note that rail steel has a medium to high carbon content and careless heating and cooling can produce material defects. For this reason, flame cutting of rails should be avoided. Rail welding should only be performed by people with specialist knowledge.

Construction of electric trolley locomotive track

19 When selecting components for electric trolley locomotive track, consideration needs to be given to electrical conductivity, earthing of rail track and bonding of rail joints. Additional information can be found in Guidance Note 2 of the Approved Code of Practice accompanying the Electricity at Work Regulations 1989, *The use of electricity in mines* L128.[4]

Fishplates and fishbolts

Fishplates

20 Fishplating is the most common method of joining rails used in underground rail track. For maximum joint rigidity, fishplates need to be fixed by at least four bolts. Figure 2 shows the principal details of the fishplates compatible with the three most commonly used rails, 35M, 50 and 60A.

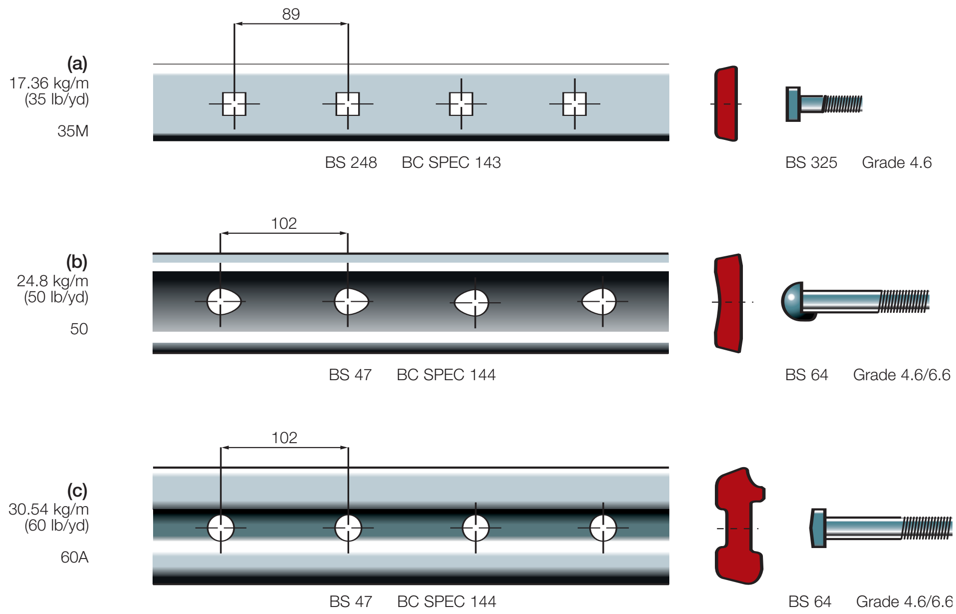


Figure 2 Fishplates and bolts, and principal dimensions

21 Standard fishplates used on 60A rail can cause problems where rubber-tyred locomotives operate. Tyre wear and compression may lead to the wheel flanges fouling on the upper part of the inner fishplate. Figure 3 shows a fishplate that has been modified by the manufacturer to eliminate fouling without significantly reducing joint strength. The original, unmodified fishplate can still be used on the outside of the joint.

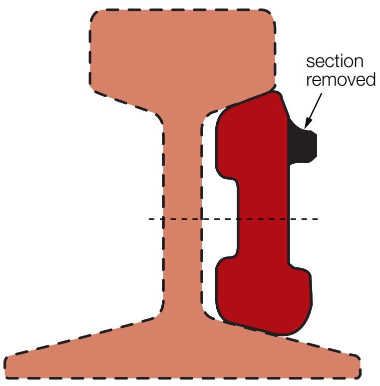


Figure 3 Modified 60A fishplate for mining applications

Fishbolts

22 Fishbolts should be positioned with the nuts on the outside of the track. This is because the nuts are bigger than the bolt heads and are prone to fouling the wheel flanges if they are fitted on the inside of the track.

Ensuring proper fit

23 Fishplates are designed to fit into the sloping surfaces inside the rail profile. These sloping surfaces are known as the upper and lower fishing surfaces. The strength of a rail joint depends on the clamping force at the fishing surfaces produced by tightening the fishbolts.

24 The top and bottom fishing surfaces slope at the same angle, so that a fishplate pulls in evenly. A working gap is always maintained between the inner face of the fishplate and the rail web when fishplates are bolted up, to ensure that the plates press against the fishing surfaces and not the rail web. When fishbolts are tightened, the fishplates are pulled hard into the fishing surfaces and the forces resulting from a wheel passing over a rail joint are distributed evenly over the whole length of the fishplated joint.

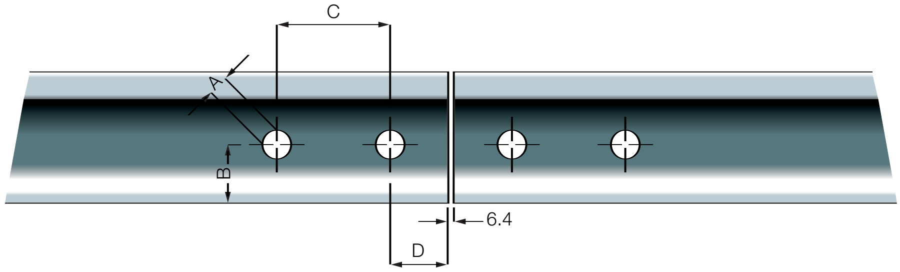
25 The torque applied to fishbolts is not always measured. Bolts are often simply tightened as far as they can be with a standard spanner. For 35M rail joints, black quality bolts tightened in this manner are usually adequate. However, with 50 and 60A rail, black quality bolts can stretch and lead to loose joints. For these rails, higher tensile grade fishbolts should be used to enable higher torque settings, resulting in a stronger, more reliable joint. Guidance on the correct torque setting should be sought from the bolt supplier/manufacturer.

26 Newly installed fishplates and fishbolts can loosen rapidly, due to bedding-in at the fishing surfaces when rust and high spots wear off the jointing faces. Checks should be made shortly after installation and the fishbolts retightened where necessary.

27 If fishbolts become loose in service, then joint strength is reduced. If left unattended, the adjoining rail ends may be bent permanently downwards, a phenomenon known as ‘dipped joints’.

Rail end details

28 Figure 4 shows the rail end details for fishplated joints in 35M, 50 and 60A rails.



Number of BS Section rail	35M	50	60A
A (mm)	19	23.8	25.4
B (mm)	34.1	41.5	47.6
C (mm)	88.9	101.6	101.6
D (mm)	41.2	47.6	47.6

Figure 4 Normal joint configuration with 6 mm gap

29 Fishplates are normally designed so that there is a gap of approximately 6 mm between rail ends to allow for thermal expansion of the rails. Where ambient temperatures are fairly constant, butt jointing will improve joint stiffness, ride quality and reduce noise. In this case, the rail gaps need be no more than 2 mm to allow a tolerance for installing them. It is worth noting that for fishplated joints on 60A rail, the bolt hole tolerances allow the rail ends to be virtually butted, although a small gap should always be left (see Figure 5). For other rail sizes, the bolt hole tolerances are less and special rail end drillings are required to achieve butt joints.

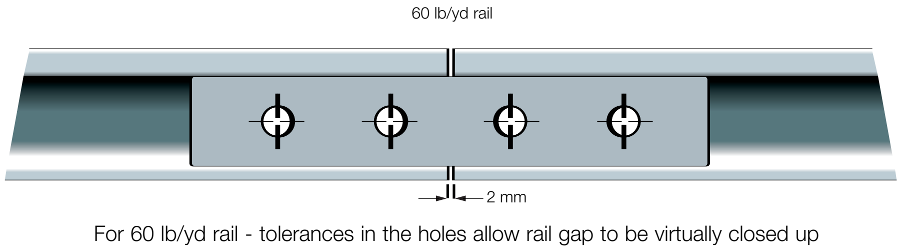


Figure 5 Normal joint configuration with 2 mm gap

Stepped fishplates

30 Stepped fishplates are used for joining rails of different sizes, they are known as joggled fishplates, and can be obtained from fishplate manufacturers. The ‘step’ usually lifts the bottom of the smaller size rail, which requires support beneath to keep the rail tops level. Stepped fishplates fabricated in-house should be avoided because they may contain inherent weaknesses, especially in fatigue strength at the change of section.

Alternatives to fishplates and fishbolts

31 For long, straight runs of heavily used permanent track where ground movement is not expected to be a problem, alternative methods of joining rails might be used. These include thermit (aluminium oxide) welding, and ‘huck’ bolts used with standard fishplates.

Sleepers

32 The two main types of sleepers used below ground are timber sleepers and steel sleepers. Concrete sleepers, which find wide application for surface rail track, are not generally used below ground in mines because they fracture readily with roadway floor movement.

Timber sleepers

33 Softwood timber, such as ‘Scot’s pine’, is suitable for sleepers. Only good quality sleepers, that are well seasoned and free from defects liable to affect their strength, should be used. Sleepers should be straight, cut square at the ends, and have their top and bottom faces parallel.

34 A standard-size sleeper is 200 mm wide and 100 mm thick. The minimum length should be equal to the rail gauge plus 600 mm. Longer and wider sleepers may be used to spread the load further where local circumstances require it. For example, where there is a damp, soft clay floor, or where ballast is of inferior stone.

35 Timber sleepers should be laid so that the smallest radius annual growth rings are at the bottom. The corners on the bottom face should be square. The corners on the top face on which the rail sits may wane by up to 20 mm on each edge (see Figure 6).

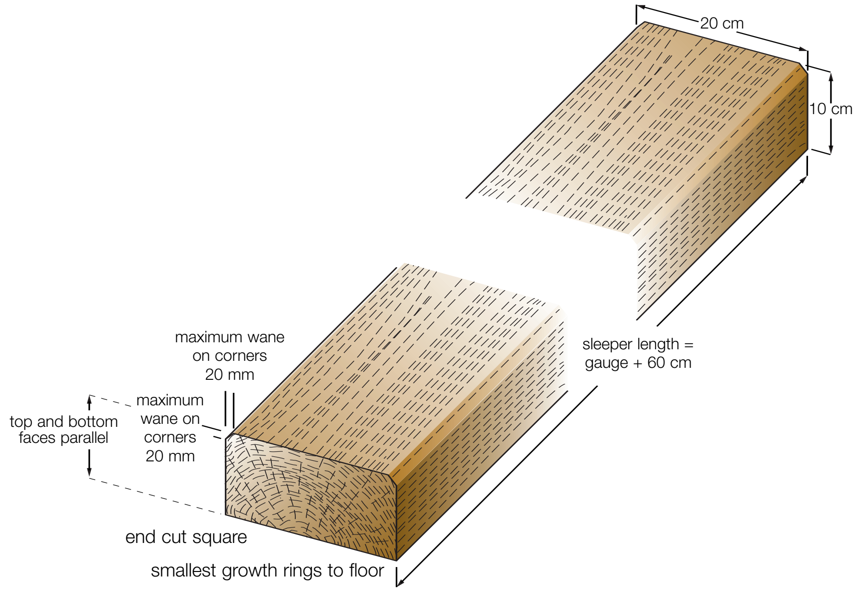


Figure 6 Requirements for timber sleepers

36 To cater for the wet or damp floor conditions found in mines, timber sleepers should be impregnated with a fire-resistant preservative.

37 Timber sleepers provide a wide base which, when properly supported by ballast, distributes the vertical load and offers good friction between sleeper and ballast, keeping the track in position horizontally. For these reasons, timber sleepers are recommended for high-speed and high-load systems used below ground in mines.

Steel sleepers

38 Steel sleepers, complete with rail fasteners, are a convenient alternative to timber sleepers, except where high speeds or heavy loads are proposed. They are convenient to install, maintain and transfer from one location to another. However, because of their shape and size, they tend to settle into the ballast far more quickly than timber sleepers. Additionally, they may not have the same resistance to lateral movement as timber sleepers unless suitable end plates are fitted.

39 Timber sleepers and steel sleepers should not be mixed in the same length of rail track, because of the differential settlement.

40 Steel sleepers are prone to bending where the mine roadway floor can move, and in this respect they need to be of suitable strength for the ground conditions envisaged. Both light-duty and heavy-duty versions are available from manufacturers.

41 Gauge ties are not required with steel sleepers having built-in abutments to position the rail on the sleeper.

Rail fastenings

42 Wheels on rail vehicles have sloping treads to assist steering. On vertical rails, this results in an angled contact between the wheel and the rail, putting an overturning force on the rail. On surface mainline rail track used in Britain, baseplates are tapered to give an inward tilt to the rail to counteract this overturning force. However, when wheels that have worn to suit tilted track are run on vertical track (or vice versa), then the uneven contact can result in loss of adhesion. To avoid this potentially dangerous situation, underground track always has the rails set normally and tapered baseplates are not used.

43 The rail-to-sleeper fastenings should be capable of:

- resisting the overturning force on the rail;
- maintaining gauge; and
- resisting lateral steering forces on curves.

Dog spikes

44 Dog spikes are the simplest means of fastening rails to timber sleepers (see Figure 7). However, as they can work loose, dog spikes should not be used on track that is heavily used, or on rail sizes greater than 35M. Where they are used, an arrangement of three spikes, two on the outside and one on the inside of the rail, will satisfactorily hold the rail squarely to the sleeper.

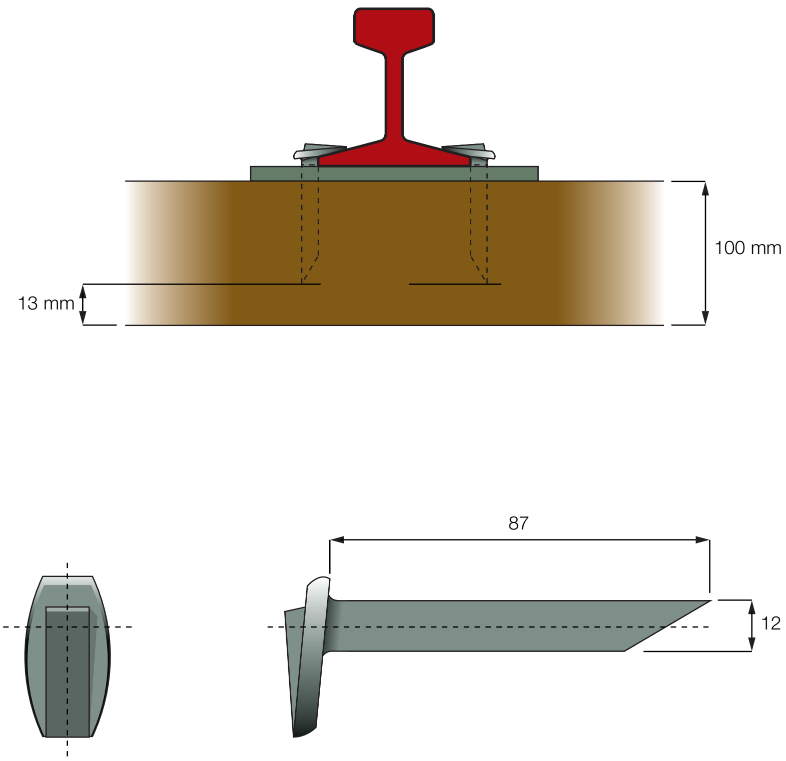


Figure 7 Typical dog-spike rail fastening

45 Steel pads, known as baseplates, may be placed between the base of the rail and the top of the timber sleeper (see Figure 8(a)). These spread the load on the sleeper and reduce the tendency of the rail bottom to press into or wear into the sleeper, which could result in the fixings becoming loose.

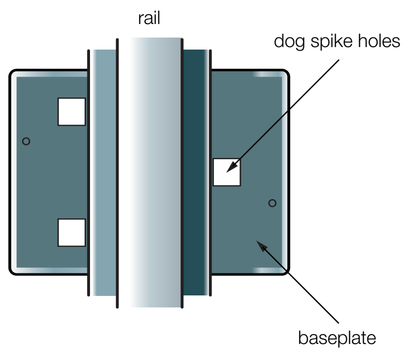


Figure 8(a) Baseplate

46 When dog-spike fixings are used, gauge ties may be required to maintain the track gauge, especially on curves. Figure 8(b) shows a combined gauge tie and baseplate.

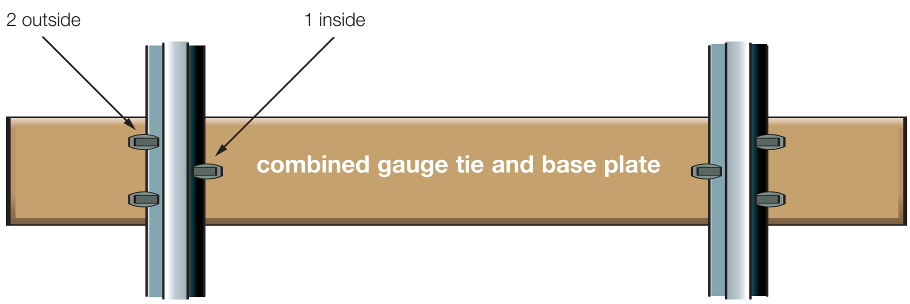


Figure 8(b) Combined gauge tie and baseplate

Coach screws

47 Component parts of crossings should be fastened down to timber sleepers using coach screws (see Figure 9). Coach screws are also used with baseplated timber sleeper assemblies. For 50 and 60A rail, using 200 mm x 100 mm section timber sleepers, coach screws 100 mm long will be satisfactory for securing steel baseplates 10 mm thick.

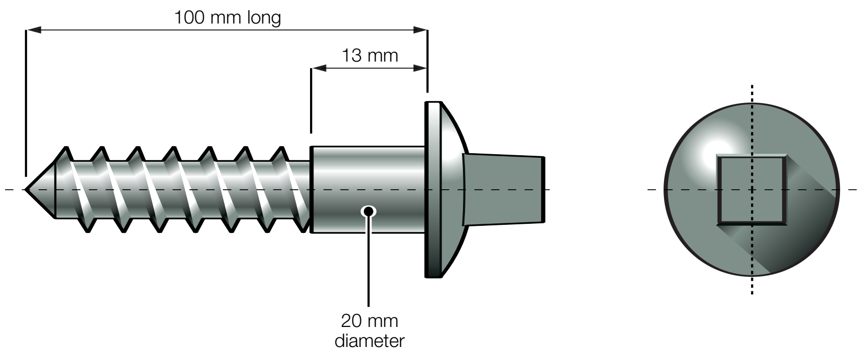


Figure 9 Coach screw

Baseplated timber sleeper assemblies with Pandrol clips

48 Baseplated timber sleeper assemblies are used when laying track to a superior standard, such as that needed for high-speed usage or main manriding systems. The assembly comprises two pressed-steel baseplates already fitted to a timber sleeper. The steel baseplates are preformed to provide a location for the rail foot of a specified flat-bottom rail size, usually either 50 or 60A. The timber sleepers are drilled on a jig to ensure accurate location of baseplates, which are then fixed to the sleepers using coach screws to ensure the correct gauge setting (see Figure 10). The preformed baseplates are designed to accept Pandrol clips for holding the rail in position.

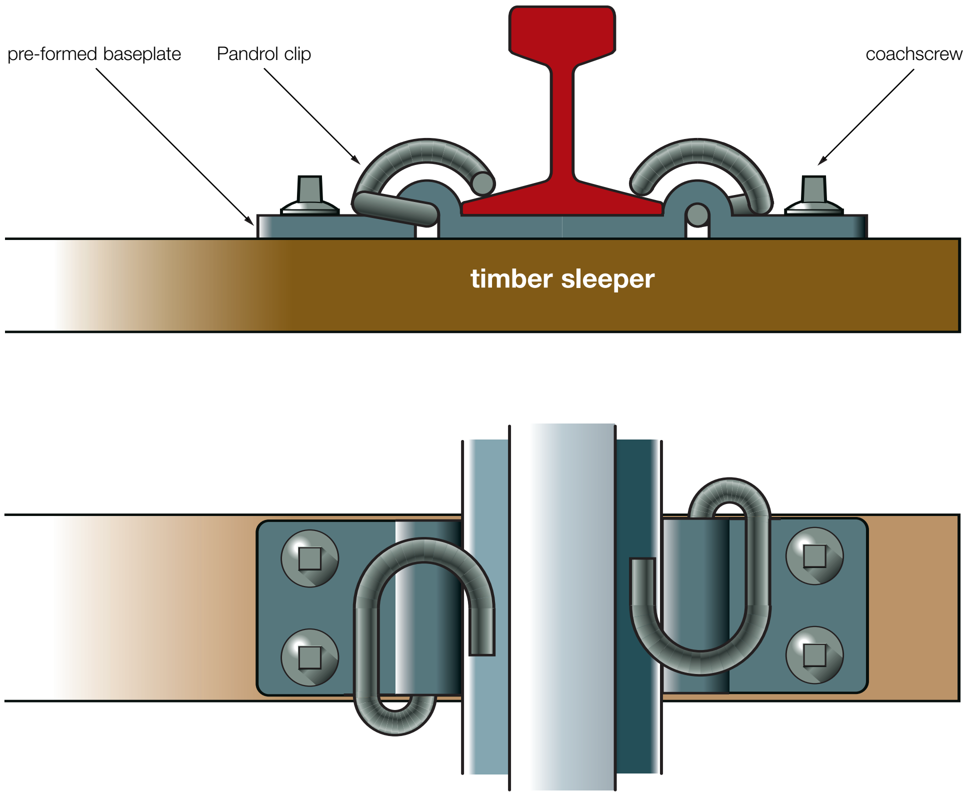


Figure 10 Baseplated sleeper assembly

49 The Pandrol clip provides a constant toe load to the rail foot and is almost maintenance free. Galvanised Pandrol clips are recommended for use in wet roadways to minimise the risk of corrosion fatigue occurring.

Rail fastenings on steel sleepers

50 Steel sleepers with screw-type rail fastenings should:

- incorporate gauge setting abutments that locate the rails relative to the sleeper;
- incorporate clamps that cannot be dislodged from a position 'square' to the rail, so that they cannot rotate off the rail foot;
- provide adequate nip force onto the rail foot; and
- tighten and secure the rail effectively without distortion.

51 Sometimes gauge setting abutments are on the clamping plates (see Figure 11(a)), and sometimes they are on the upper surface of the sleeper independent of the rail clamp (see Figure 11(b)).

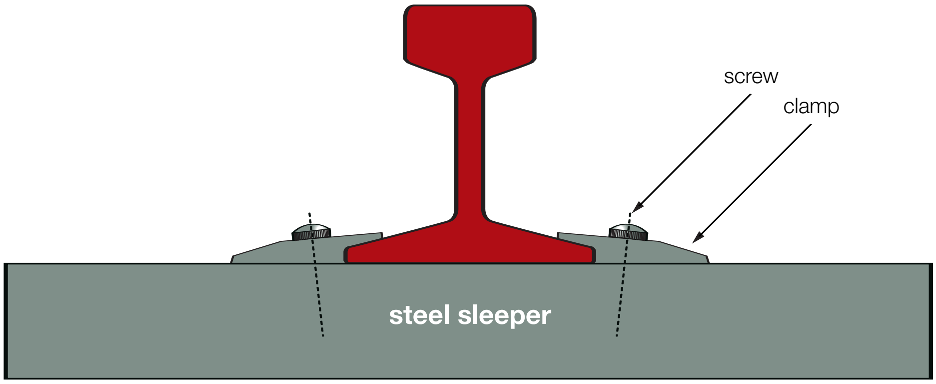


Figure 11(a) Steel sleeper with gauge setting clamps

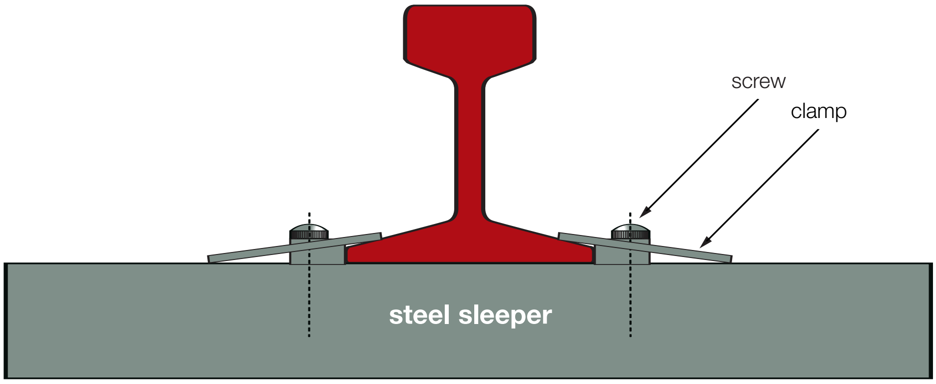


Figure 11(b) Steel sleeper with gauge setting abutments

52 As an alternative to the screw fastener, steel sleepers may have boltless Pandrol clip rail fastenings, where the clip retainer is welded onto the upper surface of the sleeper. These retainers also provide a shoulder for locating the rail and setting the gauge.

