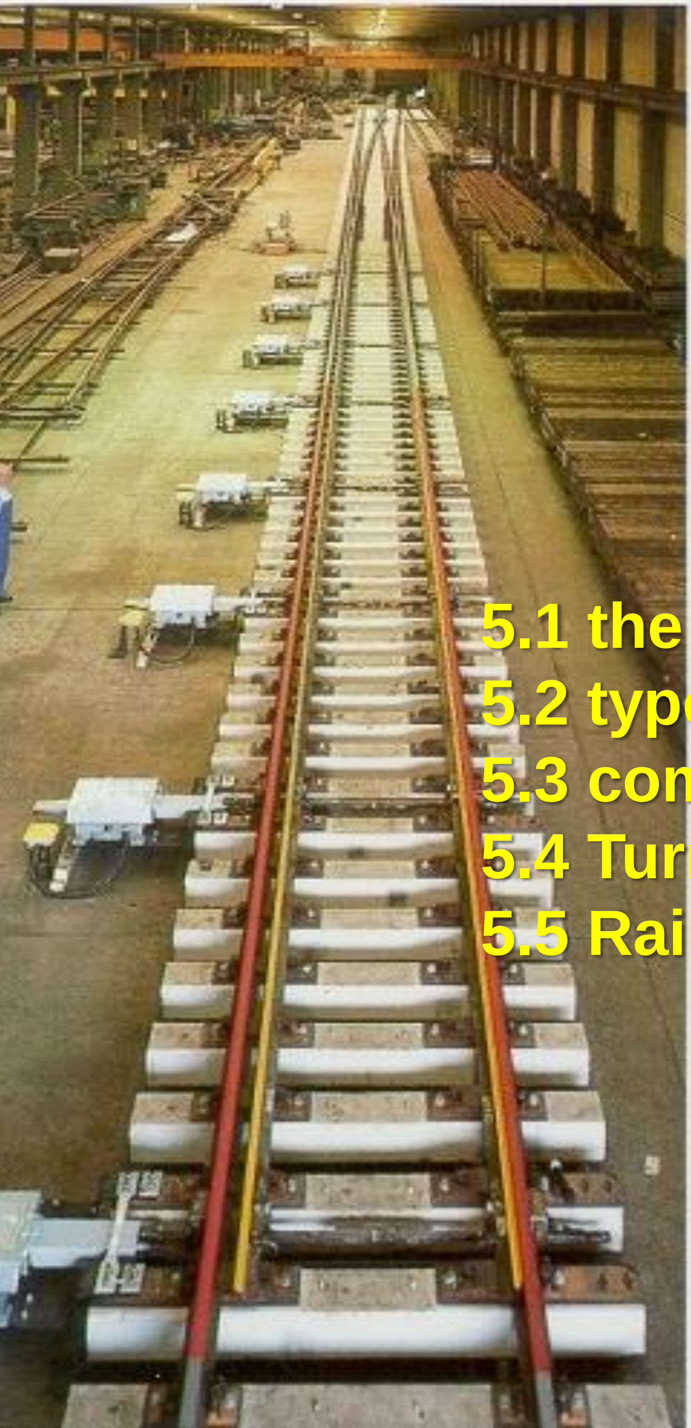