Gauge widened sleepers
53 Steel sleepers and baseplated timber sleepers that have been gauge widened for use on curves are generally available to order from suppliers. Alternatively, plain sleepers can be adapted at the mine. For more information on gauge widening on curves, see paragraphs 103-108.

Ballast

54 Proper ballasting is essential to ensure good quality track. Ballast fulfils several purposes:

- transferring the load to the roadway floor;
- holding the sleepers in place;
- allowing water to drain; and
- permitting the regrading of track.

55 The essential characteristics of ballast are:

- it must not crumble under load or wet conditions; and
- it should bind together as a mass when laid, yet still retain its open structure to allow drainage.

56 Selection of ballast material should be based on an acceptable specification for the job rather than on convenience of supply.

57 For high-speed manriding track, the ballast size should be nominally 28 mm single sized. Ballast below 20 mm single size has poor cyclic load-bearing capability, while ballast greater than 40 mm single size is difficult to work with and does not allow accurate regrading of the track.

58 Granite ballast is recommended for its superior resistance to wear and crushing. Carboniferous limestone ballast can be used as an alternative, but it is not as durable as granite and will need more frequent maintenance.

59 Run-of-mine waste stone is only suitable as ballast where the rail track is subjected to light-duty use. It should not be used for ballasting high-speed or heavy-load rail track.

60 Track built into concrete is not recommended because it does not allow adjustment following floor movement in a mine roadway.

Special track for steep gradients

61 On gradients where it is not possible to achieve adequate adhesion or braking, it may be necessary to use captive rail track. Asymmetric trapped conventional (ATC) rail, Becorit Roadrailer track, or UMM Railer track are commercially available types of captive rail track. Alternatively, rack locomotive systems may be used.

ATC rail track

62 Where ATC rails are installed, baseplated timber sleepers should be used to give better stability under severe braking. It is also recommended that some of the sleepers be bolted directly to the roadway floor. The spacing between bolted sleepers should be determined from the braking forces involved. The bolted sleepers should be longer than standard sleepers to allow the floor bolts to pass through them on the outside of the baseplates.

63 ATC rail only uses one fishplate per joint, with countersunk head bolts, to maintain an unobstructed surface on the outside of the track (see Figure 12).

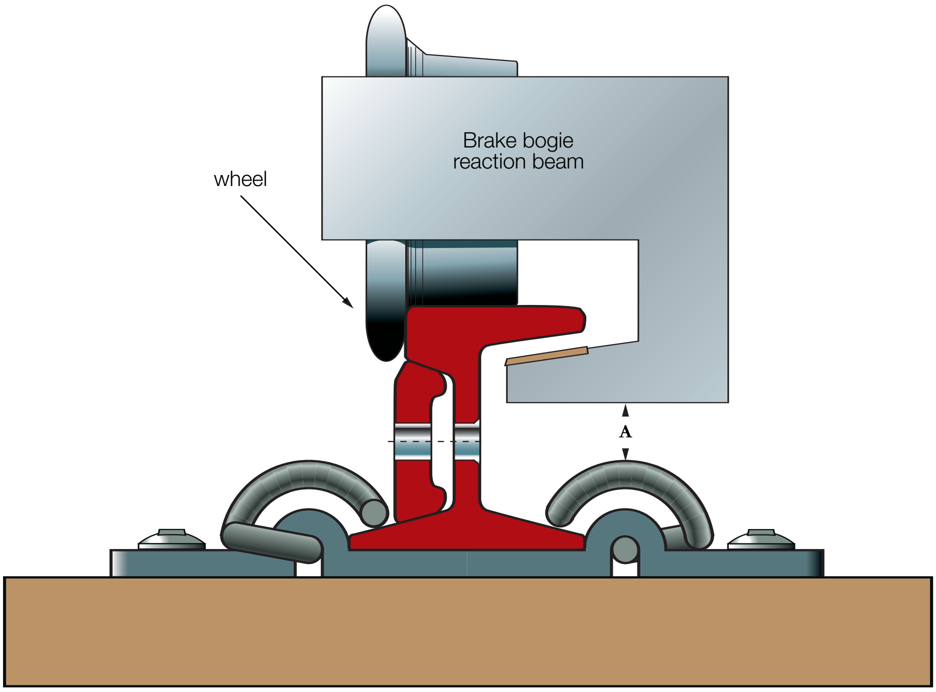


Figure 12 ATC rail and fishplates

64 Care should be taken to ensure that there is adequate clearance between the brake bogie and the Pandrol clip at 'A' in Figure 12. If the clearance is insufficient, it may be necessary to replace the Pandrol clip on the outside of the track with an alternative design that gives adequate clearance.

Becorit Roadrailer track and UMM Railer track

65 Some captive rail track is made in prefabricated sections (see Figures 13(a) and 13(b)). Typically these are 3 m, 6 m or 9 m long and are designed for use with vehicles with special wheel sets.

Figure 13(a) Becorit 400 mm

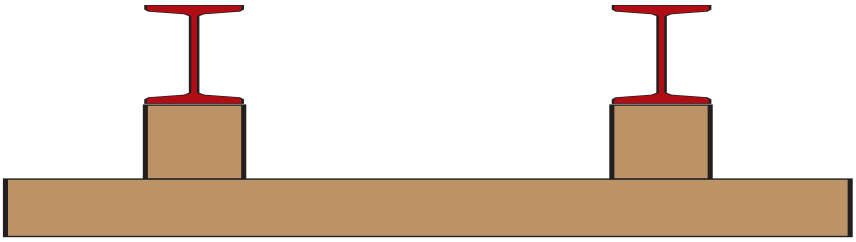


Figure 13(b) UMM Railer

66 The rail track manufacturer's advice should be sought on the interval for bolting this type of track to the floor, especially on steep gradients. If such track is not adequately secured to the floor, the track may move forward and jackknife at joints when the vehicle's emergency track brakes are applied.

Rack loco track

67 Where racks are installed, the sleepers, rails and racks should be compatible to ensure proper engagement of the drive pinions and the rack teeth.

Curved track

68 When vehicles travel around curves, forces are generated that increase the wear and tear on the track and the potential for derailment. These forces need to be minimised by designing the curve with its maximum practical radius, together with one or more of the following additional measures as necessary:

- super-elevation of the outer rail;
- check rails fitted to the inner rail;
- gauge widening.

Flange climbing

69 When a vehicle travels around a curve, the flange of the leading outer wheel presses heavily against the inside face (the gauge face) of the outer rail as it guides the vehicle laterally around the curve. At the same time, because the leading outer wheel is actually directed towards the outside of the curve at an angle with the rail, the wheel flange strikes the gauge face with a downward force. This downward force, combined with the lateral pressure, will cause abrasive wear on the side of the wheel flange and on the rail gauge face. If the lateral pressure is great enough, the wheel flange can climb up the rail, resulting in derailment. This phenomenon is known as 'flange climbing'. Flange climbing is resisted only by the weight of the vehicle acting downwards on the wheel (see Figure 14).

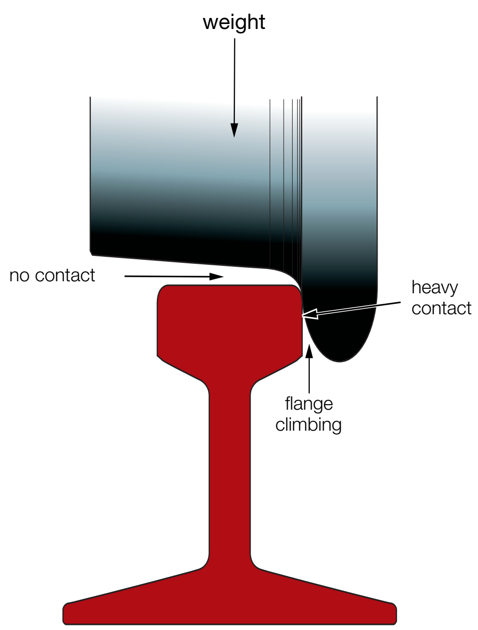


Figure 14 Flange climbing

Radius of curves

70 Curved track should be set out with the largest radius possible. This will ease the passage of vehicles around the curve, reduce wear and tear on wheels and rails and save on maintenance costs.

Minimum radius
71 The minimum curve radius that a vehicle can travel around should be sought from the vehicle manufacturer. Alternatively, the minimum radius for a vehicle or bogie can be calculated. For a twin-axle four-wheeled vehicle (see Figure 15(a)) the following formula is used:

$$R_{min} = \frac{BL}{2S}$$

where:
B is the wheelbase of the vehicle or bogie;
R is the radius of curve to outer rail;
S is the difference between track gauge and wheel gauge (see paragraph 164);
L is the length of portion of flange below rail top;

and where:

$$L = \sqrt{8dr - 4d^2}$$

d is the depth of flange; and
r is the radius of wheel to flange tip.

Note 1: For the majority of underground applications, the minimum value of *S* will be 12 mm.
Note 2: All of the above to be in the same units.

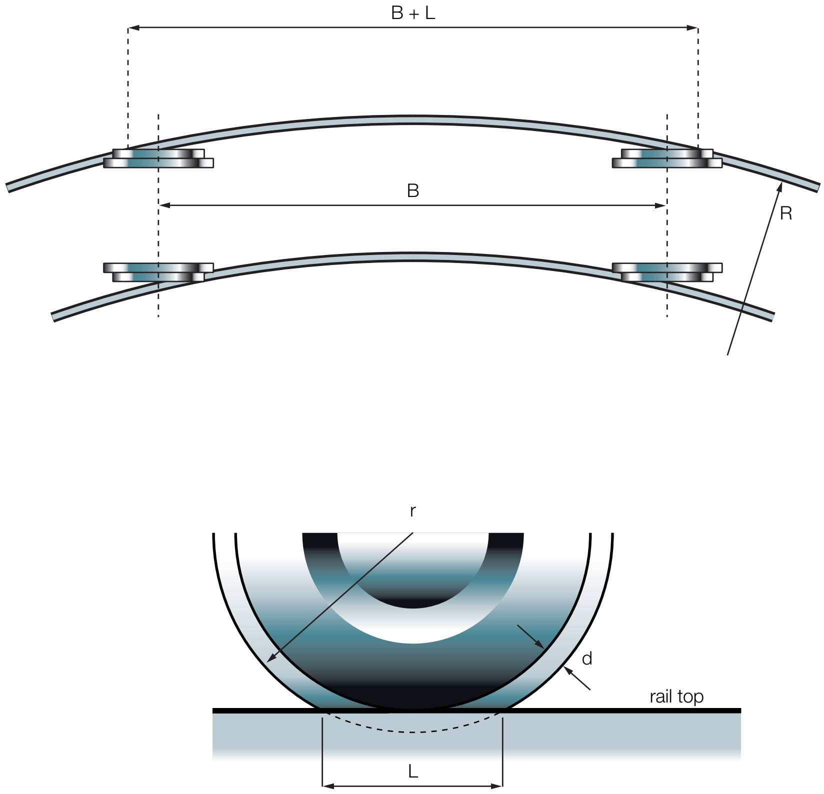


Figure 15(a) Calculating minimum curve radius with a four-wheeled vehicle

72 For a triple-axle six-wheeled vehicle or bogie (see Figure 15(b)) the formula is:

$$R_{min} = \frac{(B + L)^2}{8(S + X)}$$

where:
B, R, S and *L* are as described in paragraph 71; and
X is the amount by which the middle pair of wheels can move out of line with the end wheels.

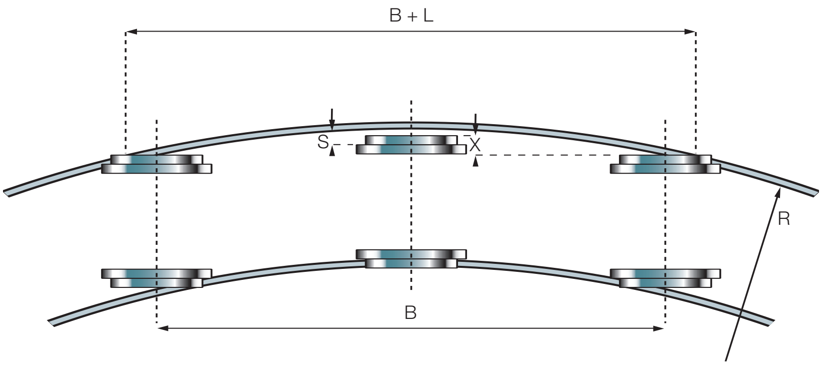


Figure 15(b) Calculating minimum curve radius with a six-wheeled vehicle

73 The minimum calculated radius that a particular vehicle can travel around may not be suitable for vehicles with different axle arrangements, nor for a train of vehicles coupled together. For example, a vehicle with a long overhang will have a greater end throw than a vehicle with a short overhang, and if they are coupled together, the lighter vehicle may be derailed as the combination travels round the curve. A similar problem may be experienced as a result of limited articulation at couplings. For this reason, all the different vehicle types that may operate on the curve should be taken into account.

74 Locomotives and other vehicles may be able to negotiate a curve having the calculated minimum radius, but this should be avoided and a larger radius should be used if possible. Operating on a curve having the minimum radius will:

- take more effort to haul the vehicle around the curve;
- increase the flange climbing forces between the guiding wheel and the outer rail;
- result in greater component wear and noise; and
- increase the potential for derailment.

75 When vehicles are connected with twin outer safety chains, the chains need to be of the correct length to avoid:

- undue tensioning on the outside of a curve, which will restrict articulation and increase the tendency to derailment; and
- undue slackening on the inside of a curve, which may allow the chain to catch on the track.

Note: Where this problem can occur, consider providing a single central safety chain.

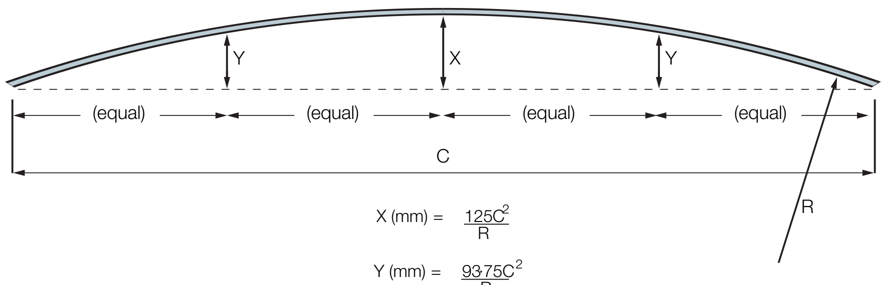
76 For manriding carriages, the manufacturer should be consulted before determining the minimum curve radius required.

Manufacturing a curve

77 To manufacture a smooth curve, it needs to be formed accurately to a template or to lines on the floor set out by surveyors.

78 The preferred method of forming curves is by rolling the rails. Alternatively, power presses having a curved profile head can give acceptable results. Curves cramped on site using a portable tool are often unsatisfactory, except for short sections and where the radius is significantly greater than the minimum acceptable. This is because a continuous true curve is difficult to make and the ends of the rails remain straight. Both of these factors can increase the risk of derailment.

79 For a large-radius curve, there may not be enough space available to mark out from the centre of the circle. Setting out a large-radius curve can be achieved by using offsets (versines) to the chord of the curve (see Figure 16). Where it is necessary to measure the radius of an installed curve, then the offset method gives a good approximation of the radius by rearrangement of the formula in Figure 16.



$$X \text{ (mm)} = \frac{125C^2}{R}$$

$$Y \text{ (mm)} = \frac{93{\cdot}75C^2}{R}$$

also $Y \text{ (mm)} = 0{\cdot}75X$

where C = chord length and
R = radius in metres of respective rail

Figure 16 Setting out a rail curve using offsets

80 To provide a continuous smooth curve at rail joints, and maintain joint strength, fishplates may also require bending slightly to suit.

81 Outer and inner rails need to be clearly marked as they will have different radii.

Speed and minimum curve radius

82 The speed and curve radius combinations set out in Table 1 overleaf may be used as a quick guide. The values in this table have been derived by experience of satisfactory operation of trains on curves over many years. Table 1 assumes the curve has the required amount of super-elevation in each case.

Table 1 Table of speed versus minimum curve radius

Speed around curve in km/hour	Minimum curve radius in m
8.0	40
up to 16.0	70
up to 22.5	100
up to 32.0	140

Super-elevation (cant)

83 The centrifugal (radially outwards) force, created as a vehicle travels at speed round a curve, significantly adds to the lateral pressure between the gauge face of the outer railhead and the wheel flange. This increases the tendency for flange climbing and derailment. It also increases the strain on rail fixings and can cause the track to move. Other effects are that loads tend to move outwards and passengers feel uncomfortable.

84 The effects of centrifugal force can be reduced by raising the outer rail on a curve relative to the inner rail. This is known as super-elevation or cant. The amount of super-elevation required to counteract the centrifugal force is easily calculated. The centrifugal force is completely neutralised when the outer rail is raised above the inner rail by an amount that, for a given speed and radius, results in an equal weight distribution on both the outer and inner rails (see Figure 17). However, there is a limit to the amount of super-elevation that can be safely applied (see paragraph 88).

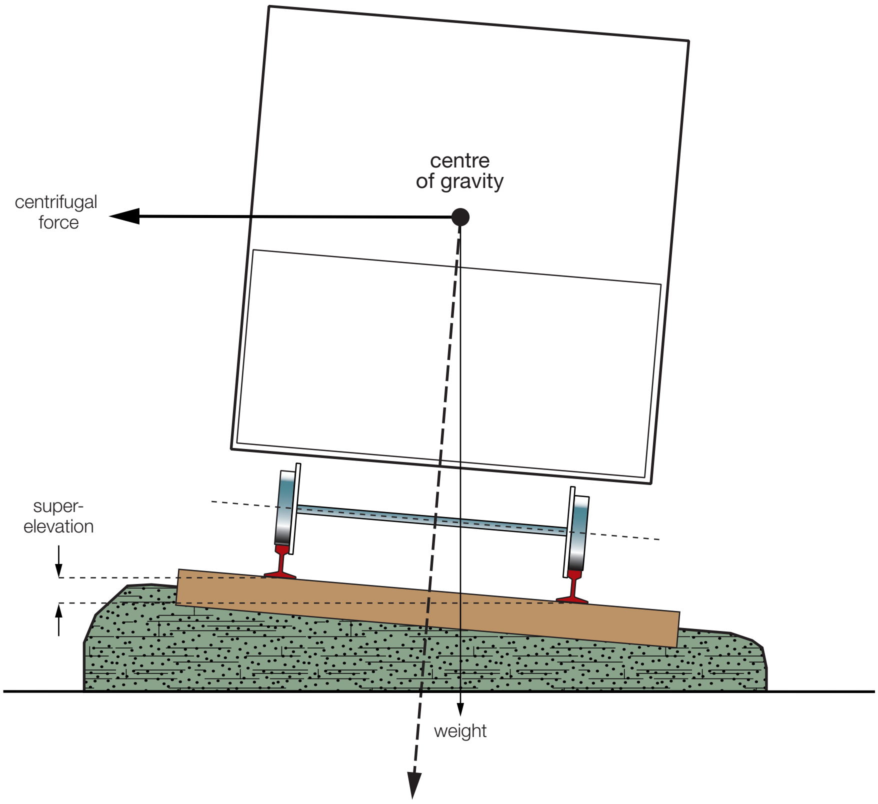


Figure 17 Super-elevation to neutralise centrifugal force on a curve

85 For curve radii less than 40 m, a speed limit not exceeding 8 km/hour should be imposed. At this speed, super-elevation is not required.

Calculating super-elevation

86 The amount of super-elevation required to neutralise the centrifugal force can be calculated using the formula:
where:

$$E = \frac{7.87v^2G}{R}$$

v is the speed in km/hour;
E is the super-elevation in mm;
G is the track gauge in m; and
R is the centre line radius of the curve in m.

87 If vehicles use the curve at slower speeds than that used in the formula, the effect of super-elevation will be to increase the weight on the inner rail and reduce the weight on the outer rail. This reduction in weight on the outer rail increases the potential for flange climbing, and so increases the tendency to derailment. The formula in paragraph 86 gives the amount of super-elevation required to neutralise the centrifugal forces at full speed. In practice, 75% of this value is adequate and makes some allowance for slower traffic.

Maximum permitted value of super-elevation

88 There is an upper limit to the amount of super-elevation that can be safely applied in practice, which is not taken into account in the theoretical calculation in paragraph 86. The maximum permissible value of super-elevation that can be safely applied is approximated by the formula:

$$E_{max} = 0.1\,G + 5.7$$

where:
G is the track gauge in mm and E is the super-elevation in mm.

Limiting speed

89 Floor movement in mines often makes it difficult to maintain super-elevation to the value determined using the formulae in paragraphs 86 and 88. Consequently, the speed of travel round a curve needs to be reduced to that which is commensurate with the track standard that can be reliably maintained.

90 If adequate super-elevation cannot be provided to the outside rail, then a reduced speed should be set for the curve, and a check rail fitted to the inside rail for the length of the curve.

91 Speed restrictions may also be necessary over turnouts, because the curved track cannot normally be super-elevated.

Vertical transitions into super-elevated curves

92 Where a curve is super-elevated, a suitable transition is required from level track to cross-tilted track. The rate of change of cross tilt should be gradual, to avoid weight being suddenly taken off any one wheel. The required transition length can be determined on the basis of 1 mm increase in super-elevation in 360 mm of length. The rate of change of cross tilt is referred to as the ‘cant gradient’, ie 1 in 360.

93 If a transition curve is used (see paragraphs 111-115), the gradual change from level track to the required super-elevation should take place over the length of the transition curve. If a transition curve is not used, then the build-up of super-elevation should be on the straight section of track before entering the circular curve.

Negative cant on rope-haulage systems

94 On rope-haulage systems that have to negotiate curves, it may be necessary to provide some negative cant to counteract the rope pull towards the inside of a curve, ie the outer rail will be lower than the inner rail.

Check rails on curves

95 A vehicle travelling round a curve relies on the leading outer wheel to guide it round the curve. This wheel has a tendency to climb the rail in its effort to go in a straight line, which is countered only by the weight on the outer wheel. A check rail fitted to the inside of the inner rail can assist in guiding a vehicle round a curve, by allowing the inside face of the leading inner wheel to bear against it at the same time as the outer wheel flange bears against the outer rail (see Figure 18). Since the back face of the inner wheel is vertical, it provides more resistance to derailing than the sloping outer face of the outer wheel flange.

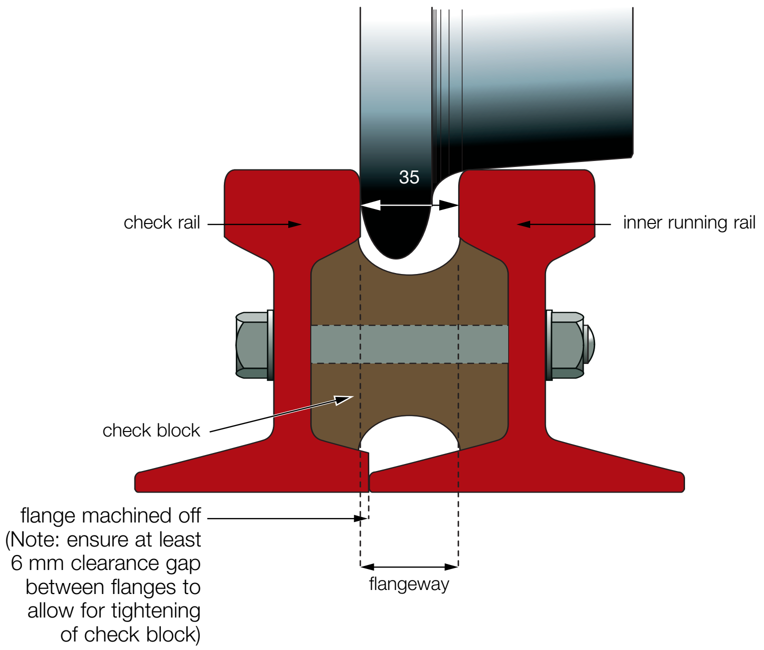


Figure 18 Fitting a check rail

96 Check rails should be provided over the full curve length as follows:

- when the curve radius is close to the calculated minimum;
- when the curve radius is satisfactory, but adequate super-elevation cannot be provided;
- on turnout curves, because the outer curve rail does not provide a continuous guiding face at the crossing nose.

97 Check rails are essential on curves that are to be negotiated at speeds over 16 km/hour, and on curved declines. Most other curves in underground mine rail track systems would also benefit from the additional protection of a check rail.

98 Check rails should be specified during the manufacture of a curve because it is often difficult to retrofit them.

99 The gap between the check rail and the running rail is called the flangeway. To give adequate clearance for the wheel flanges of vehicles typically used underground in mines, this should not be less than 35 mm (see Figure 18).

100 The check rail foot may need machining to achieve the required flangeway clearance dimension shown in Figure 18.

101 When using baseplated timber sleepers, check rails need special baseplates.

102 On rope-haulage systems that negotiate curves, it may be necessary to provide a check rail on the inside of the outer rail to counteract the rope pull towards the inside of the curve.

Gauge widening on curves

103 When a curve radius is near to the calculated minimum, the track gauge will need to be widened. If the gauge is not widened, vehicle wheels may bind on the rails, leading to flange climbing and derailment.

104 The amount by which the gauge on a curve needs to be widened can be approximated from the following formula:

$$W = \frac{72}{R}$$

where:
W is the amount in mm by which the curve should be widened; and
R is the track curve centre line radius in m.

105 A gauge widening of 12 mm is sufficient in most cases.

106 The calculated gauge widening should be built up progressively from the standard gauge. For all practical purposes, gauge-widened sleepers can be applied in 4 mm increments (see paragraphs 256-258). Any gauge-widened sleepers should be clearly identified to prevent them being used in straight track.

107 On curves greater than 30 m radius, the calculated requirement for gauge widening is minimal and can be neglected.

108 Gauge widening may be needed on the curve section of turnouts. The amount of widening can be calculated using the formula in paragraph 104.

Curves with gauge widening and check rails

109 When a curve includes gauge widening and a check rail, the check rail flangeway clearance needs to be increased by the same increment as the gauge widening, to prevent the inner wheels from binding between the running rail and the check rail (see Figure 19).

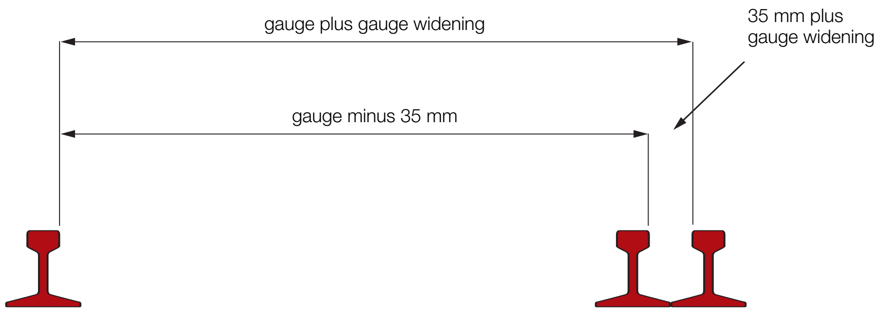


Figure 19 Increased flangeway clearance on a curved track with gauge widening and a check rail

Gauge ties

110 Gauge ties should be fitted on curves where simple rail fixings are used, such as dog spikes. This is because lateral forces may loosen fixings and allow the rails to spread. Additional gauge ties are not needed on curves when fixed gauge sleepers are used, such as baseplated timber sleepers, or steel sleepers with rail foot abutments.

Gradual transitions into curves

111 A simple curve is one in which two straight sections of track are joined by a circular curved section having a constant radius. A transition curve is one in which the curve radius gradually changes from a large radius down to the required circular curve radius.

112 Transition curves may be added at one or both ends of a simple curve, to ease the passage of vehicles into and out of the curve. In practice, transition curves are not generally used below ground in mines, because operating speeds on curves are fairly slow. However, the provision of transition curves should be considered at vehicle speeds of 8 km/hour and above because they can significantly improve safety and ride comfort.

113 When setting out a transition curve that is to be inserted between straight track and a circular curve of fixed radius, the tangent point of the straight track and the circular curve needs to be offset as shown in Figure 20. This offset is known as the shift *S* and is the amount that the curve radius centre has to be adjusted to allow the circular curve centre line to merge with the transition curve centre line.

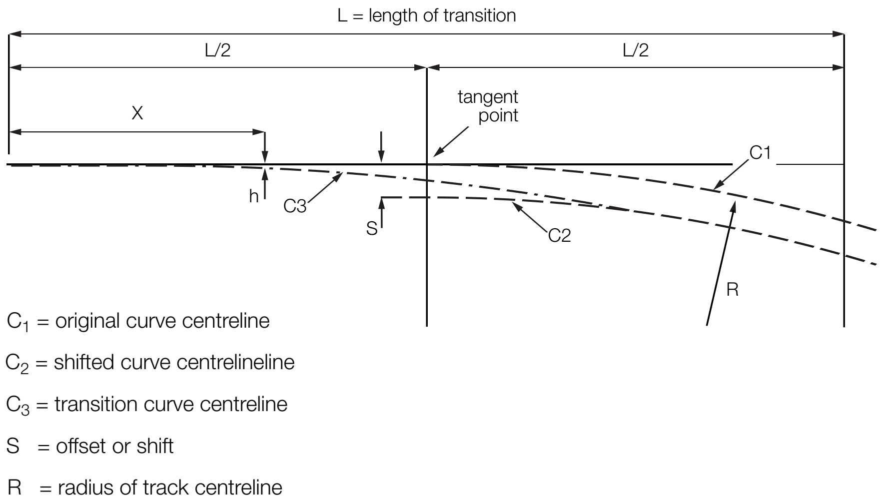


Figure 20 Offsets for transitional curves

114 The provision of transition curves is normally coincident with the requirement for super-elevation. Consequently, the length *L* of a transition curve is determined on the basis of 1 mm increase in super-elevation in 360 mm of rail length (see paragraphs 92 and 93).

115 From the length of the transition *L*, determined as above, the shift *S* and the offsets *h* at distances *x* from the start of the transition curve may be calculated using the following formulae:

$$h = \frac{X^3}{6LR}$$

and

$$S = \frac{L^2}{24R}$$

where:
R is the radius of the circular curve; and
h is the offset for any selected distance *x* from the beginning of the curve.
All dimensions in the formulae are in metres.

Reverse curves

116 A reverse curve is formed where one curve runs into another curve of the opposite hand, and is commonly a feature of passbye turnouts.

117 Where vehicles have to negotiate reverse curves, a length of straight track should be placed between the two curves. The straight section should be long enough to:

- accommodate the longest wheelbase of a vehicle or bogie;
- prevent vehicles on each half of the reverse curve having end throws to opposite sides, which either exceed the limits of free travel of the couplings or result in the couplings misaligning.

118 Where the centre line distance between two parallel tracks is limited, the turnout radius will need to be as large as practicable to allow a section of straight track to be inserted. This will result in an increase in the overall turnout length (see Figure 21).

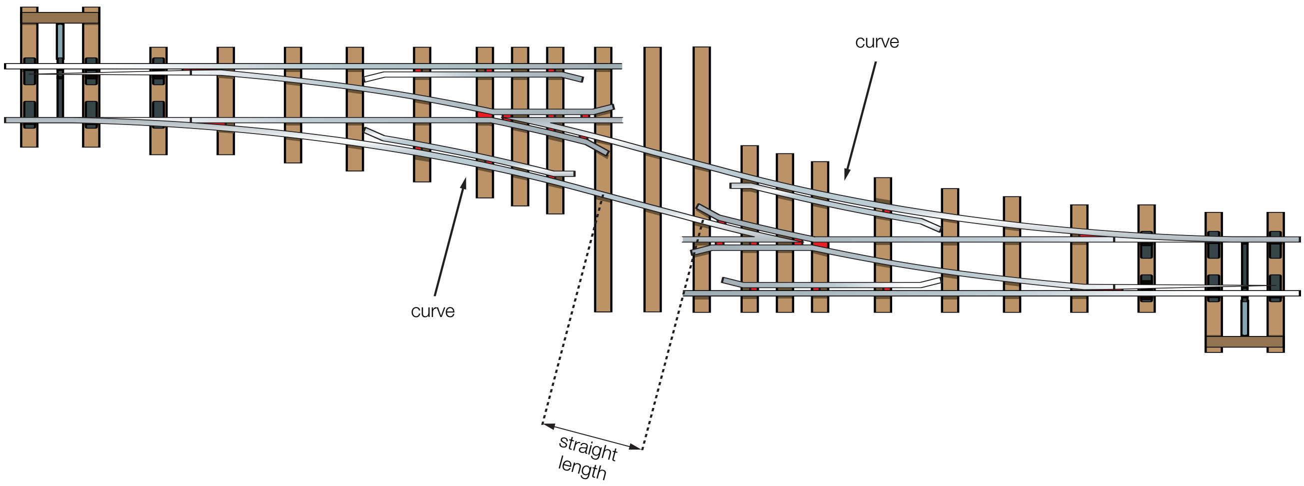


Figure 21 Reverse curves

Clearances on curves

Horizontal curves

119 The effects of vehicle end throw on the outside of a curve and centre throw on the inside of a curve should be taken into account when laying out the trackwork, particularly at roadway junctions or where double track is installed. The end throw and centre throw also need to be taken into account when determining operating clearances.

120 The end throw and centre throw of vehicles on a curve can be determined by the following formulae (see Figure 22):

centre throw (m): $$C = \frac{B^2}{8R}$$

end throw (m): $$E = \frac{L^2 - B^2}{8R}$$

where:
R is the centre line radius of curve in m;
L is the vehicle length in m; and
B is the wheelbase in m.

121 If loads carried on the vehicle are likely to overhang the vehicle length or width, then the dimensions C, E and L in Figure 22 should refer to the load and not to the vehicle.

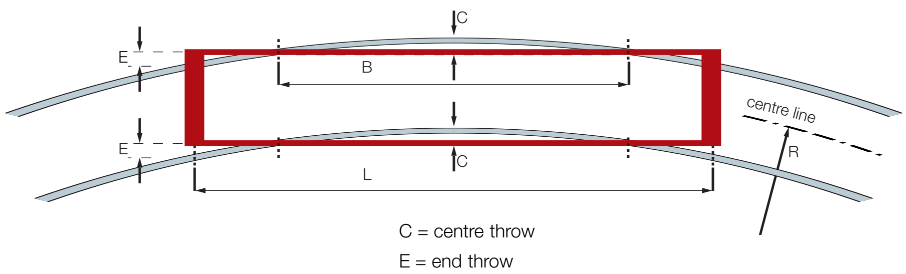


Figure 22 End throw and centre throw

Vertical curves

122 It is necessary to install vertical curves in rail track at places where there is an abrupt change of roadway gradient. The minimum vertical curve radius that a vehicle can safely negotiate should be sought from the vehicle manufacturer. Alternatively, the minimum radius may be calculated using one of the following formulae (paragraphs 124-126). The first formula is for a vehicle having symmetrical ends, ie the same length of overhang from a central wheelbase and same ground clearances at each end, such as might be found on a double-ended locomotive. The second formula is for a vehicle having non-symmetrical ends, such as those on a single-ended locomotive, where the overhang and ground clearance on one end are significantly different from the other end.

123 The critical point to identify on all vehicles is that which would first make contact on a vertical curve. This depends on two factors, the distance the point overhangs from the wheels and the ground clearance at that point. In most cases, the critical point will be either on the underside of the vehicle at one end of the mainframe, or at the underside of a coupling.

124 For a symmetrical vehicle, see Figure 23(a). The formula is:

$$R = \frac{L^2 - B^2}{8(x - y)}$$

where:
R is the radius of vertical curve in m;
L is the length in m between the points at each end of the vehicle that would make contact on a vertical curve first;
B is the vehicle wheelbase in m;
x is the clearance in m above rail of the lowest points when standing on level track;
y is the clearance in m above rail of the lowest points when standing on the vertical curve. This is a pre-specified minimum desired value to be selected by the user. Some allowance should also be made for permissible wear on tyres and suspension, permissible coupling droop, likely ground movement etc.

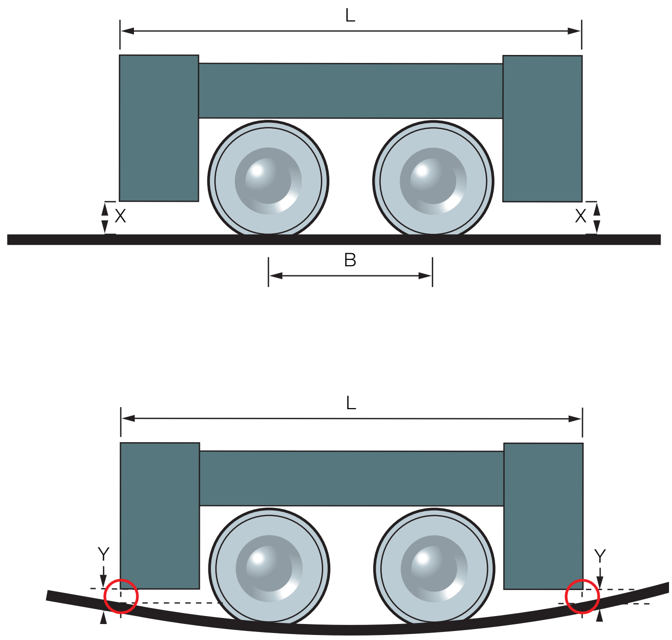


Figure 23(a) Symmetrical vehicle

125 For a non-symmetrical vehicle, see Figure 23(b). The formula is:
where:

$$R = \frac{T^2 + BT}{2(x - y)}$$

T is the overhang in m measured from the wheel centre, to the part of the vehicle that would make contact on a vertical curve first. *B, R, x* and *y* are as described in paragraph 124.

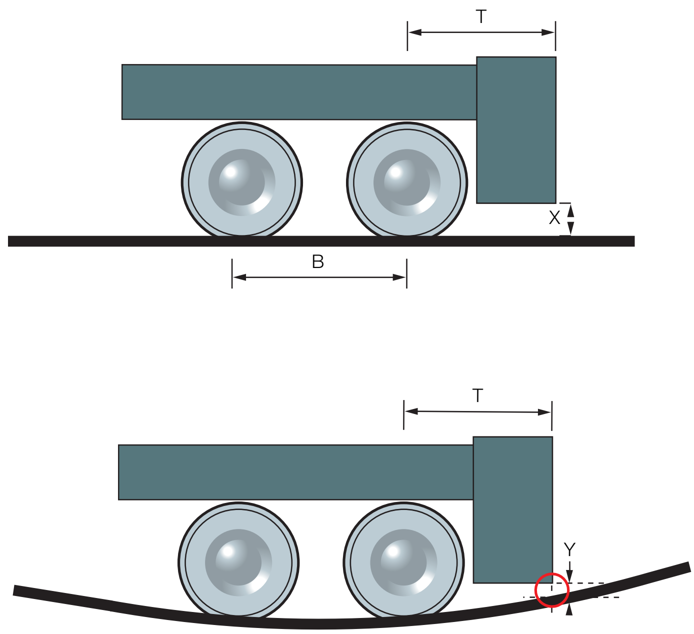


Figure 23(b) Non-symmetrical vehicle

126 Using Figure 23(c), the length and height of the curved rail may be calculated from the following formulae:

$$A = \frac{\pi R}{180} \times C$$

$$B = \frac{A^2}{2R}$$

where:
A is the length of the vertical curve in m;
B is the vertical height of the curve in m; and
C is the angular change of grade in degrees.

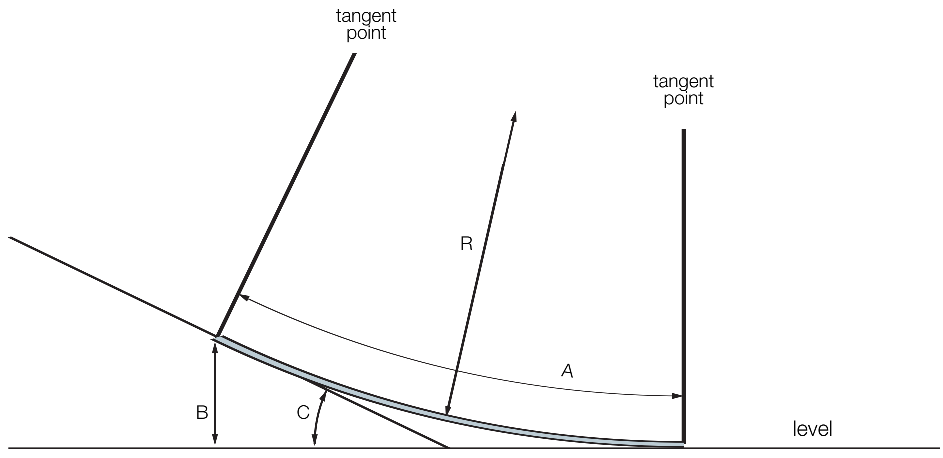


Figure 23(c) Vertical curves at significant changes of grade

127 A vertical curve causes a vehicle to change direction and imposes additional forces on the track. These forces may be increased by the application of heavy braking. Therefore, particular attention should be given to the design, construction and maintenance of track and its foundations at vertical curves.

128 Where necessary, drainage should be provided at the lowest point on a vertical curve to prevent it becoming a natural collecting point for water, which could result in the track's foundations softening.

Turnouts and crossings

129 A turnout is used to transfer vehicles from one track to another track. It has three principal features:

- a switch (set of points) that divert the vehicle towards the chosen track;
- a crossing that allows a vehicle's flanged wheels to cross the path of the other track without loss of guidance; and
- a curve that provides the required change of direction.

130 Figure 24 identifies the railway terms used to describe the individual parts of a turnout.

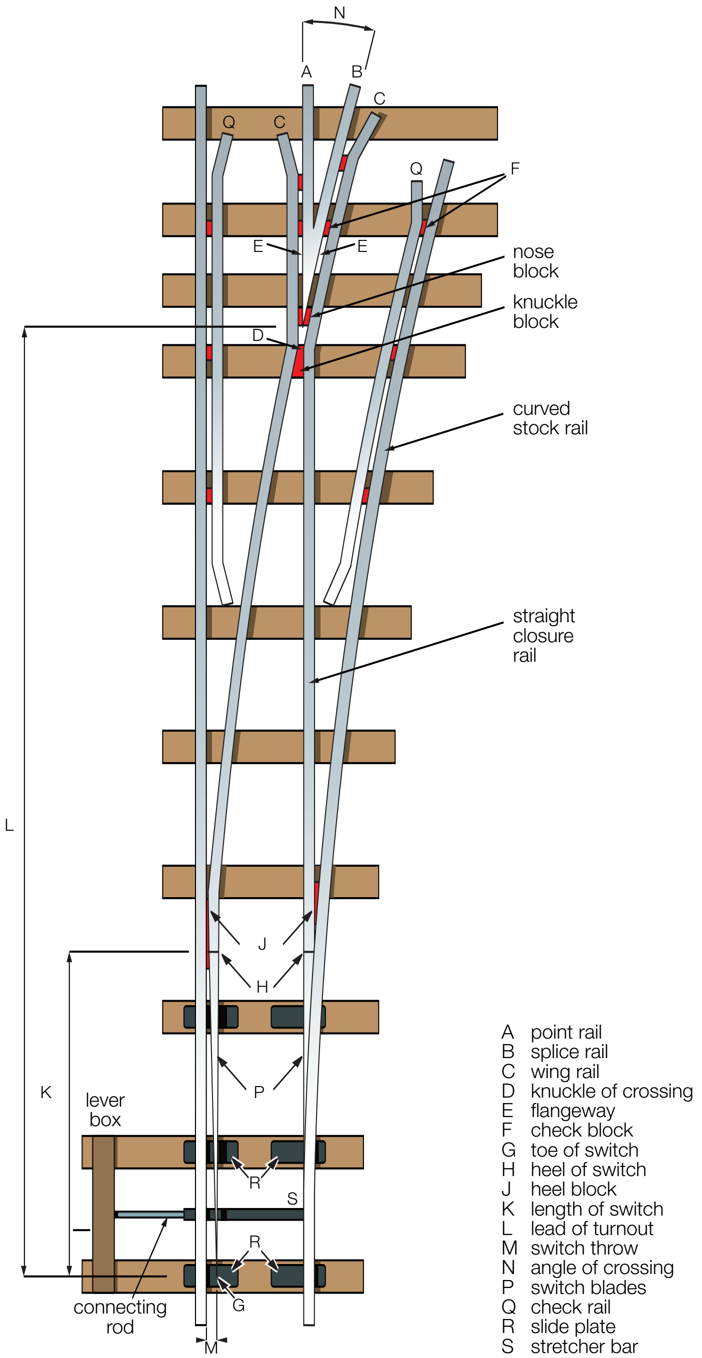


Figure 24 Components of a turnout

131 If the tracks converge in the direction of travel then the turnout is being approached in the 'trailing' direction. If the tracks diverge in the direction of travel then it is being approached in the 'facing' direction. A turnout may be described as a facing turnout or a trailing turnout if the majority of traffic approaches it from that direction.

132 Turnout rails will be subject to abnormal wear and should always be made from new rail, not worn rail.

133 Where turnouts have to be manufactured in sections for ease of transportation underground, the joints should be staggered to reduce flexing of the assembly in service.

Switches

134 There are two types of switches in general use, the loose heel type and the flexible blade type. The loose heel switch is most commonly associated with small radius turnouts and slow-speed operations. The flexible switch is usually associated with larger radius turnouts and high-speed operations.

Loose heel switches

135 The loose heel switch pivots about loosely hinged joints. Each joint is supported by a specially shaped heel block and a cranked fishplate (see Figure 25). Switches that are pivoted about a pair of standard fishplates with no heel blocks should not be used, because this reduces joint stability.

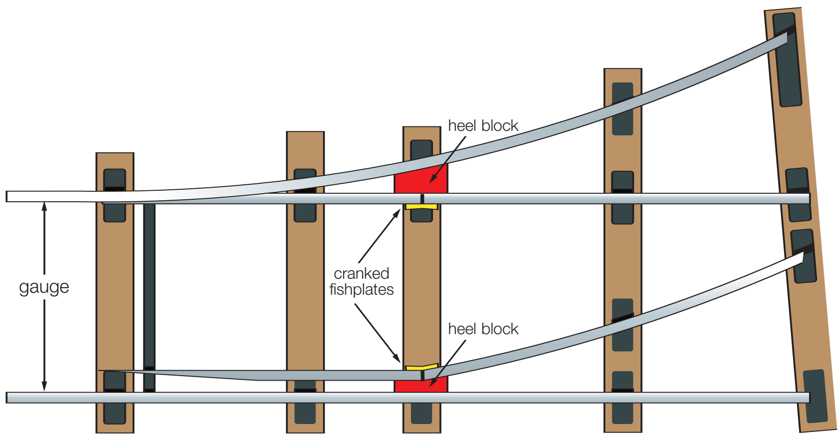


Figure 25 Loose heel switch

136 A loose heel switch can open inadvertently when a vehicle passes over in the facing direction of travel. This is caused by the guiding wheel on the leading axle passing over the hinged joint and giving it a 'kick', which opens the switch slightly, allowing the guiding wheel on the following axle to 'split the points'. To counteract this effect, switch blades should be longer than the longest wheelbase of any vehicle using the track.

137 A curved switch blade will give a smoother entry into the turnout. For smaller radius turnouts, say less than 8 m, there may be a problem in achieving a curved switch blade longer than the longest wheelbase, because of insufficient length in front of the crossing vee. In this case, straight switch blades of a suitable length are used, and the curve starts at the switch heel.

138 Loose heel switch blades should be properly supported to prevent rocking movement when a vehicle passes over them. Each switch blade should be supported by at least two steel slideplates, one supporting the toe and one supporting the heel. The slideplates also allow for free sliding and the addition of lubrication to ease switch change movement, and prevent the switch blades from being pressed into timber sleepers under load. Where more than two slideplates are fitted to support a switch blade, they will need to be carefully installed so that they all maintain uniform contact with the underside of the blade.