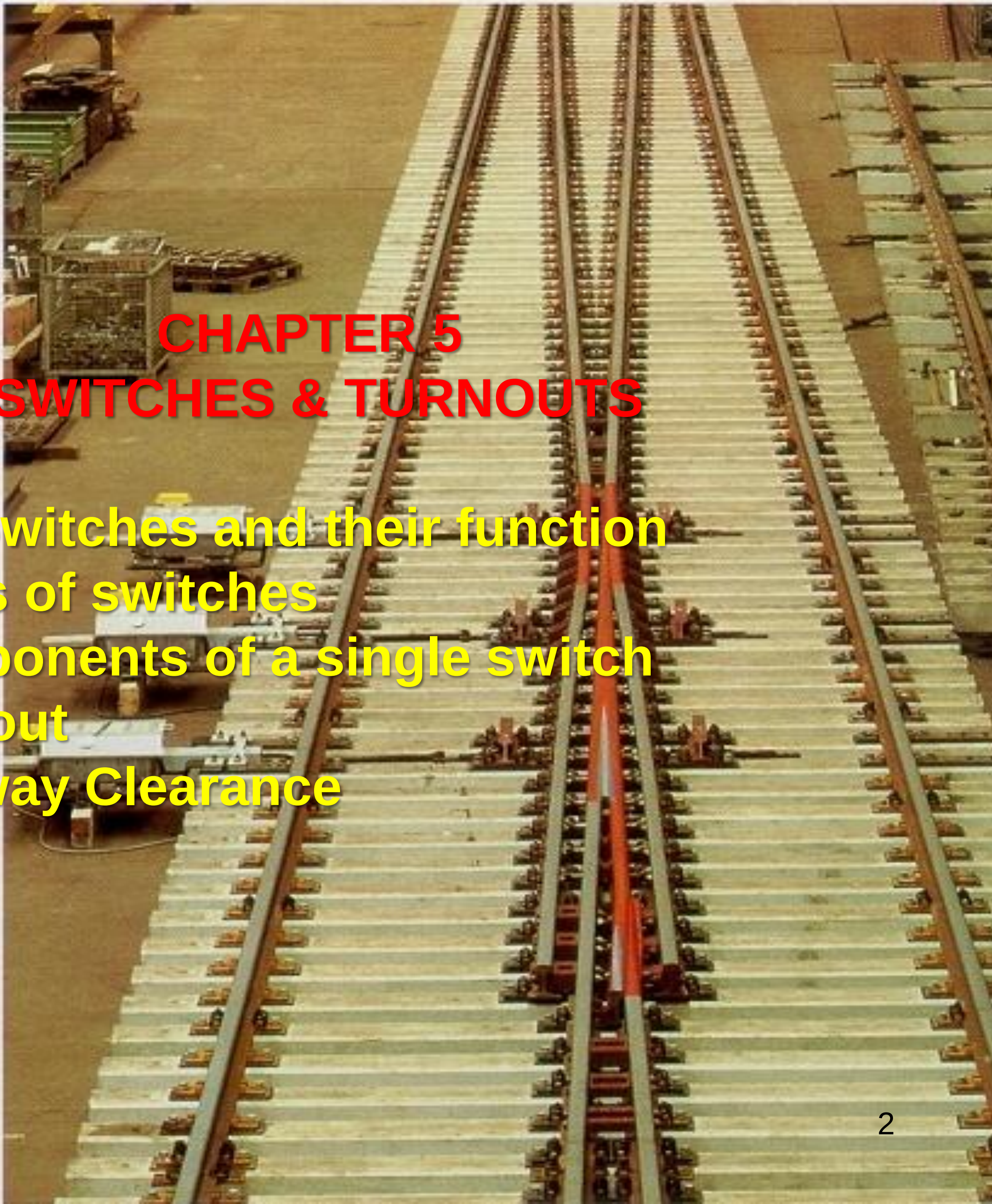
RAILWAY ENGINEERING (CENG 5242)