Flexible switches

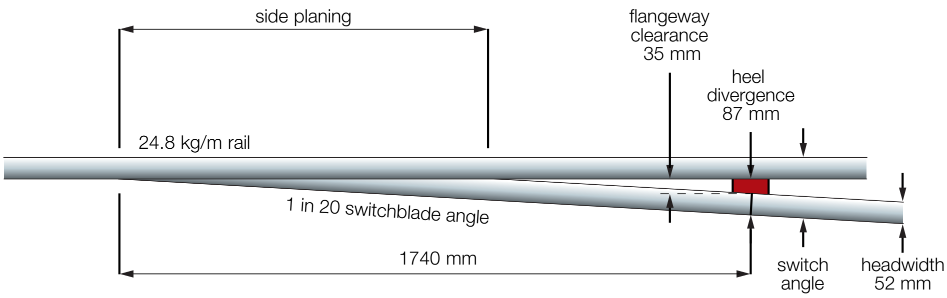
139 Switches on track used for high-speed operations are designed so that the blades are fixed at the heels and flex as they move from side to side. For this reason, they are called flexible switches (see Figure 26).

Figure 26 Flexible switch

140 Flexible switches are generally much longer than loose heel types and are fixed nearer to the crossing vee. The outer blade forms part of the curve, giving a smoother transition into the turnout, and the design minimises the risk of inadvertent switch blade movement. On turnouts below 15 m radius, it may be necessary to remove a section of the bottom flange, otherwise the blade may be too stiff for the operating mechanism to 'flex' it. Removing part of the bottom flange weakens the rail and localises rail bending to the relieved section. These factors may limit the turnout's suitability for carrying high-speed or heavy-load traffic, even in the straight-through direction, unless sleeper spacing and slideplate support adequately compensate for the reduction in rail strength.

Switch angle and switch length

141 The switch provides the initial transition into a turnout and, to minimise the reaction forces on the trackwork from locomotives and heavily loaded vehicles, the change of direction needs to be as gradual as possible. The switch angle is normally expressed as a rate of divergence 1 in M, where M is equal to the switch length divided by the heel divergence (rail width + 35 mm flangeway clearance). Figure 27 shows that, for a switch angle of 1 in 20, with 50 'O' rail, the resulting switch length is 1740 mm. Shortening the switch length increases the switch angle, increasing the switch length reduces the switch angle. Ideally, the switch angle should be limited to a maximum of 1 in 10. For heavy traffic, or high speeds in excess of 16 km/hour, the switch angle should not be greater than 1 in 20.



for this example, switch angle = 1 in M, where $M = \frac{1740}{(35 + 52)} = 20$

Figure 27 Switch angle and switch length

Side planing

142 Side planing is a term used to describe an arrangement where the side of the switch blade is cut away to allow it to fit closely up to the stock rail. The length of side planing depends on the switch angle and will be determined by the manufacturer (see Figure 27).

Notching and chamfering

143 The switch blade toe has to fit closely to the head of the stock rail, to make a smooth passage for a wheel as it travels in the facing direction from the stock rail onto the switch. However, for the switch blade to have sufficient strength to cope with its expected usage, it has to retain a definite thickness of metal at its tapered end. This is typically 3 to 6 mm. Consequently, this blunt toe end of the switch blade needs to be protected from impact with wheel flanges, which will eventually cause toe damage and could lead to vehicle wheels splitting the points, and derailment.

144 On loose heel switches, a notch is sometimes machined into the head of the stock rail to allow the switch toe to fit flush with the running edge of the stock rail (see Figure 28). However, there is a risk that a wheel may strike the notch when travelling in the trailing direction, and toe protection by notching is only suitable for slower-speed systems. A preferred alternative is to chamfer into the underside of the stock-rail head as shown in Figure 29.

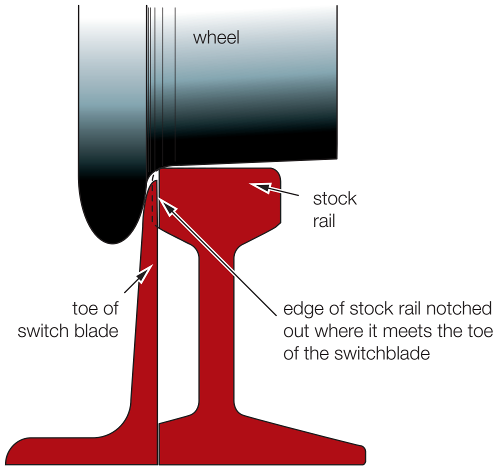


Figure 28 Notched stock rail

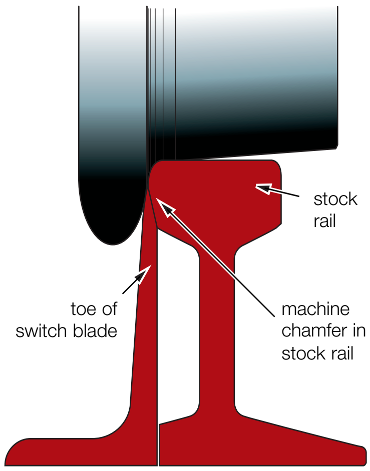


Figure 29 Chamfered stock rail

Top planing

145 On all flexible switches and good quality loose heel switches, the top of the switch blade is chamfered towards the toe. This is called top planing. Its purpose is to ensure that the wheel running surface does not come into contact with the switch blade running surface until it is some distance along the blade, typically about 300 to 400 mm (see Figure 30).

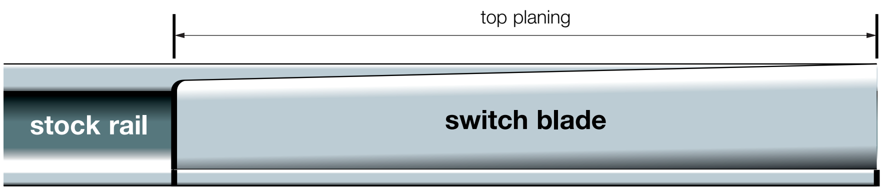


Figure 30 Top planing

Trailing a switch

146 The terms 'trailing a switch' and 'trailing the points' are used to describe the action of allowing the locomotive wheels to force the switch blades over when travelling through a turnout in the trailing direction, rather than operating the switch changeover mechanism. Where trailing a switch is a planned activity, the turnout should be specifically designed for that purpose. If the switch is not designed to be trailed, then this practice should be prohibited. This is because it can result in an immediate derailment, or affect the adjustment of the switch changeover mechanism and cause a derailment in subsequent use.

Crossings

Parts of a crossing

147 A crossing is an essential part of a turnout. It can also be used alone, where one track crosses another but it is not required to divert a vehicle from the original track. Figure 31(a) shows a crossing that forms part of a turnout. Figure 31(b) shows a crossing where two tracks cross, known as a 'diamond crossing'.

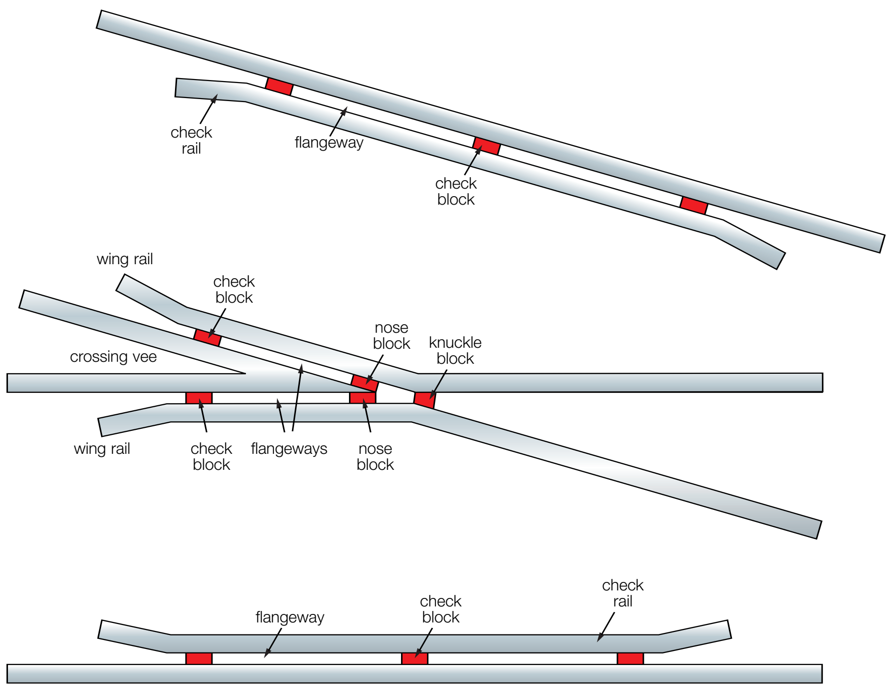


Figure 31(a) Build-up of a turnout crossing

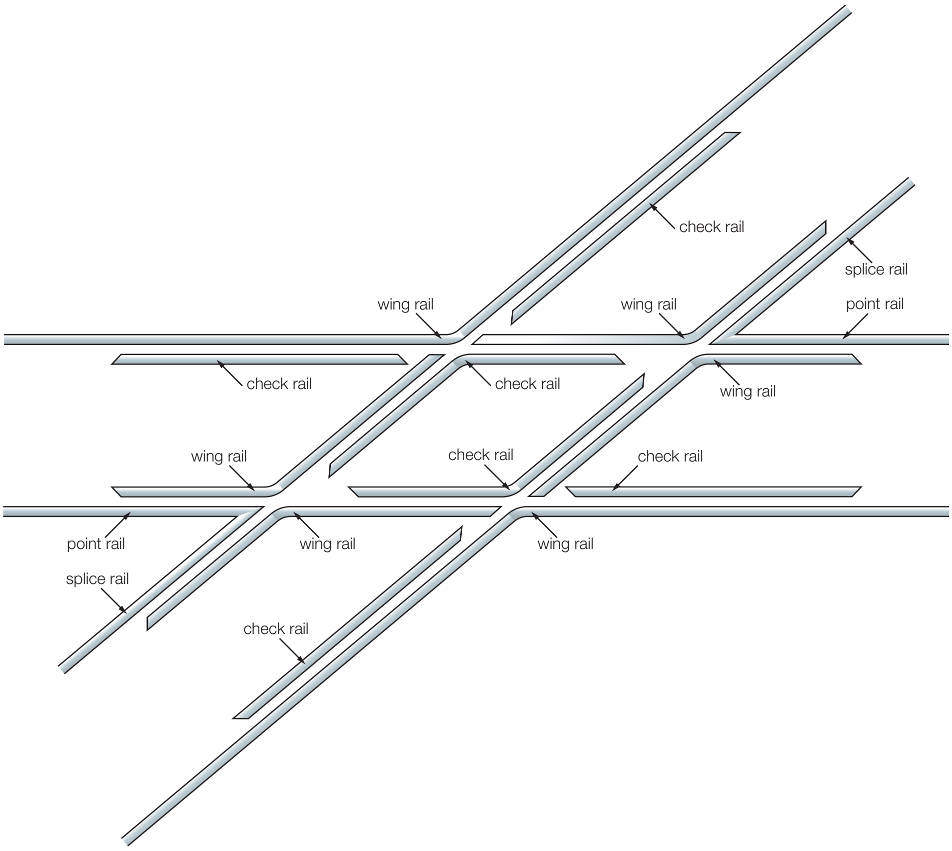


Figure 31(b) Diamond crossing

Turnout crossing angle

148 The turnout crossing angle *'N'* is the angle between the two rails forming the crossing vee and is normally quoted as a rate of divergence, ie 1 in *N*, where *N* is equal to the distance along the crossing centre line divided by the distance across the rails at that point (see Figure 32). The crossing angle can vary considerably depending upon the circumstances. For example, some light-duty transport systems may be able to tolerate turnouts having crossing angles as great as 1 in 2, whereas a crossing angle of 1 in 10 would be more appropriate for systems operating at higher speeds.

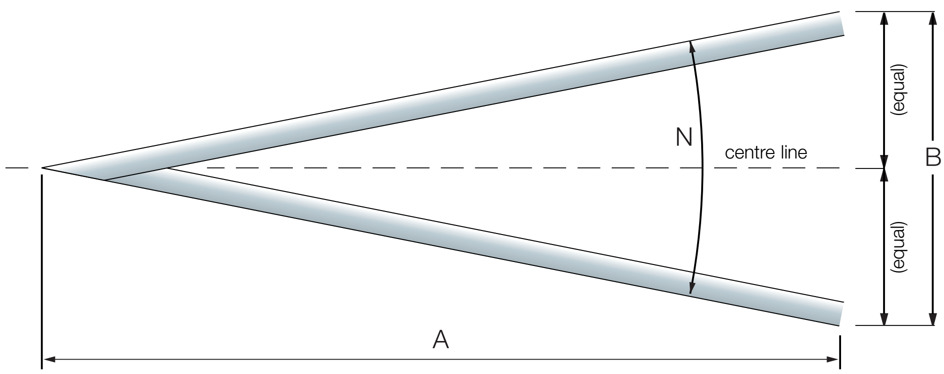


Figure 32 Crossing angle

Crossing vee
149 A crossing vee consists of a point rail and a splice rail; both accurately machined and securely fastened together with high-tensile lock bolts. Cast manganese vees are alternatives if wear is a problem, but generally the fabricated crossing has proven adequate for mining service, even for high-speed systems.

150 The point of intersection of the two rails making up the crossing vee forms the theoretical crossing nose. For practical reasons, the actual crossing nose does not run to a fine point but remains blunt, approximately 10 mm wide. Thus, the actual nose is 10 mm x crossing angle *N* behind the theoretical nose (see Figure 33).

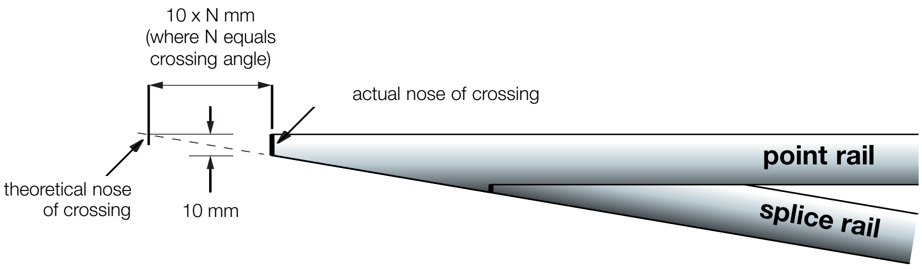


Figure 33 Enlarged view of nose

Spacer blocks
151 Spacer blocks are used to fasten two rails side by side with a gap between them sufficient for wheel flanges to pass through. A crossing vee is attached to the wing rails by spacers known as check blocks, the nose of the vee is held secure by spacers known as nose blocks, and the wing rails are joined in front of the crossing vee by a knuckle block. These items are identified in Figure 31(a) relating to a turnout crossing.

152 The crossing assembly may become loose during service unless suitable spacer blocks are used. For heavily used crossings and crossings in high-speed systems, cast iron spacer blocks, accurately ground to fit into the rail fishing surfaces and secured by high-tensile locking bolts, are generally used to attach the wing rails and locate the crossing vee. The spacer blocks may be bedded in filler resin during assembly to improve the 'fit' and further safeguard against loosening. For lightly used crossings, mild steel flame-cut blocks are sometimes used. However, these still need accurate fitting to avoid loosening and increased maintenance. Simple substitutes, such as tubular spacers, may quickly deform in use leading to loosening of the crossing and wing rail assembly, and should be avoided.

Geometry of a turnout

153 An understanding of the geometry of a simple turnout will assist in selecting the safest and most efficient turnout for a given location and the intended traffic. Figure 34 shows the principal features of a simple turnout. The switch angle and switch length are dealt with in paragraph 141. This leaves three principal variables in the geometry of a turnout:

- the radius of the turnout curve;
- the crossing angle; and
- the overall turnout length.

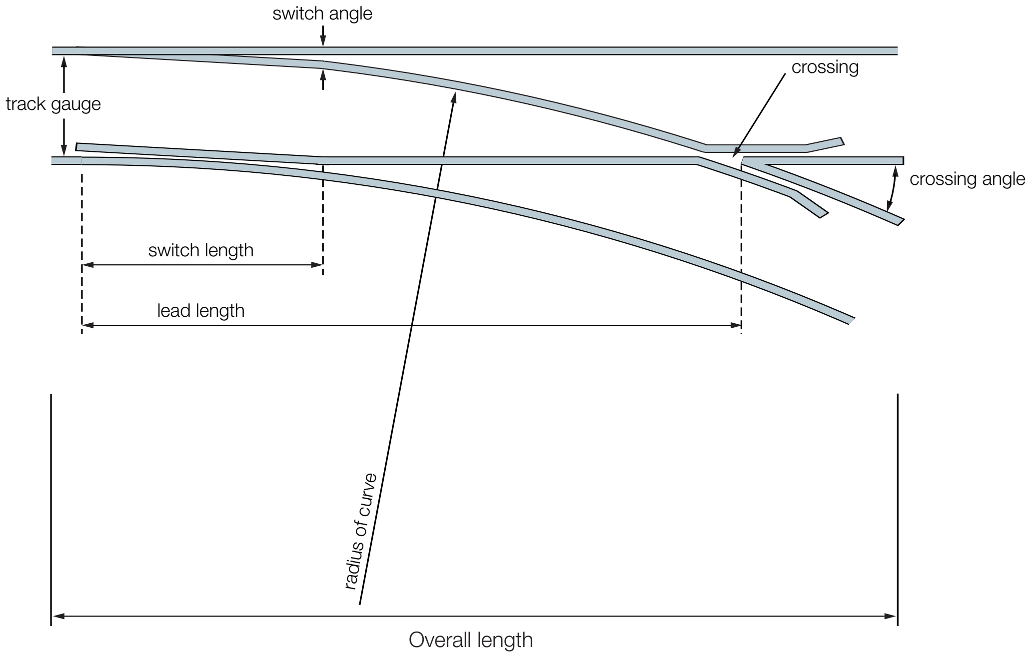


Figure 34 Principal features of a simple turnout

154 The distance between the actual crossing nose and the switch toe is known as the lead length. The lead length is variable and will determine the overall turnout length. For minimum lead length at a given radius, the switch toe and the crossing nose are tangent points, marked 'A' and 'B' in Figure 35(a), connected by a true circular curve.

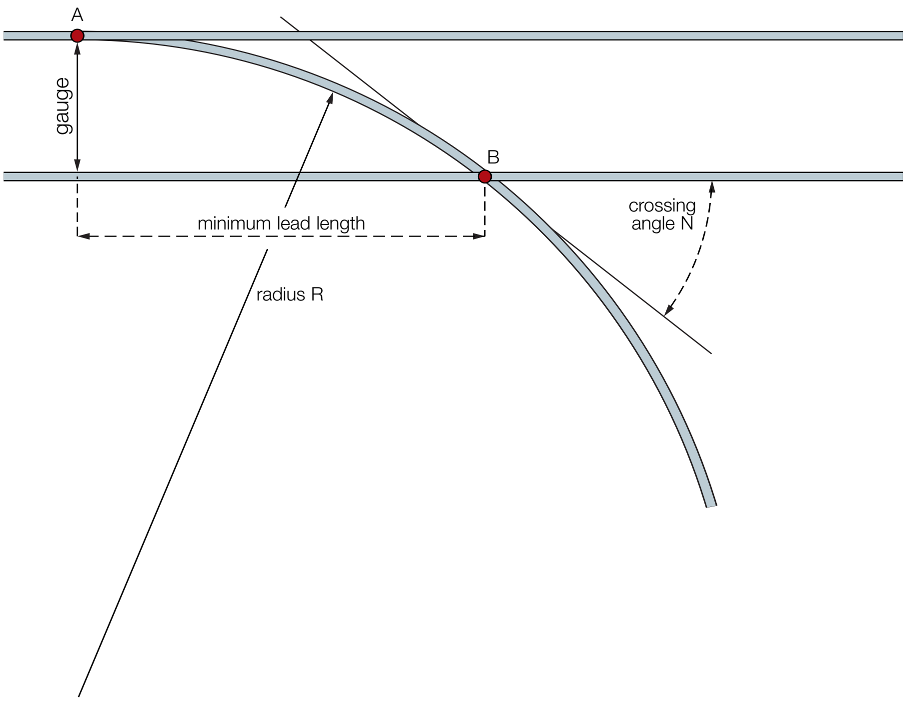


Figure 35(a) Geometry of a simple turnout

155 For this simple turnout, where the tangent points of the true curve are at the switch toe and crossing nose, the relationship between the crossing angle and the radius of the turnout is given by the following equation:

$$N = \sqrt{\frac{R}{2G}}$$

where:
N is the turnout crossing angle (see paragraph 148);
R is the outer turnout rail radius in m; and
G is the rail gauge in m.

156 A turnout should be designed to give the maximum radius practically achievable at its location, to ensure the smoothest transition possible from one track to another. Figure 35(b) shows the benefits of increasing the radius, ie a smoother transition and reduced crossing angle. The effect will be to reduce the lateral forces on the turnout, which in turn will reduce the likelihood of derailment and reduce wear and tear. The only disadvantage is the slightly longer lead length, which increases the overall turnout length.

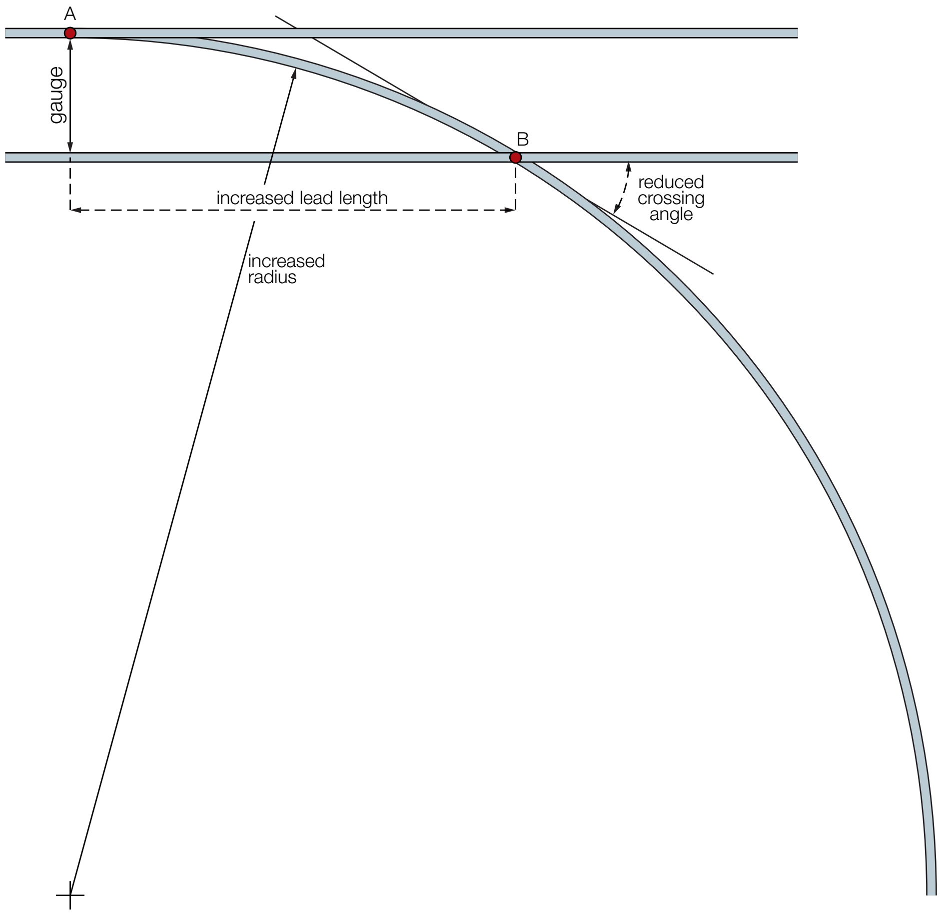


Figure 35(b) Geometry of a simple turnout

157 The crossing angle can also be reduced significantly, by moving the tangent point to 'B1', with straight track between 'B1' and the new crossing nose at 'B2' (see Figure 35(c)). This is sometimes necessary where reverse curves feature, as in passbye turnouts (see paragraphs 116-118).