CHAPTER 5 SWITCHES & TURNOUTS





CHAPTER 5
SWITCHES & TURNOUTS

5.1 the Switches and their function
5.2 types of switches
5.3 components of a single switch
5.4 Turnout
5.5 Railway Clearance

5.1 The Switches and their function

- Switches are of special importance for railways, as they are the prerequisite for the development of networks, i.e. for the branching and joining of tracks
- The productivity and line speed of a railway is essentially influenced by the number and type of its switches

- Turnouts and crossings facilitate to the rolling stocks to run from one track in to or across another track.
- The structure of a switch is far more complicated and expensive than that of the track grid

The Switches

- **The purpose of crossings is allow two track to intersect at same level**
- **Switches are structural elements requiring high investment and large-scale maintenance, they can severely hinder vehicle traffic**

- **The purchase costs for one effective meter of a switch (depending on the type of switch) are up to four times higher than for one meter of track**

- **Switches must be arranged and designed in such a way as to achieve a favorable layout of the line-** ***from the point of view of the dynamics of vehicle movement***

The Switches

- These design decisions are very important, as high dynamic forces might occur due to structural defects which then lead to defective track position and early wear

- The same standard of maintenance has to be achieved for switches and for track in order to prevent switches from becoming sources of disturbance.

The Switches

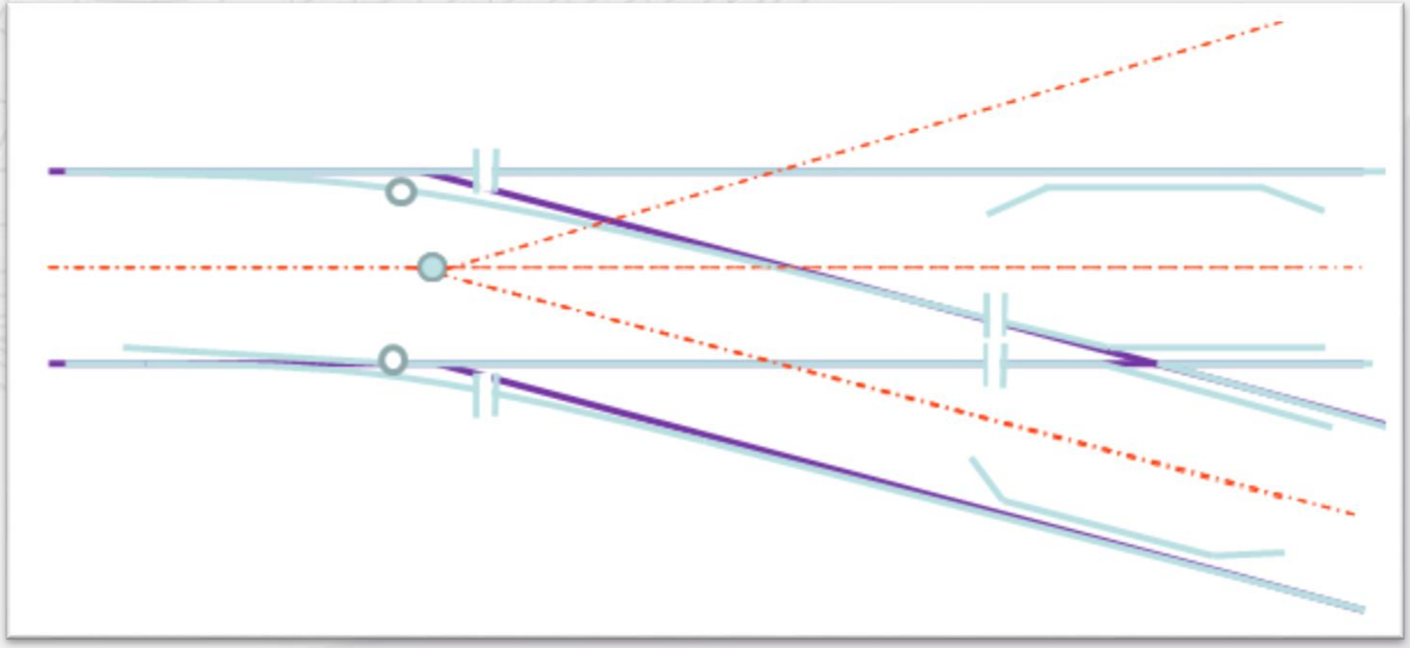
- The stress on the structural elements of switches is much higher than on track elements, as it is not possible to avoid places of discontinuous stress.
- Therefore, traditional switches can fulfill their task only up to a certain speed and stress level.
- New solutions have had to be found for the geometry and structure of switches on which trains pass at high speed and which are subject to high stress