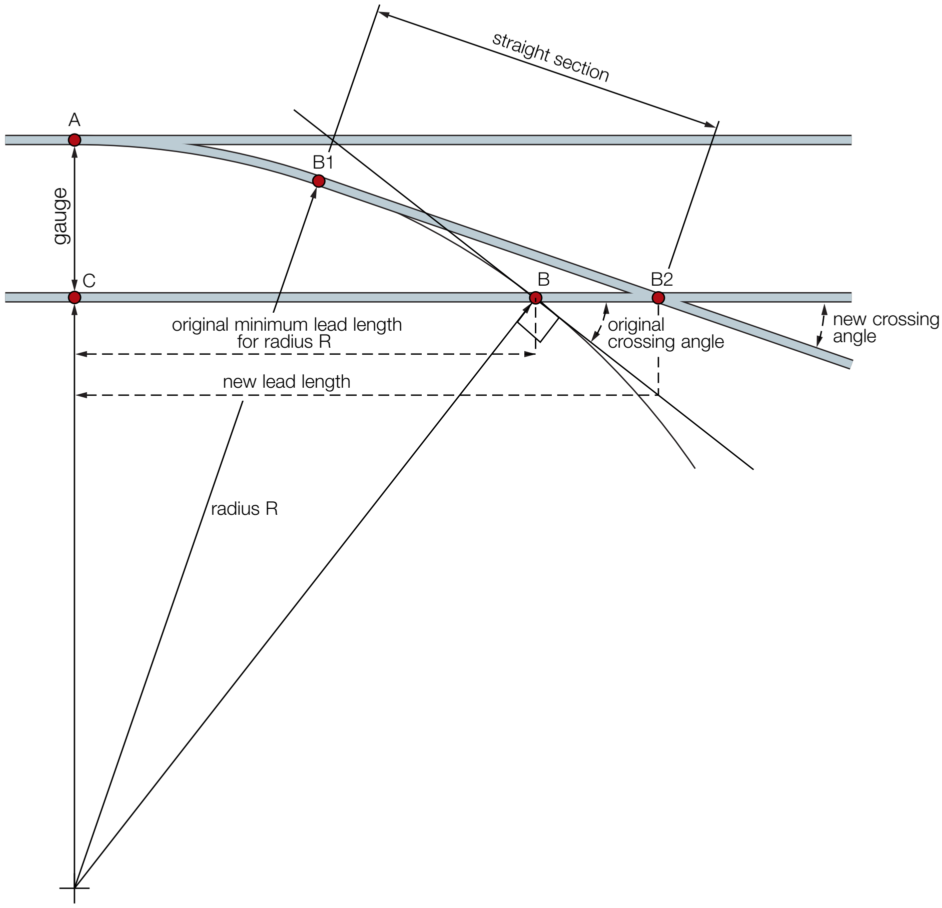


Figure 35(c) Geometry of a simple turnout

Check rails on crossings

158 At a crossing, the running rail is not continuous and an unguided wheel could enter the gap instead of crossing it, and strike the crossing nose. This is avoided by fitting a check rail to each stock rail, opposite the crossing vee. The vehicle's wheel is then positively restrained from entering the gap by the back face of the opposite wheel on the axle as it bears against the check rail (see Figure 24 item Q and Figure 31(a)).

159 The start position of a check rail should be such that it already controls the wheel well before the opposite wheel approaches the crossing. Check rails should also be longer than the longest wheelbase of any vehicle, or bogie, running over the crossing.

160 Check rails should be flared out at each end to ensure that wheel flanges are guided into the flangeway. This can be achieved either by bending the check rail ends or by machining tapers on the check rail ends.

161 Check rails also need to be secured by suitable spacer blocks (see paragraphs 151 and 152).

Flangeway clearance

162 The standard flangeway clearance for track below ground in mines is 35 mm. This includes an allowance for wheel flange thickness plus a margin for clearance.

Effect of gauge widening on flangeway clearance

163 Where gauge widening is required on a curve, the flangeway clearance between the curved stock rail and its check rail needs to be increased by the amount of gauge widening.

Relationship between wheel gauge and track gauge

164 The wheel gauge is the distance between the root of each wheel flange on an axle, sometimes referred to as the wheel 'fitting gauge', and is generally 12 mm less than the track gauge (see Figure 36). The 12 mm running clearance between the wheel gauge and the track gauge, together with the wheel coning, allows the wheels to self-centre and run with minimal flange contact on straight track.

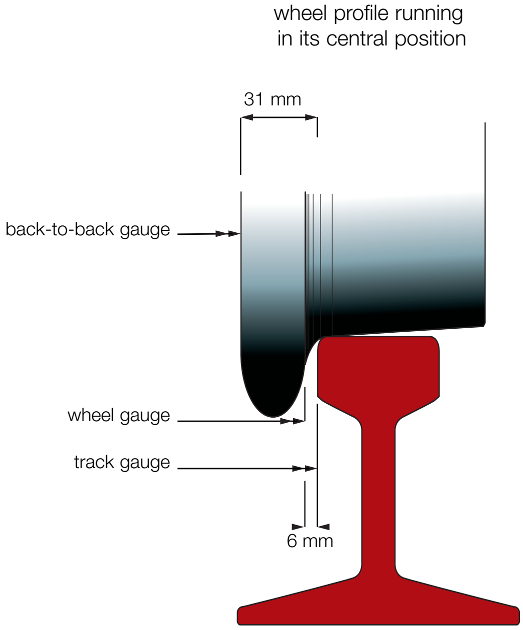


Figure 36 Wheel profile

165 In practice it is difficult to measure wheel gauge, and so the back-to-back dimension, the distance between the flange faces on the inside of an axle, is often measured instead, and a distance added that is equal to twice (once for each wheel) the wheel flange thickness plus the running clearance. As a broad guide, for each wheel, this added distance is 31 mm, which derives from a flange thickness of 25 mm plus 6 mm (half the running clearance). However, flange thicknesses do vary, so the added distance may vary.

166 If the wheel gauge is too small with respect to the track gauge, then at a crossing there is a danger that a wheel will strike a check rail and derail the vehicle. This is because the wing rails form additional check rails and effectively captivate both wheels on an axle.If the wheel gauge is too large, then the running clearance is lost and there is a tendency to flange climbing (see Figure 14).

167 Ideally, all vehicles that run over a turnout should have the same wheel gauge, but in practice this is not always the case. The crossing manufacturer needs to be advised of all variations in wheel gauge of vehicles that will be using the crossing. The manufacturer will then use knowledge and experience to ensure that any variations in wheel gauge, flange thickness, wheel base etc fall within acceptable design tolerances for the crossing.

168 When quoting the required track gauge to a vehicle manufacturer, care is needed, because lack of awareness of the difference between actual track gauge and rationalised track gauge (see paragraph 230 and Table 2) may result in vehicles having smaller than intended wheel gauge.

Stretcher bars and connecting rods

Stretcher bars

169 Switch blades are normally connected together by a stretcher bar, so that both blades move together when the direction of the points is changed. Stretcher bar design varies, but principally it should hold the working switch blade against the stock rail and keep the blade upright. It should also ensure adequate toe opening for clear passage of the wheel flange when in the open position.

170 The simplest form of stretcher bar is a flat steel bar bolted to the bottom flanges of the switch blades. With this type of stretcher bar it is necessary to ensure that bolted connections are kept tight, so that both blades move together and the working switch blade is held firmly closed. A variation on this simple stretcher bar uses brackets that fasten to the rail web. These provide better vertical support to the switch blade, and allow for fine adjustment of the switch setting by the insertion of shims between the web and the bracket (see Figures 37(a) and (b)). Whatever type of stretcher bar is used should be robust enough to prevent bending, which will result in incorrect blade position.

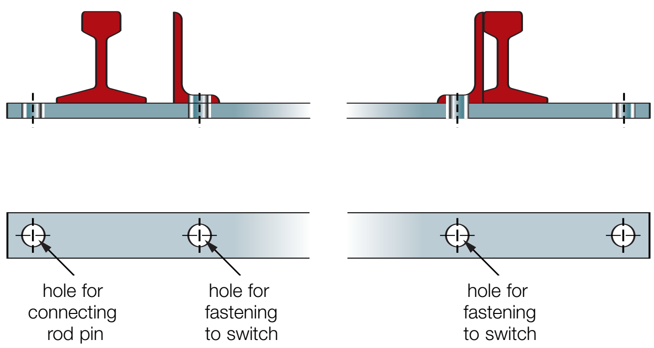


Figure 37(a) Simple stretcher bar

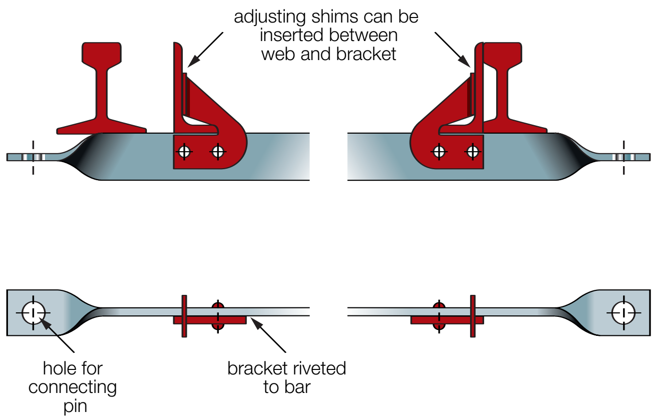


Figure 37(b) Stretcher bar with brackets

171 Where the clamp lock system of holding the blade closed is used, the stretcher bar is not directly attached to the switch blades and the two blades move independently of each other. To give the required switch blade movement when open, and provide positive locking when closed, the system relies on the stretcher bar having correctly located machined notches for the locking arms (see paragraph 191).

Connecting rods

172 Unless a lever box or other operating mechanism is mounted directly to the stock rail, the stretcher bar will be connected to the operating mechanism by an adjustable connecting rod. This gives additional scope for setting up the lever box action without the need to move the lever box mounting position.

Lever boxes

173 Lever boxes should be provided for all manually operated switch blades, except where the lack of lever boxes will not result in significant risk of injury to people operating the switch blades, or derailment of vehicles caused by inadvertently operated switches.

174 Switch blades not having lever box operation should only be used on systems where vehicles and loads are:

- lightweight;
- not mechanically propelled;
- have a low travel speed (eg less than 5 km/hour);
- have low frequency of use; and
- have no risk of inadvertent movement.

Lever box types

175 The spring lever box is the most commonly used mechanism for changing points. The two main types are:

- the two-way lever box, as shown in Figure 38(a); and
- the one-way lever box, as shown in Figure 38(b).

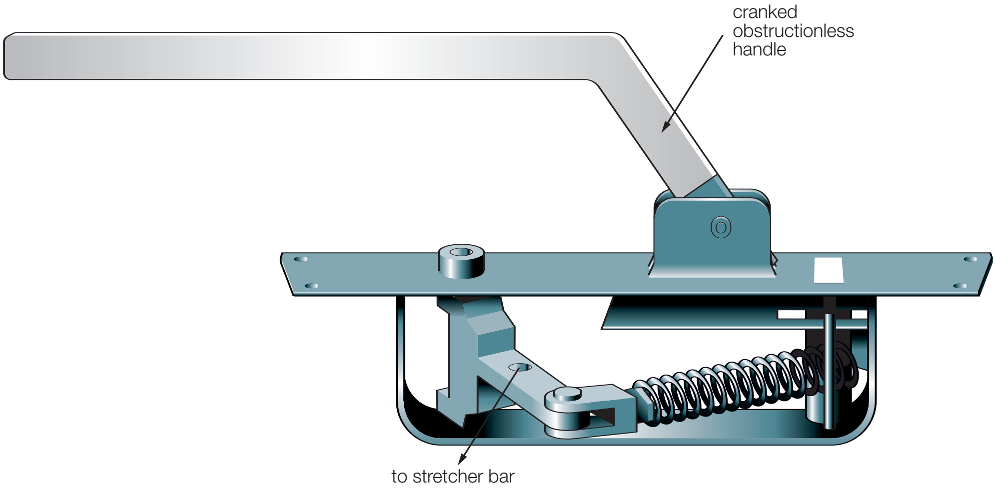


Figure 38(a) Two-way box with obstructionless handle lever

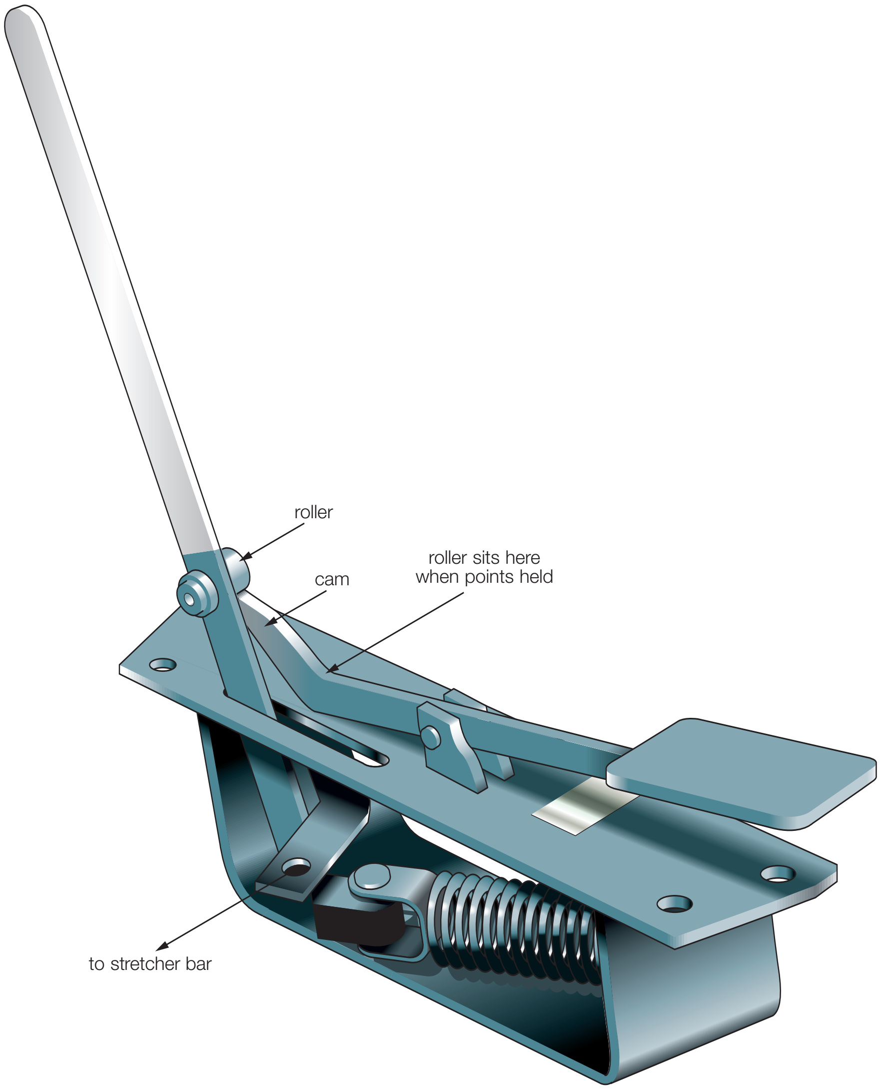


Figure 38(b) One-way box

The two-way lever box

176 In the two-way lever box, a spring presses one of the switch blades against its stock rail, holding the switch closed until the hand lever is operated again. When the hand lever is operated, the spring compresses and an internal lever moves over-centre to press the opposite switch blade against its stock rail.

177 One type of two-way lever box, known as the 'treble leverage type', incorporates three lever actions, combining minimal effort for operation with a strong positive action to the switch blade. This is suitable for the larger rail sections of 50 (24.8 kg/m) and 60A (30.54 kg/m). For smaller rail sections of 35M (17.4 kg/m), the mini lever box operates in a similar manner but with a reduced spring rating.

The one-way lever box

178 The one-way lever box is spring loaded in one direction only, in the other direction the hand lever has to be held over. The one-way lever box also has the treble leverage action. It is used on turnouts where traffic predominately uses one direction, and the switch is designed to be trailed in the opposite direction.

179 The one-way lever box has the advantage that it reduces the risk of inadvertent misdirection of vehicles. It has the disadvantage that it has to be held with sustained effort while a train passes. A foot pedal can be provided to reduce the effort required to hold the lever in position, as shown in Figure 38(b). Connecting bars should be used to mount this type of box far enough away on the outside of curves to avoid the risk of injury to the operator from vehicle end swing.

180 Where a locomotive driver works alone, the provision of one-way lever boxes can lead to the unacceptable practice of wedging switches open. For safe working, staffing levels should ensure that another person, in addition to the driver, is present to operate one-way lever boxes. One-way lever boxes should not be used in 'driver only' operations.

Lever box handle design

181 Lever box handle designs vary, they can be removable or fixed and upright or obstructionless. Where there is a risk of people or vehicles making contact with lever box handles, they should be of an obstructionless design.

182 Unless there are justifiable safety reasons, handles should move in line with the track not at right angles to it. This reduces the risk of an operator falling into the track.

183 If a switch is designed to be opened in the trailing direction by the action of the vehicle wheels, the lever box design should be such that this does not cause the lever handle to move.

Setting up spring lever boxes

184 For correct installation and operation, the lever box should be set up in accordance with the manufacturer's setting up procedure.

185 The two-way lever box needs to be set up with an adequate equal 'throw' (movement) about the centre point of travel. The mechanism throw can be equalised by adjusting the connecting rod screw. The throw determines the toe opening, which is the gap between the open switch blade toe and its stock rail (see Figure 39).

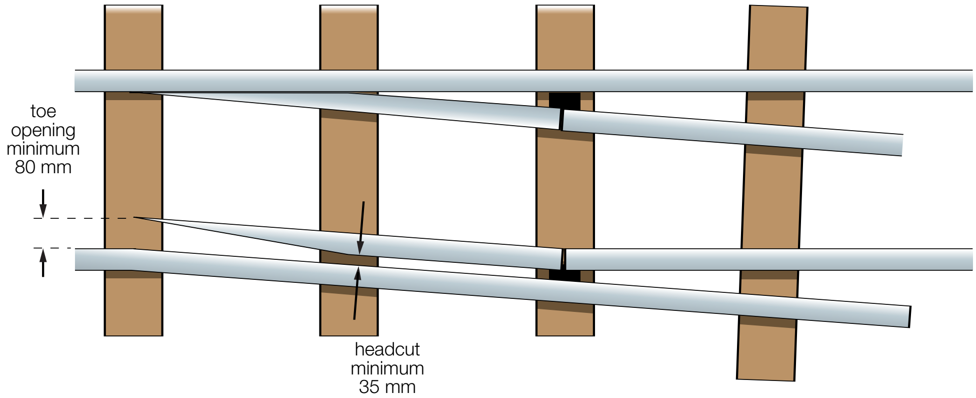


Figure 39 Toe opening/headcut

186 The minimum toe opening should be 80 mm, but it may have to be greater than this to ensure that the minimum flangeway clearance of 35 mm is maintained at the head cut. This is a feature of switch blade design, and the head cut is the place some distance along the switch blade where the side planing finishes.

187 If the lever box is not properly adjusted for equal throw in both directions, then the pressure on each switch blade as it is closed will also be unequal.

188 With the throw centralised and the toe opening properly set, the spring tension can be set using the spring tension adjusting nut to give adequate closure pressure of the working switch blade to its stock rail (see Figure 40(a)).

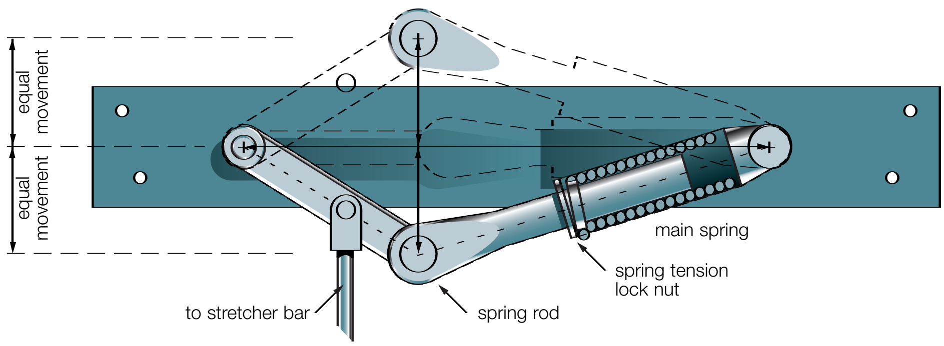


Figure 40(a) Two-way lever box action

189 If there is insufficient spring tension then the switch blade will not be held firmly closed. This may happen if the spring length is extended in an attempt to increase the throw. Conversely, if spring tension is increased too much then the lever box will be difficult to operate, because the spring will become coil bound as the mechanism passes over-centre. For example, on the two-way lever box, with 130 mm nominal throw, the spring has to be capable of taking 23 mm of compression at the on-centre position (see Figure 40(b)).

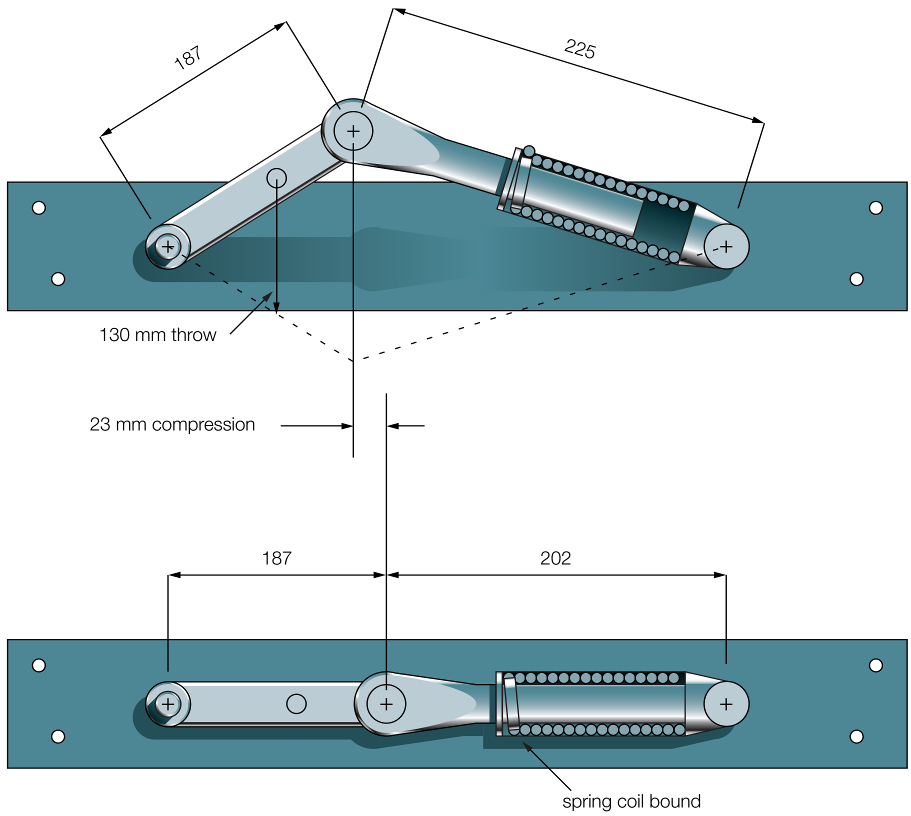


Figure 40(b) Spring compression on a two-way lever box

Remote operation of switch blades

190 Switch blades may also be operated by pneumatic or hydraulic cylinders coupled to remote controls. In these systems, the switch blade operating system should be designed so that if operating pressure is unexpectedly lost, the switch blades cannot inadvertently move.

Clamp locking mechanisms

Operation of clamp locking mechanisms

191 Clamp locking mechanisms are a means of holding a switch blade tightly against the stock rail and preventing it from inadvertently opening (see Figure 41). They are normally used in conjunction with flexible switches for safety on high-speed rail track. They may also be used with loose heel switches for added security.

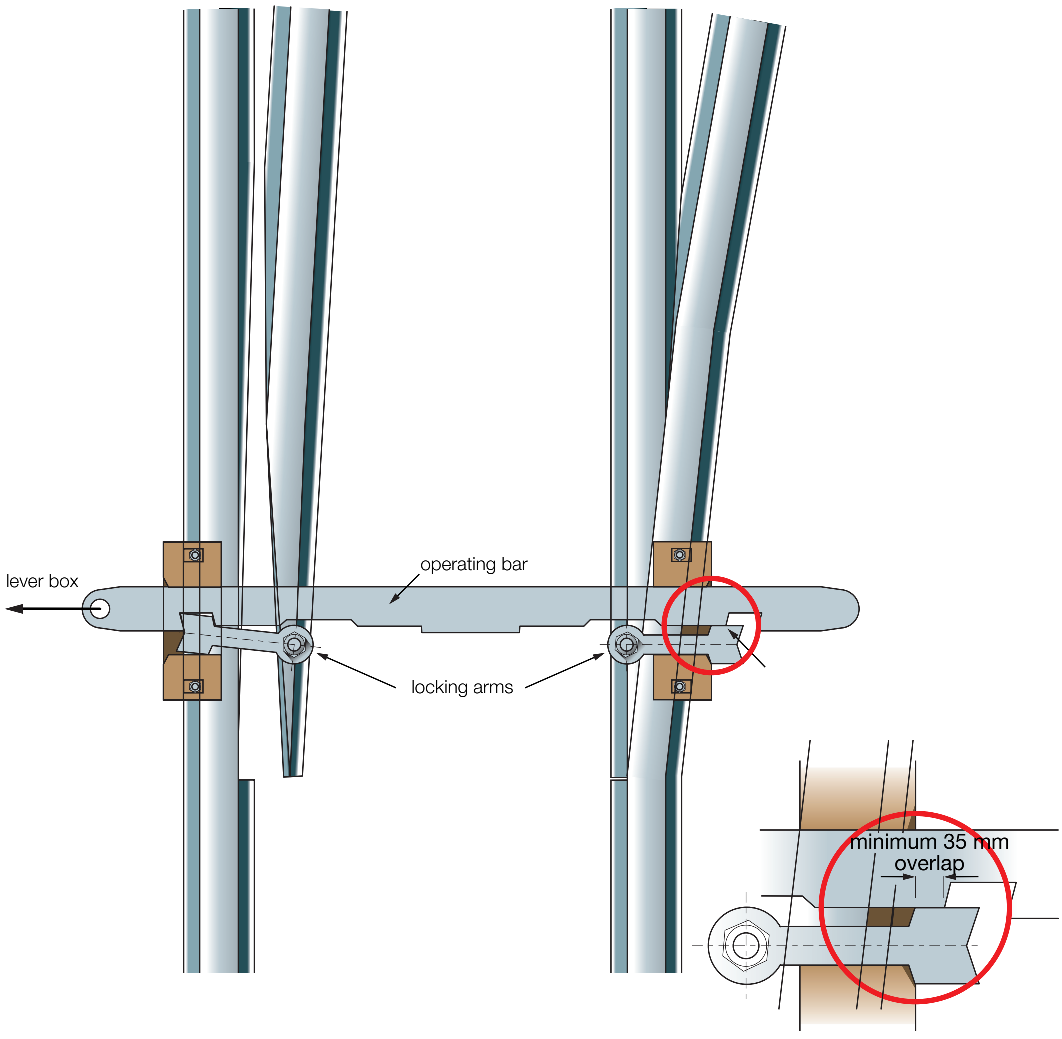


Figure 41 Clamp locking mechanism

192 Switch blades incorporating a clamp locking mechanism do not move together. They are joined by a notched operating bar instead of a fixed stretcher bar, and movement is in three stages:

(a) the open blade starts to move and completes about half of its travel with the closed blade remaining stationary;
(b) the closed blade starts to open as the previously open blade approaches closure and is forced against its stock rail; and
(c) the opening blade completes its travel leaving sufficient gap for the wheel flanges to pass through.

193 The operating bar has to travel through a certain amount of 'free movement' before the closed switch blade is unlocked and starts to open. This free movement is the basic safety feature of the locking mechanism, and 50 mm is the ideal setting. In practice some tolerance in setting up is required, but the free movement should never be less than 35 mm (see the magnified inset drawing to Figure 41).

194 The mechanism relies on the operating bar being machined with the notches in the correct position to ensure positive locking when closed and adequate toe opening when open.

Setting up clamp locking mechanisms
195 The clamp-locking operating bar needs to be operated by a heavy-duty lever box such as the two-way treble leverage type. The 50 mm of free movement of the clamp-lock operating rod will increase the lever box throw by a similar amount. Consequently, a minimum throw of 130 mm is required to achieve the minimum toe opening of 80 mm. Therefore, to ensure adequate throw and permit adjustment, it is recommended that all clamp locking mechanisms are fitted with extended-throw lever boxes capable of giving a throw of at least 130 mm.

196 All designs of clamp locking mechanisms provide for fine adjustment of the locking arm. One design uses eccentric bolts; another design uses shims between the mounting bracket and the rail web. Fine adjustment is critical to ensure the closed switch blade is held firmly against the stock rail, otherwise the blade toe may protrude, become damaged and eventually the points may be split.

197 Lockable switches are designed to be automatically unlocked if the switch is accidentally trailed through, but this may upset the fine adjustment, and ‘trailing the points’ should be prohibited.

Interchangeability of components
198 Care must be taken if it is proposed to replace components of one clamp lock mechanism with those from another, because components of mechanisms made by different manufacturers may not be interchangeable. It is advisable to mark components of each turnout with the maker’s identification mark, for reference when obtaining replacement parts in the future. Even components of mechanisms supplied by the same manufacturer may not be suitable for all turnout angles and rail sizes.

Switch blade monitoring

199 Monitoring provides indication of switch blade direction, and confirmation that the blades have reached the end of their travel and are correctly located in position.

200 For locomotive systems and rope-hauled manriding systems, monitoring should be provided. The exception to this is when the vehicle speed is less than 5 km/hour and the train driver or manriding guard can clearly see the position of switches as they are approached. Monitoring may also be necessary in other installations where the vehicle operator needs to know the position of switches and they are not clearly visible.

201 Speed restriction should not be used as a substitute for the proper design of turnouts and switch blade monitoring.

202 When monitoring is provided, indication of the switch blade direction should be located sufficiently in advance, to enable the driver to stop before the turnout if the direction indicated is not correct, or if the switch setting has not been completed.

203 Monitoring requires a positive indication that the appropriate blade is fully located against its stock rail. Even where a pair of switch blades are positively connected and move together, the closed position of each switch blade should be monitored individually. Monitors should be capable of detecting and indicating any unsafe gap that will cause the points to split.

204 Where switch blades move independently of each other, as with the clamp locking mechanisms, monitoring the closed blade alone does not guarantee that the other blade has fully opened. Where these mechanisms are installed, additional monitoring of the open blade position should be provided.

205 Monitoring should be robust enough to ensure that it is not affected by vibration from passing traffic. This may be reduced by mounting the monitoring away from the rail and operating it through linkages.

206 For rope-hauled manriding systems, switch blade monitoring should be interlocked to trip motive power and apply emergency engine brakes if the manriding carriage approaches switch blades that are not proven to be correctly set.

Non-standard turnouts

The swing-wing conventional rail turnout

207 The swing-wing turnout has a combined switch blade and closure rail assembly moving as one (see Figure 42).

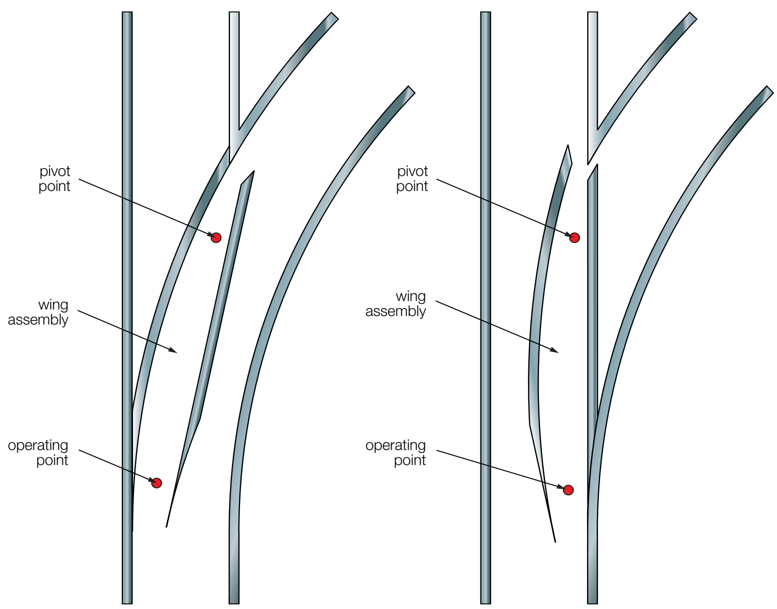


Figure 42 Swing-wing turnout

208 On large radius turnouts, having crossing angles of the order of 1 in 5, the moving assembly is very long and heavy and would generally require hydraulic or pneumatic cylinder actuation to move it. On small radius turnouts, with crossing angles of about 1 in 3, the moving assembly can be manually operated, but may require a lever box with a throw greater than that provided by the standard design. A purpose-designed lever box will then be required.

209 Swing-wing turnouts require regular lubrication of the slideways, to allow easy movement of the swing-wing. Also, regular checking and maintenance of the pivot point to ensure that alignment at the crossing is maintained.

Turnouts with asymmetrical trapped conventional rail (ATC)

210 On steep gradients, ATC is sometimes used to provide improved track braking for rope-hauled systems. The ATC rail weight usually used is 25.7 kg/m.

211 Where turnouts are provided in ATC track, the design should take into account the clearances needed to accommodate vehicle brake callipers. The force required to operate an ATC turnout is too great for manual operation with conventional lever boxes. Hydraulic or pneumatic cylinders should therefore be used to provide the increased effort and stroke.

212 When using ATC turnouts, the use of 24.8 kg/m flat-bottom rail for the curved rails allows a compatible rail height and profile to be maintained across the joints.

Other trapped rail systems

213 On other trapped rail systems, whole sections of track are moved over to allow vehicles to change tracks.

Turnouts on rack systems

214 In a rack turnout, there is a necessary gap in rack continuity as it passes over the straight closure rail, and similarly over the curved closure rail. This gap must be less than the distance between the two drive sprockets on the locomotive, or loss of rack braking will result. It also needs to be equal to an exact number of rack teeth pitches otherwise there will be poor re-engagement of the driving sprocket. This applies to each type of locomotive operating over the turnout if the drive sprocket spacing is different. For this reason, special care is required when fitting rack turnouts retrospectively. Poor re-engagement across a joint will lead to excessive rack/sprocket tooth wear, or the locomotive may even ride up onto the top of the rack and derail.

Track installation and maintenance

Track standards

215 Neither the internal layout of manriding carriages nor their superstructure are designed to afford full protection for passengers in the event of a derailment, collision or overturning. The same applies to locomotive cabs. Therefore, it is of primary importance that the standard of rail track installation and maintenance be such that the likelihood of derailment is minimised.

216 Mine managers should ensure that procedures are in place to design, install, commission and maintain rail track and associated equipment to a satisfactory standard that will ensure the safe operation of vehicles.

Track specification

217 Track should be installed to a suitable, predetermined specification. Mine managers should ensure that the track specification includes the following details:

- rail weight;
- sleeper type;
- sleeper spacing;
- fastening requirements (Pandrol clips, type of fishplate etc);
- minimum ballast requirements; and
- track alignment and level limits.

218 The specification should be easy to understand by those involved with the installation and maintenance of track, and their supervisors.

Preparing the roadway floor

Direction and gradient

219 The direction and gradient of transport roadways should be as constant as practically possible. Where rope-haulage systems are used, the rope path needs to be kept straight and rope lift at undulations avoided. Where locomotives are used, sharp curves should be avoided. Steep or undulating mine roadways will also restrict the loads that can be transported.

220 The degree of surface irregularity remaining after the roadway floor has been prepared directly affects the amount of ballast required. An adequate depth of the correct type of ballast should be laid on the roadway floor to take up surface irregularities and to support sleepers along their full length (see Figure 43).

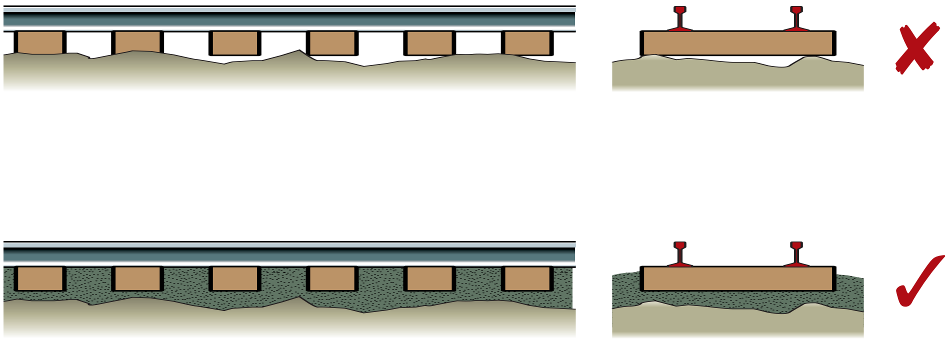


Figure 43 Ballast giving support to sleepers

Drainage

221 Failure to drain a wet roadway floor before laying rail track will result in track movement under load and joint loosening. In the longer term, it will also lead to local undulations and deterioration of sleepers and rails. The edge of any drainage channel should be sufficiently far away from the edges of the track to avoid erosion of ballast from under sleepers. Where there are significant flows of water, properly constructed drainage channels will need to be provided along the side of the track and pumps installed where necessary.

Installing straight track

Alignment and grade

222 Surveyors' lines marked on the roof and roadway side will help to ensure that track is installed to the correct line and grade respectively.

223 Where there is only a single track in a roadway, it should be installed as close to the roadway centre line as possible, to maximise operating clearances.

224 In roadways where there is fixed equipment, the track alignment should be such that satisfactory clearances are provided between vehicles and the equipment, as well as between vehicles and the roof and side. Attention should be paid to the corners of vehicles and loads in arched or circular roads, where clearances will be least. Setting out track in a conveyor roadway can be achieved using a fixed offset from the roadway centre line that coincides with one of the rails.

225 For installation work in a long straight roadway, a survey laser mounted in the roadway, with a target board mounted on a vehicle, may be quicker and more suitable (see Figure 44).

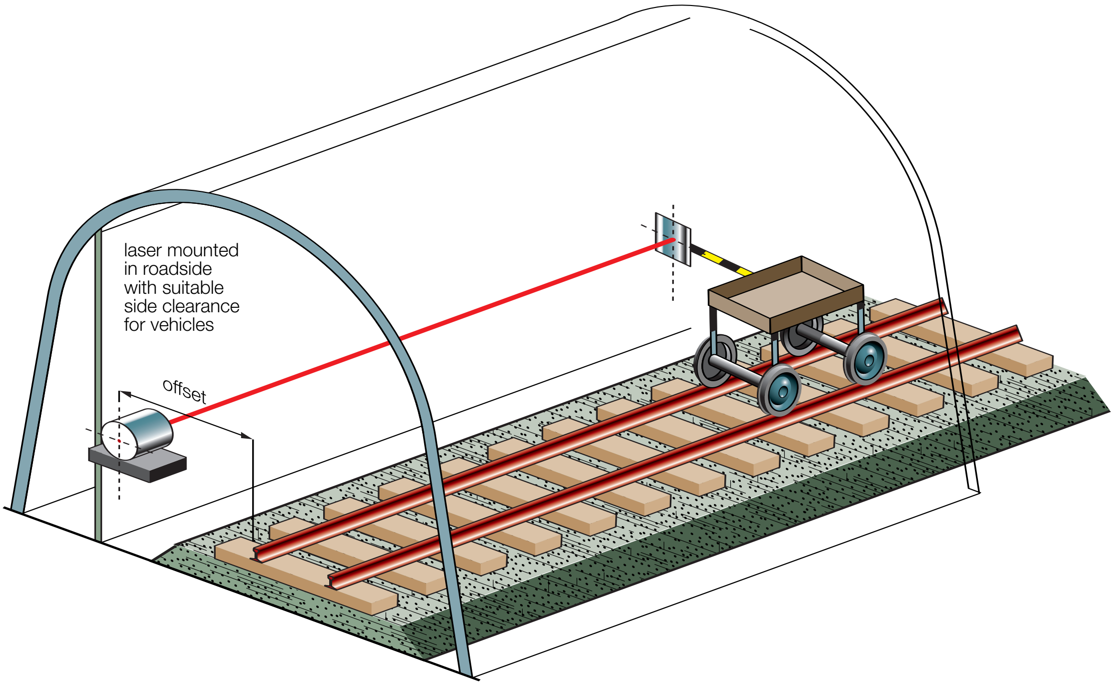


Figure 44 Using lasers for track alignment

226 Typically the laser is set up at a suitable offset to one rail and at a suitable height above the track. It should be aligned to strike on a distant target positioned at the other end of the straight section of track being installed and set to the same offsets.

227 A second target is mounted on a rail vehicle. This target is marked with vertical and horizontal centre lines that can be graduated to indicate the amount of track movement required. The target vehicle is usually lightweight in construction to enable it to be lifted clear of the track and allow the passage of other vehicles.

228 The target vehicle should be run along the length of track at least twice. On the first pass, the track should be pulled to line by moving the track sideways until the laser beam strikes the vertical centre line on the target. On the return pass, the track should be lifted until the laser beam strikes the horizontal centre line of the target (see Figure 45).

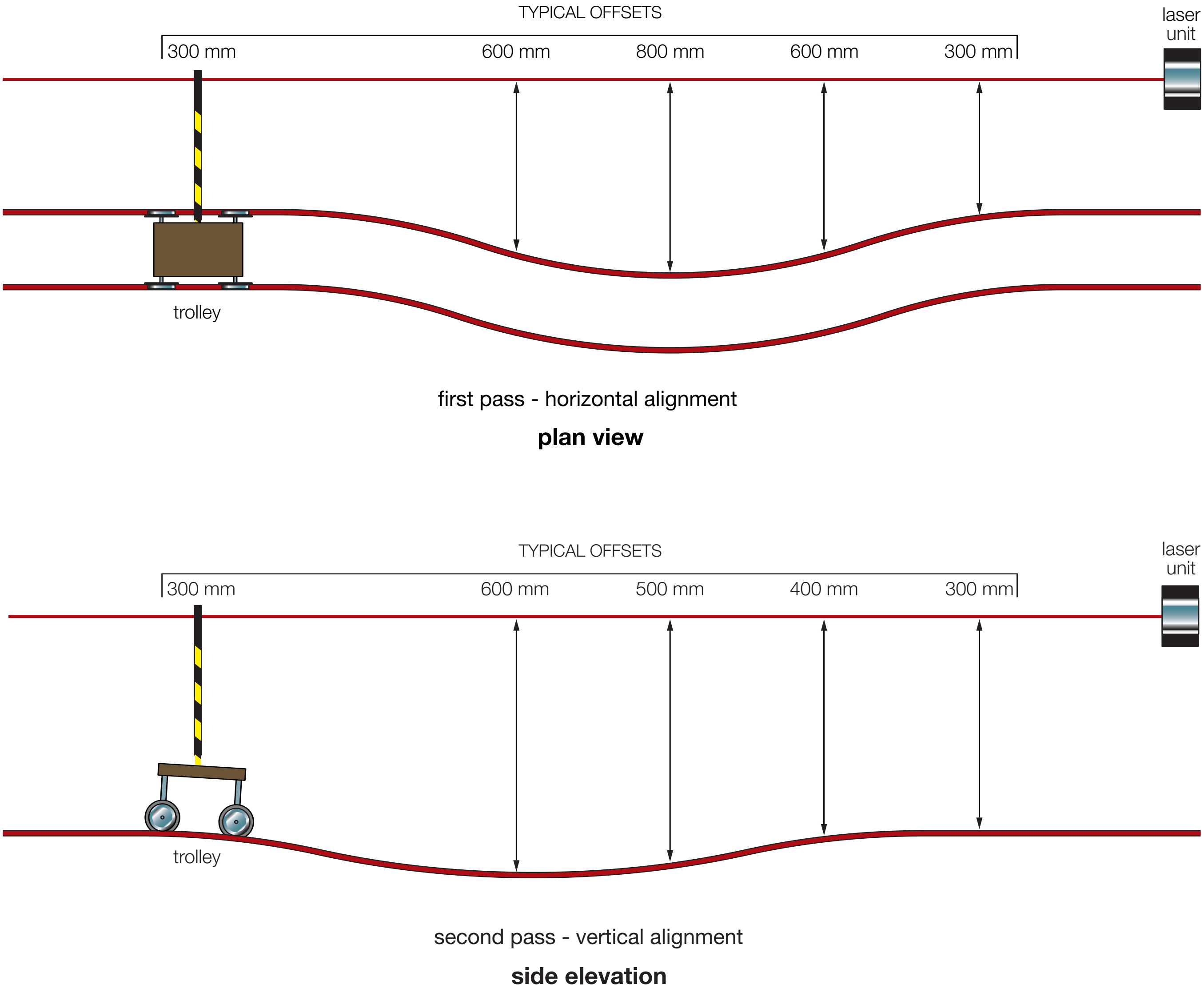


Figure 45 Using lasers for track alignment

229 Track workers and pedestrians should be made aware of any precautions to be taken when in the vicinity of a laser beam. This will depend upon the classification of the laser and will include:

- warnings for them not to look into the beam;
- posting of warning signs; and
- training, where necessary, in the use of lasers.

Rationalised gauge

230 Historically, track gauge was measured in imperial units, and there was a wide range of gauges used at mines. Some years ago, the National Coal Board rationalised its track gauges to reduce the range and convert them to metric units. Table 2 shows the comparison between actual and rationalised track gauges. It is worth noting that there may be a significant difference between some rationalised gauges and the metric conversion. For example, 28-inch gauge converts to 711 mm, but the rationalised gauge is 704 mm – a difference of 7 mm. To ensure compatibility with rolling stock, the exact gauge in use will need to be checked.

Table 2 Comparison between actual and rationalised track gauges

Imperial gauge (inches)	Actual metric conversion (mm)	Rationalised gauge (mm)	Difference (mm)
42	1067	1066	- 1
36	914	916	+ 2
30	762	760	- 2
28	711	704	- 7
24	610	604	- 6
20	508	502	- 6

Sleeper spacing

231 Sleeper spacing is the distance between the centres of adjacent sleepers.

232 The following sleeper spacings have proven acceptable in practice and should not be exceeded:

- locomotive track – 840 mm;
- manriding rope-haulage track – 840 mm;
- non-manriding rope-haulage track – 1000 mm.

233 Increases in sleeper spacing will reduce the factor of safety against rail failure. Table 3, produced for information, shows the factor of safety for each common rail size, typical maximum axle load, and maximum sleeper spacing. The factor of safety is calculated on the assumption that the rail acts as a simple beam and (because track conditions and vehicle suspension arrangements can result in the axle load being carried momentarily on a single wheel) that the entire axle load acts on one rail. It does not include the dynamic effects of wheel hammer.

Table 3 Rail factors of safety

Mass of rail (kg/m)	Maximum axle load (tonnes)	Distance between sleepers (mm)	Factor of safety
30.54	7.5	840	4.1
24.8	7.5	840	3.1
17.36 (Note 1)	4	1000	2.5
17.36 (Note 2)	3	900	4.1

Note 1: The factor of safety for 17.36 kg/m rail is relatively low, and the maximum axle loading of 4 tonnes is considered to be an abnormal load, which is carried only infrequently, and not the regularly carried load.
Note 2: For tunnelling in the construction industry, a more acceptable factor of safety for 17.36 kg/m rail is achieved by reducing the maximum axle load to 3 tonnes and the sleeper spacing to 900 mm.

Dog spikes
234 When using dog-spike fixings see paragraphs 44-46.

235 Pilot holes should be drilled in sleepers to prevent the timber splitting. They should be drilled vertically at a diameter slightly less than the square size of the spike. It may be necessary to support the sleeper up to the rail foot in order to drive the spike fully home. Before fastening down the second rail onto the sleeper, a gauge setting tool needs to be placed between the rails to set the gauge (see Figure 46).

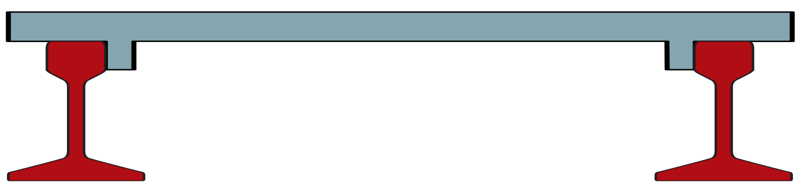


Figure 46 Gauge setting tool

236 When using dog spikes, gauge ties should be considered as an additional aid to maintaining rail gauge.

Baseplated timber sleepers
237 Where baseplated timber sleeper assemblies are used, see paragraphs 48 and 49.