- Switches enable vehicles to pass from one track to another without interrupting their run
- *Crossings are* the intersection of two tracks, diamond crossings with slips make it possible for vehicles to pass from one track to another without interrupting their run at the point of intersection
- The service life of a switch on wooden sleepers is nowadays 20 years, on concrete sleepers about 30 years

5.2 Main types of switches

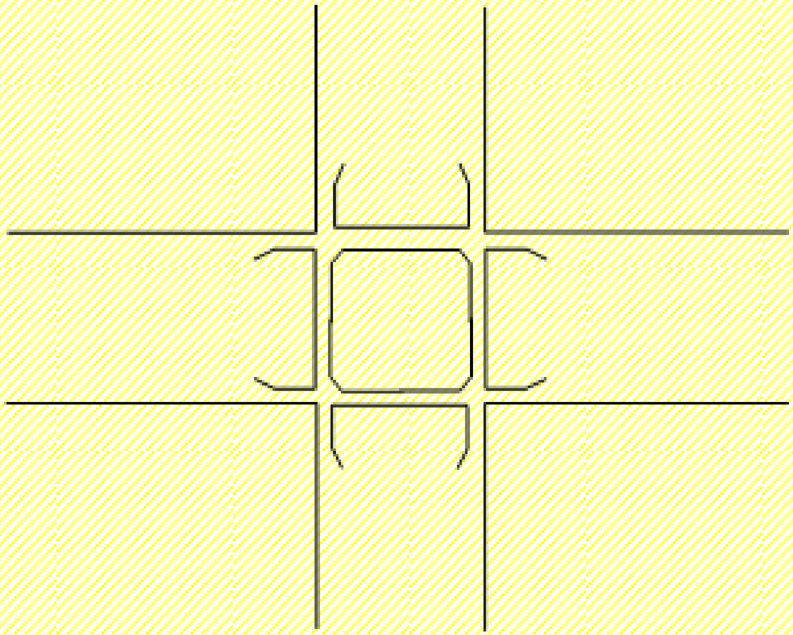
The main types of switches:

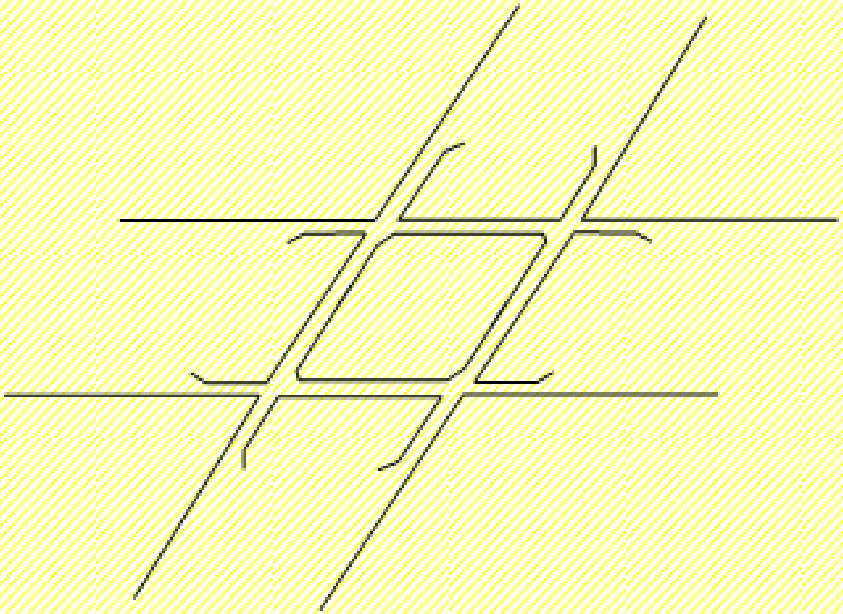
- *crossings and diamond crossings with slips*
- *split/single switches*
- *symmetrical switches*
- *three way switches*

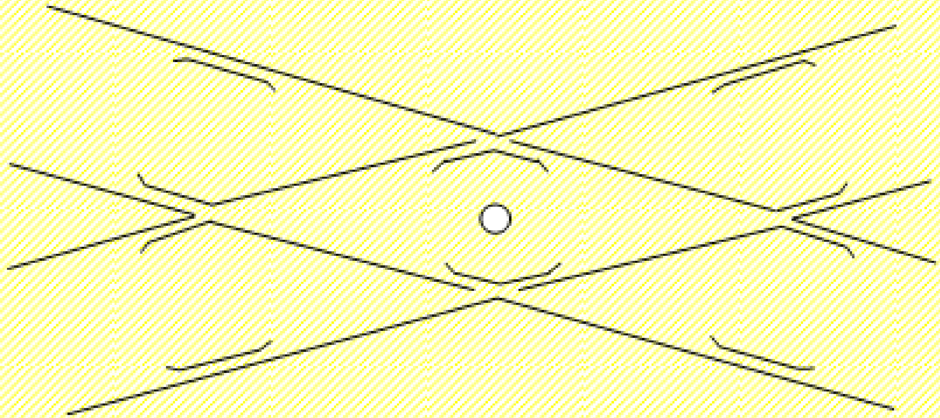


Crossings

Crossings



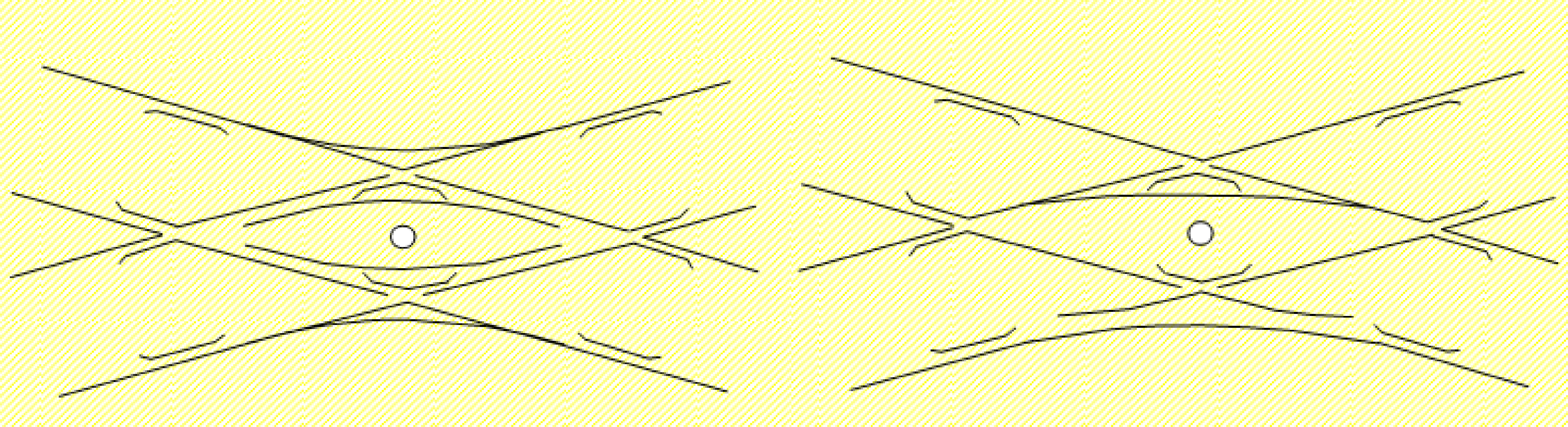




Crossings

Diamond crossings with slip/Slip switches

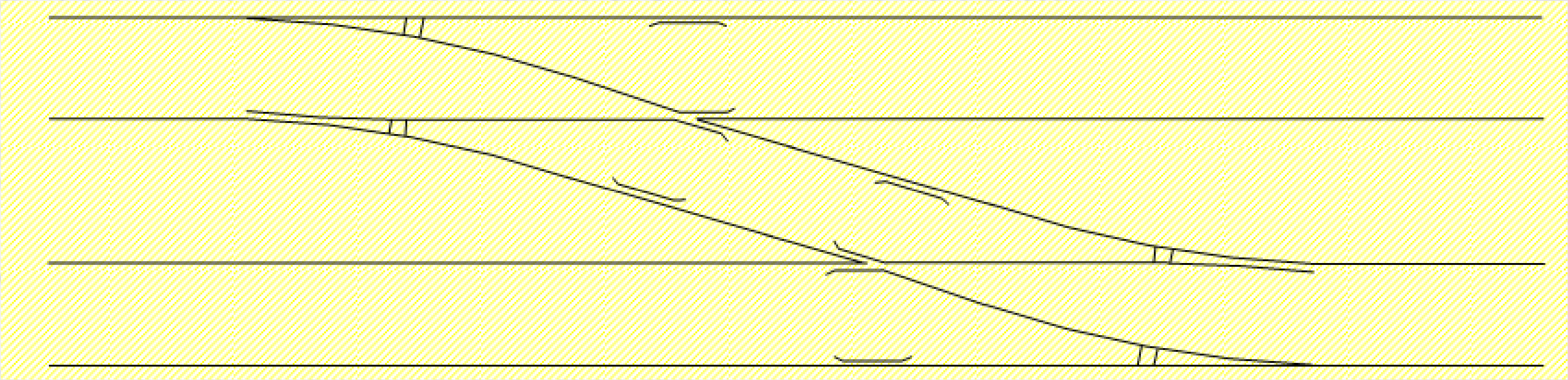