238 Pandrol clips should be pulled into place with a special 'Panpuller' tool, to avoid the risk of injury from flying clips, which could occur if attempting to hammer them home.

239 Additional gauge ties are not required with baseplated sleepers.

Steel sleepers
240 Where steel sleeper assemblies are used, see paragraphs 50-52.

241 When using steel sleepers with screw-type fastenings, it is essential that the bolts are securely tightened. After an initial running period, and then at periodic intervals, track examiners should check that all bolted fastenings remain tight to the rails.

Rail joints

242 Rail joints should be positioned opposite each other across the track, not staggered. This reduces the likelihood of vehicles rolling at 'dipping' joints, and eases installation and subsequent maintenance.

243 Joints should be placed between a pair of sleepers, with the sleepers close to the ends of the fishplates. Positioning sleepers in this way gives better support and rigidity to the joint than a single sleeper placed directly under the joint (see Figure 47). Using a single sleeper may eventually lead to the joint loosening.

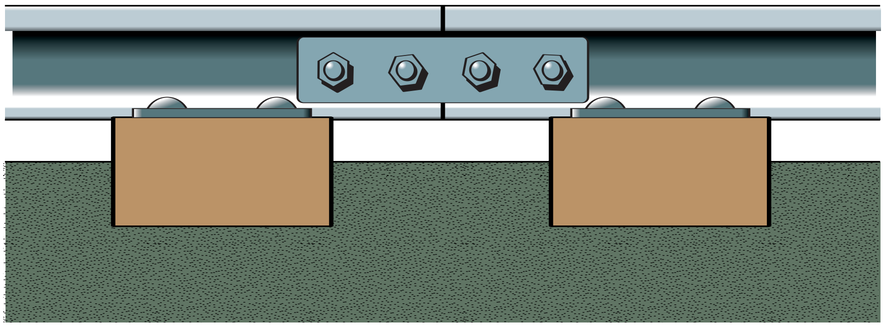


Figure 47 Method of supporting a joint

244 Positioning the joint between the sleepers and keeping the sleepers as close as possible to the fishplates will also ensure that the maximum sleeper spacing is not exceeded across the joint.

245 All four bolts must be used when fitting fishplates, to ensure that the joint is adequately supported. Fishplates with only two bolts do not give adequate support to the joint and should not be used, as this will result in excessive maintenance even on lightly used track.

246 Fishplate bolts should be hand tightened initially, until the track is lined up, and then fully tightened, preferably using a torque spanner. Following a brief period of regular traffic over the track, the fishplate bolts should then be re-torqued to take up any slack caused by the fishing surfaces bedding-in on the fishplates and rails.

Ballasting

247 Sometimes track has to be laid before ballast can be supplied to complete the installation. In this case, speed and load restrictions should be imposed until the proper standard of ballasting has been achieved. When track is ballasted later, it should be lifted to allow the required depth of ballast to be placed under sleepers. Ballast placed just as an infill between sleepers serves no useful purpose.

248 The type and size of ballast is very important for the reasons described in paragraphs 54-60. The depth of ballast has to be sufficient to allow the track to be laid to an even grade, with sufficient margin to allow for future regrading. Where floor lift is anticipated, ballast depth may be increased to allow for subsequent removal to maintain the track level.

249 For manriding rail track, a minimum depth of ballast under sleepers of about 150 mm will usually be sufficient. For other track, a minimum depth of 100 mm is recommended.

250 Ballast needs to be packed tightly under the parts of sleepers that are directly beneath each rail, and for up to 230 mm each side of each rail. The ballast inbetween, and the ballast round the sleeper ends should be loosely packed (see Figure 48).

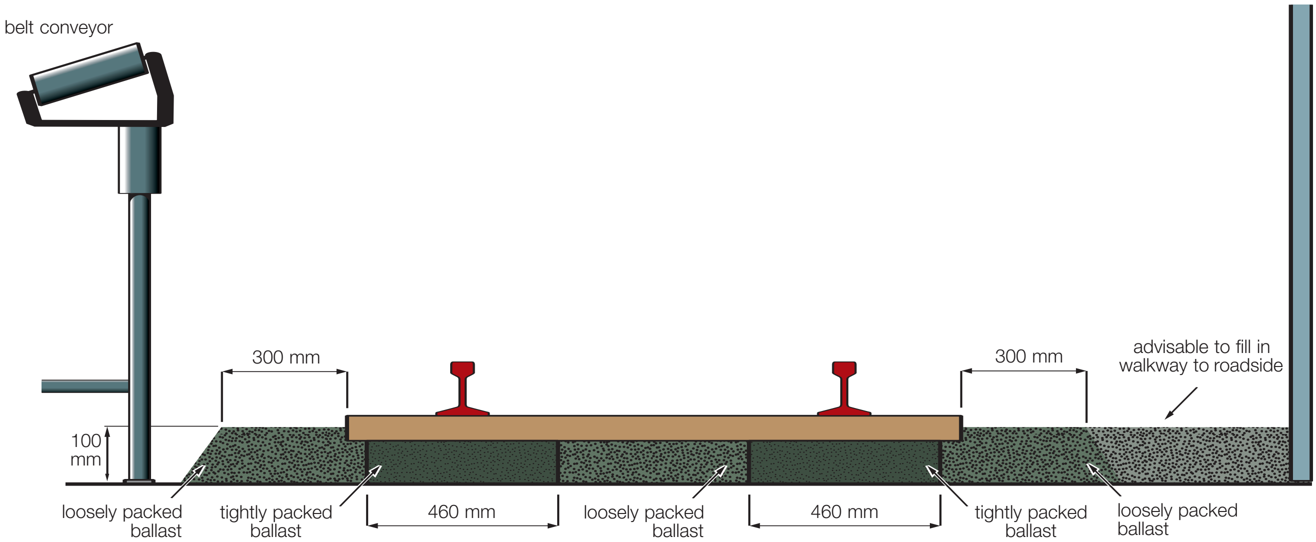


Figure 48 Ballasting requirements

251 The width of ballasting should be extended for at least 300 mm beyond the ends of the sleepers, to prevent sideways movement of the track. If this brings the shoulder of the ballast close to the roadway side, it is good practice to fill up to the roadway side to prevent disturbance and erosion of the ballast by people walking alongside the track.

252 Where steel sleepers are used there may be some settlement as ballast finds its way into any voids in the underside of the sleeper. Re-levelling should be carried out after a short initial period of use. It is **not** good practice to mix steel and timber sleepers, as any difference in base area will result in unequal settlement.

Additional requirements for installing curves

253 When installing track on curves, consideration should be given to:

- gauge widening;
- super-elevation of the track; and
- the provision of a check rail.

Note: Further information can be found in the section *Curved track* (see paragraphs 68-128).

Cramping on site

254 Cramping tools usually place a series of distinctive bends in a rail, and care is required to limit the amount of bending at any one place and to form as smooth a curve as possible. To avoid straight rail ends on cramped rails, allowance should be made for cutting this end off after cramping (see paragraphs 77-81).

Preformed curves

255 For longer curves, it is strongly recommended that rails are:

- preformed by rolling to the designed radius;
- fully assembled on the surface; and

- clearly marked so that the inner and outer rails can be identified below ground.

Gauge widening
256 Where dog spikes are used to secure curved rails to timber sleepers, gauge widening can be achieved on site by use of a modified, suitably extended gauge setting tool.

257 When steel sleepers or baseplated timber sleepers are used, these have to be specially produced to suit the gauge widening required. Only three increments above the standard gauge are required to be able to produce a selection of sleepers that will meet most requirements for curves and transitions into curves (see Table 4).

Table 4 Tables of gauge widening increments for various radii curves

Radius	Gauge increase
>30 m	NIL
13-29 m	4 mm
8-12 m	8 mm
<7 m	12 mm

258 Progressive gauge widening will normally be achieved on the straight section of rail at each end of a curve, in one, two or three increments with 4 mm steps. Gauge widening should change over the length of a rail and not across a joint.

Super-elevation
259 Where a curve is to be super-elevated, additional ballast needs to be placed towards the outside of the curve. The amount of super-elevation should be strictly controlled, as too little or too much can affect the stability of vehicles travelling round the curve (see paragraphs 83-94).

Joints in curved track
260 When laying rails on a curve, it is difficult to maintain rail joints opposite one another; therefore it is acceptable to stagger the joints round the curve. In practice, it gives additional stiffness to the assembly if the curve commences with a short, half rail length. Care should be taken to ensure that staggered joints are properly supported (see paragraphs 242-246).

261 Care should be taken to ensure that fishplates are properly seated along their full length. Otherwise, in addition to the joint having a reduced load-bearing capability, the butt ends of the outer rails may float sideways and will be forced out of alignment by the guiding wheel, which can lead to derailment. On small radius curves it may be necessary to bend the fishplates to the same radius to achieve proper seating over the full length of the fishplate.

Curves for rope haulages and captive rail systems
262 On curves where there is a high radial reaction force, eg rope haulages and captive rail systems, it will be necessary to fasten the rail track to the floor to prevent track movement.

Installing turnouts and crossings

263 When turnouts or crossings have to be dismantled for transportation, it is good practice to mark each part so that it can be identified for reassembly.

Sub-assemblies ought to be as large as practicable to minimise the number of joints required. Joints should be staggered to avoid the assembly flexing in use.

264 Turnouts need to be carefully aligned to the adjacent sections of track, to ensure the main line is not suddenly deflected (see Figure 49).

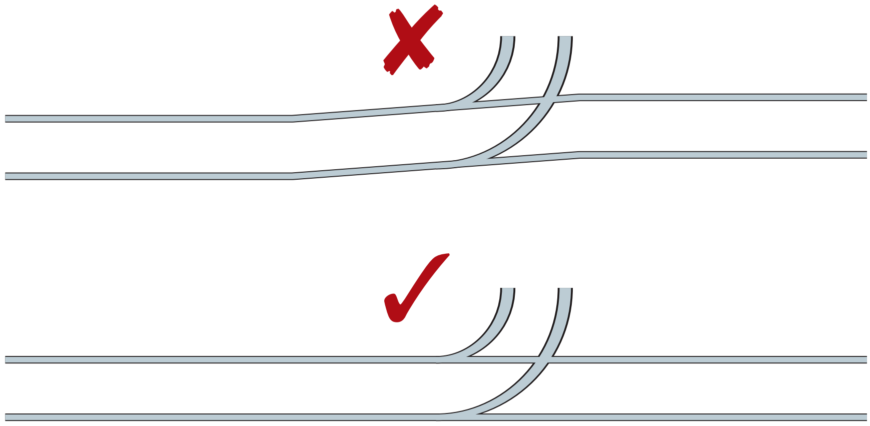


Figure 49 Turnout alignment

265 When assembling a turnout, the straight stock rail needs to be aligned and fixed in position first. The crossing components can then be assembled and positioned to gauge from this stock rail.

266 The supporting sleepers should be evenly distributed throughout the turnout so that the assembly is adequately supported, with no undulations at joints in the running rails. A uniform level track should be achieved by having extended length sleepers to support both diverging tracks (see Figure 50). At the leading ends of the turnout, two extended-length sleepers will be required to support the switch blade operating mechanism. The sleepers should be adequately supported on suitable ballast.

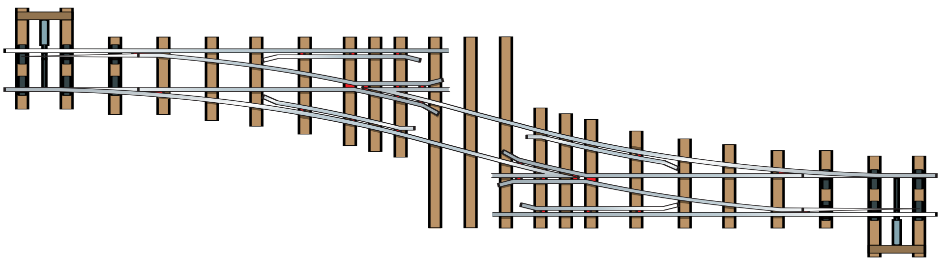


Figure 50 Sleeper support for turnouts

267 Switch blades and their operating mechanism should be properly adjusted to ensure adequate toe opening and flangeway clearances, and should operate with a positive action when changing from one direction to the other.

268 When two turnouts are connected back-to-back, to form a crossing between adjacent tracks, it may be necessary to introduce a short section of straight rail between them to reduce the effect of the reverse curve on vehicle couplings (see paragraphs 116-118).

Statutory requirements

269 Rail track is equipment to which the Management and Administration of Safety and Health at Mines Regulations 1993, regulation 11 and Approved Code of Practice[5] apply. It should be included in the manager's scheme for commissioning, systematic inspection, maintenance and repair. For the general statutory requirements relating to rail track see the Appendix.

Commissioning

270 All newly installed rail track, including extensions to existing track and major repaired sections, should be formally commissioned by competent people before use. The commissioning document should verify that the standard of installation meets the required specification for the intended duty. It should also include reference to clearances, safety devices, refuge holes and notices etc.

271 Commissioning should be carried out at each stage of use during installation. For example, an initial commissioning to permit restricted speed and load use on new track prior to ballasting, and final commissioning to permit full usage on completion of all work.

272 Little-used sections of track not routinely inspected or maintained (eg providing access to a conveyor drive for breakdown purposes) should be isolated to prevent access, by provision of an effective barrier and notices. Before reuse, the track should be recommissioned by a competent person.

Planned preventive maintenance

Track inspection and examination

273 Managers should ensure that there are adequate formal arrangements for the inspection and maintenance of trackwork by competent people in accordance with a suitable scheme. They should also ensure that there is an effective system for dealing with reported defects that are liable to affect safety.

274 Mining officials may be competent, with instruction and training, to routinely carry out daily visual inspections of track as part of the roadway inspection. However, purpose-trained people with greater experience, such as engineering staff, should carry out more detailed, periodic inspections and examinations, especially of turnouts, curves and points mechanisms etc.

275 All major items of trackwork, such as safety devices, turnouts, crossings, curves and switch blade monitoring, should be individually identified and separately listed in the manager's scheme for planned preventive maintenance. It is recommended that for long sections of track, the rail joints be numbered for identification and reference purposes.

Effect of rail wear

276 Rail top wear should not exceed permitted limits; otherwise there will be a significant reduction in rail strength.

277 If rail top wear is excessive, wheel flanges may contact fishplates and fishplate bolts, eventually causing damage. In this respect, wear is more critical on lighter section rail, such as 35M, than it is on heavier section, such as 60A, because the depth of the rail head is much less to start with.

278 Wear on the side of the rail head should also be monitored, particularly on the outer rails of curves, as the likelihood of flange climbing, and hence derailment, increases with side wear.

Effect of twist

279 Track twist is defined as the maximum variation in height between the rail at one wheel and the plane of the rails at the other three wheels. It is determined by measuring the change in cross level over the wheelbase of any vehicle which runs over the track.

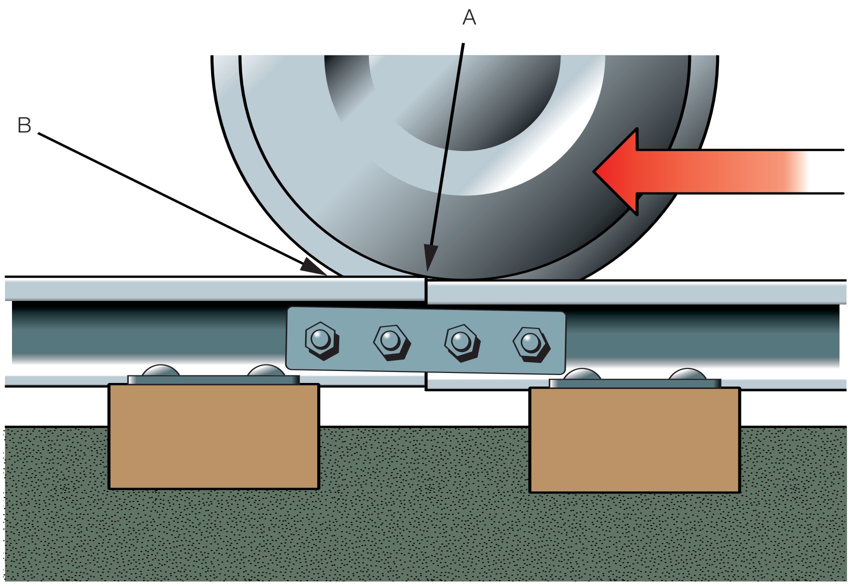
280 Track twist can cause the weight to be transferred off a wheel, which increases the risk of flange climbing and derailment. This is why it is particularly important to maintain a constant super-elevation or cross level on curves. Severe twist can cause the wheel to lift completely clear off the rail.

281 Short wheelbase bogies are often selected for higher-speed systems to reduce the effects of twist. For example, a 3 m wheelbase vehicle would require track twist maintaining within a limit of approximately 3 mm per metre length of track, whereas for a 1 m wheelbase bogie the maintenance limit would be 10 mm per metre length of track.

282 Rigid chassis (unsprung axles) will tolerate less track twist over the vehicle wheelbase than vehicles with suspension. Where enhanced margins of safety are required, vehicles with suspension arrangements that allow for some track twist should be used, eg manriding cars.

Checking rail joints and fixings

283 Poorly supported joints lead to the fishplate bolts loosening, which must be dealt with promptly, otherwise joints will dip under load. Dipping joints are caused by the end of the trailing rail deflecting downwards under the load of the vehicle. The wheel then strikes the leading end of the next rail and jumps a short distance before landing back on the rail with a hammer action (see Figure 51).



wheel strikes rail end at A, jumps a short distance, and lands back on rail at B

Figure 51 Effects of a loose joint

284 This hammer action from the wheels can cause:

- displacement of ballast;
- permanent downward bending (dipping) of the rail ends;
- increased wear on the fishplate fishing surfaces; and
- fatigue fractures across fishplates, rails or bolts.

285 Dipping joints are dangerous and should be repaired promptly. Improvised support at dipping joints, by inserting a sleeper or wedge directly under the joint, is not a substitute for proper maintenance and repair and should not be practiced.

286 Inspecting rail joints and fixings in long lengths of track can be onerous. The task can be eased by dividing the track into zones, and arrangements put in place for detailed checks to be progressively undertaken in each zone (see also paragraph 275 with regard to numbering rail joints).

287 Dipping joints can be identified by observing the passage of a locomotive or vehicle over a section of track. The observer should be safely positioned and able to note any significant joint movement.

In-line gradient, cross tilt and twist

288 Manually measuring the in-line gradient of each rail, and cross tilt and twist at wheelbase intervals, can be a lengthy process, and is not suitable for monitoring long lengths of track laid to high-speed standards. Long lengths of track can be monitored by instruments mounted on a moving train. This type of monitoring has the advantage that any track deflection due to the weight of the vehicle is automatically detected.

289 When using onboard instrumented techniques, care should be taken to ensure that the instrument mounting position is such that neither vehicle suspension movement nor long overhangs influence results.

290 Monitoring instruments are capable of giving accurate and instantaneous readouts. They can be provided with facilities for downloading onto a computer for either tabular or graphical representation of results, allowing direct comparison with maintenance tolerance limits. Such an approach allows maintenance to be prioritised.

Track alignment

291 Track alignment should be checked periodically by reference to surveyors' lines. The interval between such examinations will depend largely on the stability of the roadway in which the track is installed and its frequency of use. Track in relatively unstable roadways will need to be checked more frequently than track in roadways that are relatively stable. Daily visual inspections will give an indication of when thorough examination is required.

292 The laser equipment described in paragraphs 225-229 can also be used to check alignment. Tracklayers should be deployed at the same time to correct any sections of track that have moved out of alignment.

Turnouts and crossings

293 Turnouts and crossings require special attention, because of the number of places where they can deteriorate. All screwed fastenings should be checked for looseness. Loose-heel switch blades should be checked for heel block security and all turnouts for security of check blocks, nose blocks etc.

294 The switch blade changeover mechanism should operate without undue effort. Where the lever-box mechanism uses an over-centre action this needs maintaining to ensure an equal throw in both directions, so that the spring force holding the respective switch blade to the stock rail is sufficient to prevent the blade from being opened by the vibratory effect of vehicles passing over. Where clamp-lock mechanisms are used, a check is needed to ensure they are properly adjusted and have adequate movement to complete the locking action in both directions.

295 It is also important to ensure that when the switch is open there is an adequate toe opening, and that there is an adequate flangeway clearance at the blade 'headcut'. Also, when the switch blade is closed, it should match up to the adjacent stock rail with no undue gap, and the switch blade tip needs to be a close fit to allow a smooth transition for the wheels. If the switch blade tip is not a close fit it will be vulnerable to damage by wheel impact, which may lead to derailment if not attended to. Where switch blade monitoring is provided, a check should be made that it is properly adjusted and indicates correctly.

296 The flangeways between running rails and check rails and those around the crossing vee should be kept clear of any debris likely to impede the passage of wheel flanges. If flanges ride on compacted debris, then the effective flange depth is reduced and can lead to derailment.

297 Alignment of the turnout with adjacent track should be checked and maintained because sudden deviations can lead to derailment.

298 At the crossing vee, there will be a need to ensure that the crossing nose is not unduly worn or damaged and that the check rails continue to provide the necessary guidance.

Tolerance limits for installation and maintenance

Track standards

299 There are two recognised track installation and maintenance standards for permanently installed conventional rail track:

- basic track standard, for speeds up to 16 km/hour; and
- high-speed track standard, for speeds of 16 km/hour and above.

300 The term 'standard' covers two aspects, the quality of components used and the tolerance limits applied in the installation and subsequent maintenance of the rail track. The quality of components (including individual components, curves, turnouts and crossings) is dealt with earlier in this guidance. This section of the guidance deals only with tolerance limits applicable to the standard of installation and maintenance.

301 The tolerance limits applied during installation are generally more onerous than those applied in subsequent maintenance, to allow for some deterioration before undertaking maintenance.

302 In practice, even where operating speeds are less than 16 km/hour, track used for manriding or for hauling material vehicles with high axle loads is generally installed and maintained to a standard superior to the basic track standard.

303 Table 5 shows the installation and maintenance tolerance limits for basic track and for high-speed track.

Tolerance limits for basic track

304 Few tolerance limits are prescribed for installing basic standard track below ground. This should be laid to the best standard commensurate with risk and cost. But there are recognised maintenance limits at which repair work ought to be undertaken to ensure safety is not reduced.

Tolerance limits for high-speed track

305 There are well-proven tolerance limits for the installation and maintenance of high-speed track, which are superior to those for basic track.

Table 5 Trackwork tolerances for installation and maintenance

		Basic track		High-speed track	
		Installation	Maintenance	Installation	Maintenance
Straight track gauge		Gauge	Gauge +10 mm	Gauge -1 to +4 mm	Gauge -2 to +6 mm
Curved track gauge		Gauge plus gauge widening of 72/R (mm)	Gauge plus gauge widening +10 mm	Gauge plus gauge widening -1 to +4 mm	Gauge plus gauge widening -2 to +6 mm
Straight track cross tilt			Maximum of 1/10th rail gauge	Maximum of 1/100th rail gauge	Maximum of 1/60th rail gauge
Curved track cross tilt		0.75 to full super-elevation with a maximum of 0.1G +5.7 (mm)	0.5 to full super-elevation with a maximum of 0.1G +5.7 (mm)	0.75 to full super-elevation with a maximum of 0.1G +5.7 (mm)	0.5 to full super-elevation with a maximum of 0.1G +5.7 (mm)
Rate of change of cross tilt (twist)			Maximum of 25 mm over wheelbase of any vehicle using track	Maximum of 5 mm over wheelbase of any vehicle using track	Maximum of 10 mm over wheelbase of any vehicle using track
Alignment of straight track				Maximum 1 in 580, eg 7 mm over 4 m rail and 12 mm over 7 m rail	Maximum 1 in 580, eg 7 mm over 4 m rail and 12 mm over 7 m rail
Rail wear on top surface	17.4 kg/m		Maximum 7 mm	Rail size not recommended for high-speed track	
	24.8 kg/m		Maximum 8 mm		Maximum 5 mm
	30.5 kg/m		Maximum 10 mm		Maximum 5.7 mm
Rail wear on guiding face (angle measured from horizontal)	17.4 kg/m	New rail 90 °	Maximum 65 °	Rail size not recommended for high-speed track	
	24.8 kg/m	New rail 90 °	Maximum 65 °	New rail 90 °	Maximum 85 °
	30.5 kg/m	New rail 87 °	Maximum 65 °	New rail 87 °	Maximum 76 °
Rail dip across joints			Maximum 10 mm under 1 m straight edge		Maximum 5 mm under 1 m straight edge
Rail joint gaps	Constant temperature	6.4 mm		1 m ±1 mm	
	Change of temperature	6.4 mm		3 m ±1 mm	

Installation and maintenance standards for captive rail track

306 Typical examples of captive rail track are the Becorit Roadrailer system and the UMM Railer system.

307 This type of captive rail track is constructed from rolled steel sections joined together by struts and ties, and is supported on integral footplates at intervals along the track length. The track is supplied in prefabricated sections, usually 3 m, 6 m or even 9 m long, which are joined together by flanged joints or special male and female joints. Curved sections and complete turnouts are also supplied.

308 Captive rail track should have adequate strength to withstand:

- the loads resulting from the weight of any vehicles running upon it;
- the forces from driving wheels of any locomotive running upon it; and
- the loads imposed during the operation of any vehicle track brakes.

Floor bolting

309 The rigidity of the captive track is achieved by securing it to the floor using rock bolts. The number and size of the rock bolts required needs to be determined at the design stage, and will be based on the forces involved and the nature of the floor. A specification should then be drawn up for track bolting. This specification may vary for different sections of track, depending on the gradients and loads involved. On some sections, every length of track may need to be secured to the floor; on others it may be adequate to secure the track at intervals of several track lengths. The nature of the floor may be determined by inserting sample rock bolts and carrying out pull tests.

310 On high-energy systems, ie steep gradients with heavy loads, track should be adequately secured to the floor to prevent it jackknifing when emergency track brakes are applied.

311 Track that is fastened to the floor should be secured as near as practicable to the joint with the next section of track. This reduces loading on the joint.

312 Every curved section of track should be secured to the floor to ensure rigidity of position and stability against overturning.

Support

313 Track is supported on integral footplates, which may be placed directly onto a suitable floor, or onto timber sleepers. Where sleepers are provided they should be fastened to the footplate to prevent them slipping out of position.

314 The intervals between supporting footplates may be several metres, so it is particularly important that the track is properly supported at every footplate.

315 It is unacceptable practice to support one side of the track independently of the other side using loose packing blocks. Floor dinting should be carried out where necessary to allow full-width sleepers to be used.

Level and alignment

316 Track alignment and cross-levelling limits for installation and maintenance should be prescribed in accordance with the manufacturer's specifications.

Rail joints

317 Every rail joint needs to be secured by a connection of adequate strength. When flange-jointed track is being installed, the joint should be connected using the correct size and type of bolts specified by the manufacturer, and aligned by the positioning dowel. When installing male/female-jointed track, the captivating dowel should be fitted to retain the male peg in the female socket. The support feet should then be packed up to ensure that the male peg is fully supported in the bottom of the female socket. Under no circumstances should any vertical load be imposed on the captivating dowel when the track is finally levelled.

Curved track
318 Captive rail track curves tend to be of small radius compared with conventional rail track, and particular attention should be given to vehicle end throw, centre throw and the articulation between coupled vehicles, to enable them to travel the curve safely.

319 On certain haulage systems, such as manriding systems, safety chains are often used to connect each vehicle in addition to the normal coupler. Small radius curves may preclude the use of safety chains between vehicles, because the inner chain would become too slack and possibly catch any obstruction, and the outer may become over tensioned; an alternative means of preventing inadvertent uncoupling may be necessary.

Installation and maintenance standards
320 In addition to the general requirements for track examinations, the following points are particularly relevant to captive rail track:

- joint integrity may rely on small components, such as dowel pins, which should be checked individually at intervals for any sign of wear or damage;
- the track anchorages need to be checked to ensure that floor bolts have not become loosened or slack due to track settlement, or been worn away by contact with a haulage rope;
- checks need to be made to ensure that there is adequate clearance for the free passage of vehicle wheels on the inside of the track between the rolled steel sections;
- wear limits should be prescribed for the rolled steel sections and wear checks made at regular intervals. Top flange wear can seriously reduce the ability of the rolled section to resist longitudinal braking forces; and
- the top flanges may become deformed, curled upwards at the end, due to the forces imposed through reaction beams and guide wheels on vehicles. Deformed track should be replaced because it could affect the operation of emergency track brakes.

321 Open ends of track should be fitted with end stops to prevent vehicles being propelled out of the open end. Where this is not practicable at turnouts, monitoring and indication of the turnout direction should be provided to the driver or guard.

Checking roadway clearances

322 In addition to track maintenance, roadway clearances should be checked periodically to ensure that adequate clearances are being maintained, and daily checks should be made to ensure that the track is clear and free from obstruction.

323 The planned preventive maintenance scheme is a useful means of formalising the making of these inspections. This would include formal reporting of inadequate clearances and inclusion of such in the defects action scheme.

324 Flexible templates fixed to the locomotive are a useful method of checking clearances. However, it must be ensured that the template used is appropriate to the maximum size of vehicles and loads that will travel the route.

Safety during trackwork

Risk assessment

325 Those organising or controlling the way in which trackwork is carried out should ensure that a suitable risk assessment is carried out, and a safe system of work prescribed before work begins.

326 Those at risk of being struck by moving vehicles will include:

- people engaged in trackwork; and
- people walking the track for inspection purposes.

327 The safe passage of rail vehicles over temporary trackwork or track under repair is an important consideration.

328 Lifting and handling may also present additional hazards to track workers.

329 The initial risk assessment should be followed up by periodic auditing of work in progress.

Safe systems of work

Human factors

330 Human factors affecting trackwork will include:

- appropriate manpower levels;
- specialist skills and knowledge;
- attitude towards safety;
- understanding dangers involved; and
- site discipline and tidiness.

331 In addition to track workers and supervisors, train drivers and guards should also be suitably instructed and trained in respect of safety during trackwork.

332 Trackwork should be properly supervised by competent people.

Train movements

333 Where possible, the running of trains should be suspended while trackwork is carried out. This may require rescheduling of normal transport arrangements. On twin or multiple-line systems, work may be carried out on one track and locomotive-hauled trains may be diverted onto an adjacent track.

334 On rope-hauled systems, the presence of a moving rope is an additional hazard, and the risks it poses should be identified before deciding whether maintenance can be safely carried out while the rope is running.

335 When trackwork is carried out while trains are running, protective measures will need to be taken to safeguard workers. These may include:

- setting speed limits for trains;
- erecting warning markers and warning signs in the roadway;
- providing a system of communication between train drivers and track workers;
- establishing **cautionary zones** around trackwork;
- providing places of refuge; and
- provision of runaway protection devices for gradient work.

Cautionary zones
336 A cautionary zone is established around trackwork by erecting temporary markers across the track that are clearly visible to an approaching train driver or guard. The zone may encompass a local workplace only or an entire length of roadway. The train driver must stop at the markers and gain permission from a nominated track worker before passing through. The nominated person is responsible for checking that all people within the zone are in a position of safety before allowing the train to pass through.

337 Train drivers or guards should be alerted to the presence and location of cautionary zones.

338 Audible warnings from a train driver's horn should not be relied upon as part of a prescribed precautionary system of work.

339 The risks posed by short duration trackwork are similar to those that arise due to major trackwork. Similar precautions should therefore apply.

Places of refuge
340 Places of refuge should:

- be readily accessible;
- be clearly marked;
- have adequate capacity for those on site;
- not be used to store tools or materials; and
- include places for safe resting, eating etc.

341 If it is impracticable to provide sufficient suitable places of refuge for track workers, then any transport operation which may give rise to risk to those working in the transport roadway should be suspended during trackwork.

Pedestrian safety

342 Arrangements should be made for safe passage:

- to and from places where trackwork is being carried out;
- during routine roadway and track inspections; and
- for tracklayers and supervisors who necessarily move from site to site.

343 Such arrangements might include:

- organising transport (except for inspection);
- obtaining permission from the official in charge of that part of the mine;
- obtaining permission from the transport controller;
- communication with train drivers; or
- a combination of these.

344 The use of clean, high-visibility reflective work wear is important for any person travelling or working along a rail track and should always be used.

Lifting and handling hazards

345 Arrangements for packaging, transporting, manual handling, and the storage of tracklaying materials and equipment need to be considered to minimise the risk of injury from those activities. Where manual handling is unavoidable, the use of handling tools, eg for handling long rail lengths, may reduce the risk of trapped fingers and back injury.

346 Site tidiness plays an important part in preventing slipping and tripping accidents.

Vehicle arrestors

Prevention and control of runaways

347 The principal objective is to prevent runaways by:

- stopping uncontrolled vehicles from travelling onto a gradient; and
- avoiding inadvertent uncoupling of vehicles travelling a gradient.

348 Where people are unavoidably in a transport road, precautions should be taken to control any risk of injury from runaways. Arresting devices may be installed in roadways, on vehicles or both. This chapter deals with arresting devices installed in roadways. Such devices must automatically assume the safe operating position.

Retarders

349 A retarder is a device designed to withstand the force of initial impact, and then progressively absorb the energy of the train to minimise personal injury or equipment damage.

350 The amount of energy they will have to absorb will influence the location and number of retarders required in any particular situation.

351 Where locomotive haulage or manriding takes place, the type of retarder should arrest a runaway with a suitable retardation that will not cause personal injury or derailment.

352 Retarders can create risks. For example, if a retarder head rises as a train is passing over, it may cause derailment. Therefore, avoiding inadvertent operation of a retarder also needs to be considered.

353 Retarders must automatically resume the arrest position. As a precaution, indication that the retarder is set in the arrest position should be given to approaching locomotive drivers before descending a gradient. Automatic systems require further considerations, and are not dealt with in this guidance.

354 Ideally, the retarder head should contact the vehicle on a level with, or close to, the vehicle's centre of gravity. A high contact point on the vehicle will induce an overturning force in the arrestor, reducing its freedom to slide. A low contact point on the vehicle will tend to overturn the vehicle, or cause the upper part of bogie type vehicles to be separated from the chassis.

355 Fixed devices are not retarders and are only suitable for maintaining vehicles within a defined marshalling or parking area of track.

Types of retarder

356 There are three basic types of progressive arresting devices currently in general use:

- **limited movement retarders**, eg safety gates and floor Warwicks having some sliding facility;
- **sliding head friction retarders** with energy absorbing friction blocks; and
- **gravel drag retarders**.

Limited movement retarders
357 These are really fixed arrestors that have either been mounted onto a frame, which slides along fixed runners, or the base assembly displaces ballast. They have limited energy absorption capability.

358 The safety gate type (see Figure 52), has a base frame cleated to floor-bolted running rails with typically up to 3 m of sliding action.

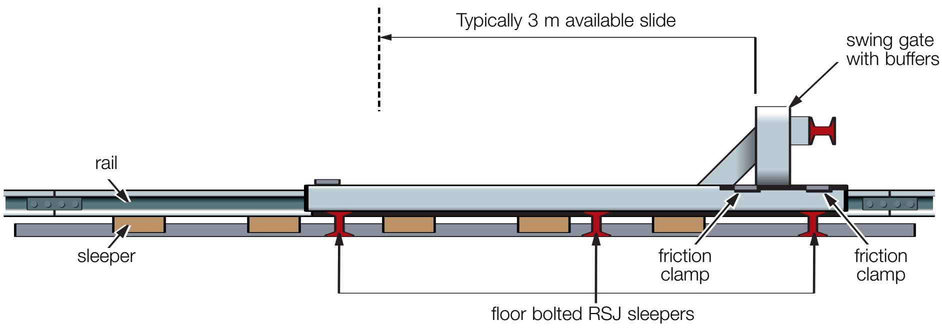


Figure 52 Safety gate retarder

359 The floor-Warwick type (see Figure 53), is set in a shallow excavation filled with ballast. The frame on which the Warwick is mounted slides on impact, displacing the ballast.

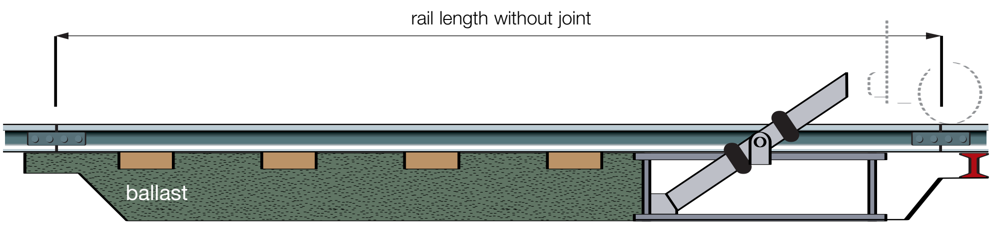


Figure 53 Floor Warwick retarder

360 Tests have shown that the energy that can be absorbed by sliding retarders without them sustaining damage is around 360 kJ for a 3 m sliding safety gate type, and 500 kJ for the floor-Warwick type with ballast displacement, compared to around 80 kJ for a fixed safety gate.

361 Vehicles and/or loads may be projected over an arrestor if the initial resistance to arrestor movement is too great, particularly at high speeds and on steep gradients. This type of retarder is normally limited to use on gradients of less than 1 in 10.

362 The rails on the upper side of a limited movement retarder should be fastened down to floor-bolted sleepers, to maintain track alignment with the arrestor. The rails through the arrestor should be continuous, to allow unrestricted movement of the sliding assembly. If fishplates are used, care needs to be taken to ensure they do not interfere with base frame cleats and stop the assembly from sliding.

Sliding-head friction retarder

363 Sliding-head friction retarders rely on a runaway vehicle impacting on an arrestor head, which then slides along special friction rails. As it slides it progressively comes into contact with friction blocks mounted on the friction rails and tightened to predetermined and increasing torque values (see Figure 54).

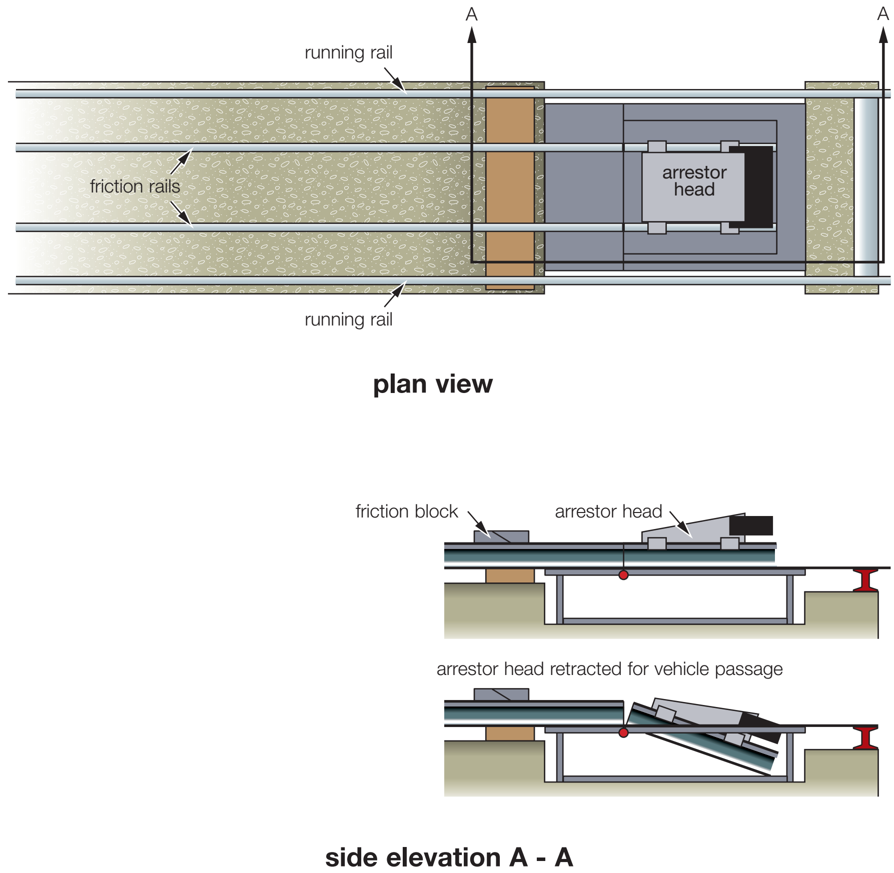


Figure 54 Friction retarder

364 This arrangement produces a known rate of energy dissipation, and the length of friction rail required can be predicted.

365 One of the main benefits of the sliding-head friction retarder is that the initial retardation can be kept low by having the first set of friction blocks at a relative low torque setting. Subsequent blocks can be set at increasingly higher torque, to gradually bring the train to rest within a reasonable distance and in a controlled manner. To arrest high values of kinetic energy, these retarders could be around 100 m long with a number of friction blocks.

366 Following an arrest, it is unusual for there to be any damage to the retarder, and friction blocks can often be refitted in their original position, re-torqued and be immediately restored to provide runaway protection. Friction block pads will need to be replaced when the limits of wear are reached.

367 Another type of sliding-head friction retarder relies on the sliding head, deforming metal to absorb energy rather than using friction blocks.

Gravel drag retarder

368 This type relies on runaway vehicles being diverted from the normal running rails such that the vehicle wheels are forced to run through a bed of gravel (see Figure 55).

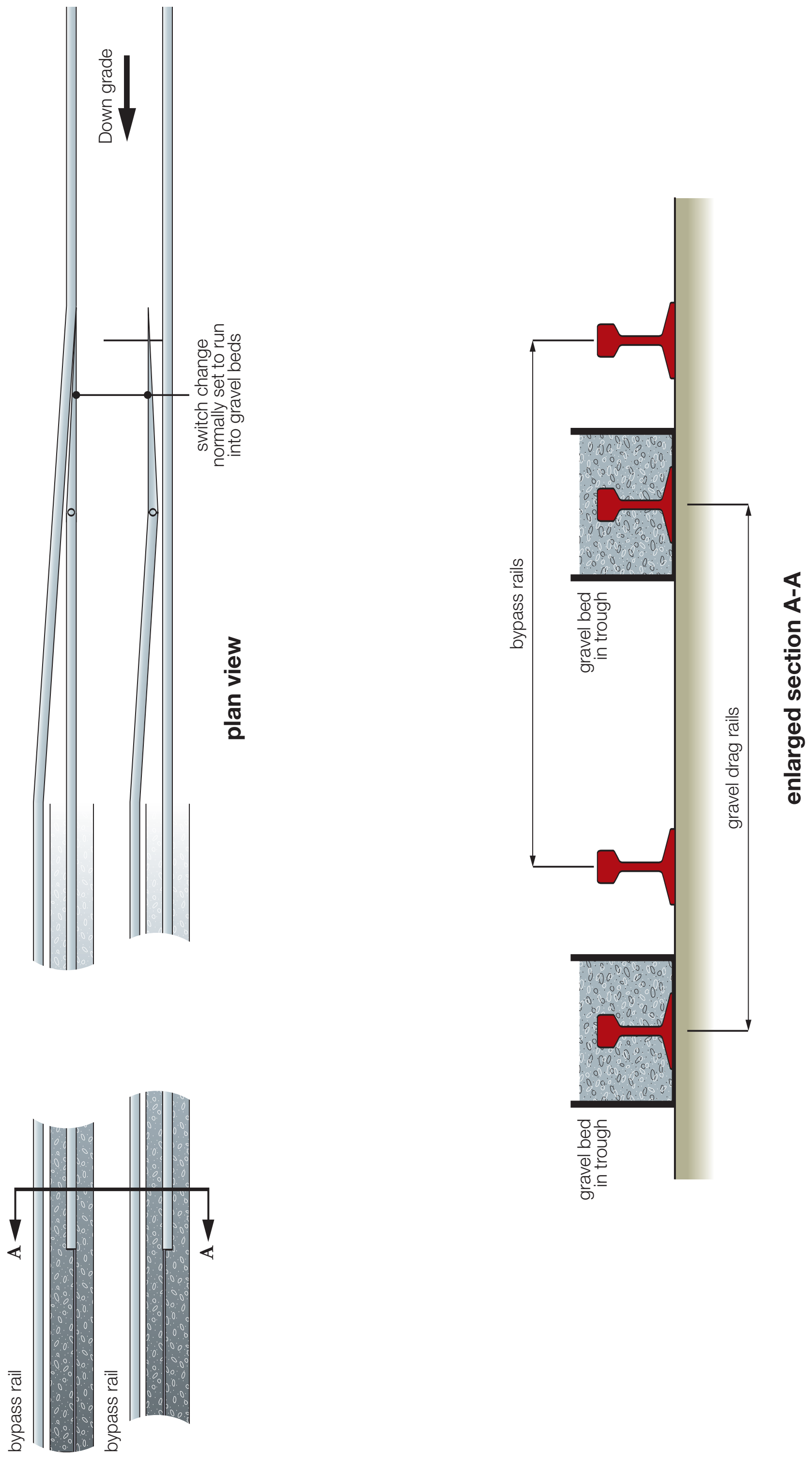


Figure 55 Gravel drag retarder

369 Tests of this type of arrestor have demonstrated that gravel drags are superior to sand drags, and pea gravel produced good predictable retardation, from which the required length of an arrestor can be determined.

370 A set of switch blades is provided in the track to divert vehicles from the normally set ‘straight-on’ position, which leads into the gravel beds, onto a separate running line that bypasses the gravel beds. The switch must automatically resume the position that leads into the retarder.

371 The gravel bed is contained within a fabricated trough surrounding each rail. The rails would initially be at full height, and taper, over approximately 1 m, down to nothing so that the wheels have to force a path through the gravel. Guidance to the back of wheel flanges is provided by rolled steel angles. The action of displacing and crushing the gravel gradually absorbs the train’s energy and brings it to rest.

372 Before installing this type of retarder, it is necessary to ensure that sufficient clearance underneath all vehicles is available to allow the wheels to fully bed into the gravel without the vehicle chassis bottoming on the gravel trough.

Appendix: Legislation relevant to this guidance

Coal and Other Mines (Locomotives) Order 1956 SI 1956/1771 The Stationery Office 1956

Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960 SI 1960/69 The Stationery Office 1960

Electricity at Work Regulations 1989 SI 1989/635 The Stationery Office 1989 ISBN 0 11 096635 X

Health and Safety at Work etc Act 1974 The Stationery Office 1974 ISBN 0 10 543774 3

Lifting Operations and Lifting Equipment Regulations 1998 SI 1998/2307 The Stationery Office 1998 ISBN 0 7176 1628 2

Management and Administration of Safety and Health at Mines Regulations 1993 SI 1993/1897 The Stationery Office 1993 ISBN 0 11 034897 4

Management of Health and Safety at Work Regulations 1999 SI 1999/3242 The Stationery Office 1999 ISBN 0 11 085625 2

Manual Handling Operations Regulations 1992 SI 1992/2793 The Stationery Office 1992 ISBN 0 11 025920 3 (as amended by the *Health and Safety (Miscellaneous Amendments) Regulations 2002* SI 2002/2174 The Stationery Office 2002 ISBN 0 11 042693 2)

Mines and Quarries Act 1954 The Stationery Office 1954

Miscellaneous Mines Order 1956 SI 1956/1778 The Stationery Office 1956

Provision and Use of Work Equipment Regulations 1998 SI 1998/2306 The Stationery Office 1998 ISBN 0 11 079599 7

Supply of Machinery (Safety) Regulations 1992 SI 1992/3073 The Stationery Office 1992 ISBN 0 11 025719 7

References

1 Coal and Other Mines (Locomotives) Order 1956 SI 1956/1771 The Stationery Office 1956

2 BS 248: 1969 *Specification for light rails and fishplates for use at mines* British Standards Institution

3 BS 11: 1985 *Specification for railway rails* British Standards Institution

4 *The use of electricity in mines. Electricity at Work Regulations 1989. Approved Code of Practice* L128 HSE Books 2001 ISBN 0 7176 2074 3

5 *The management and administration of safety and health at mines. Management and Administration of Safety and Health at Mines Regulations 1993. Approved Code of Practice* L44 HSE Books 1993 ISBN 0 7176 0618 X

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