Schematic representation of a double diamond crossing with slip, with blades arranged within the diamond crossing



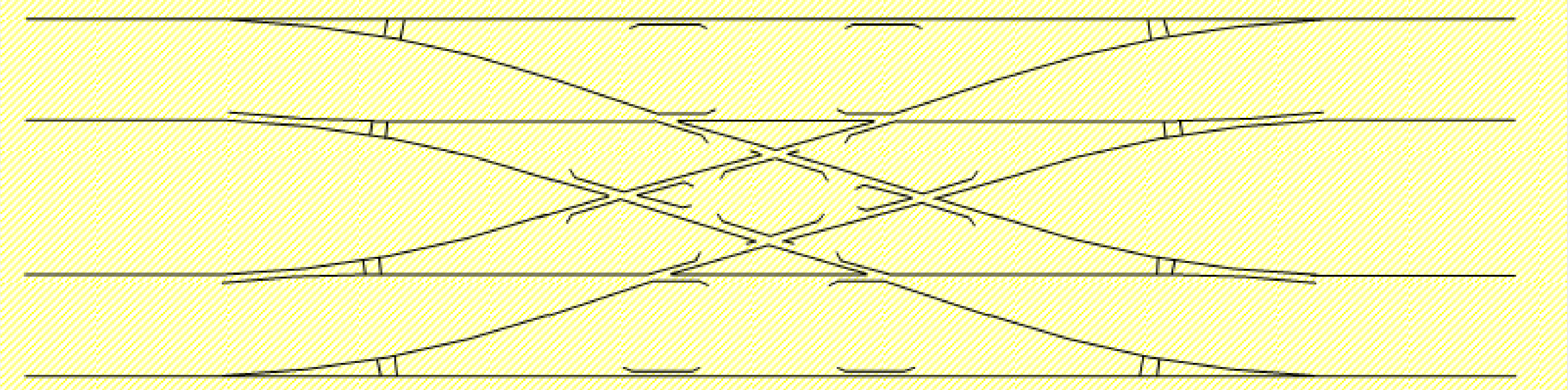
Crossings

Diamond crossings

Cross-over, double cross-over



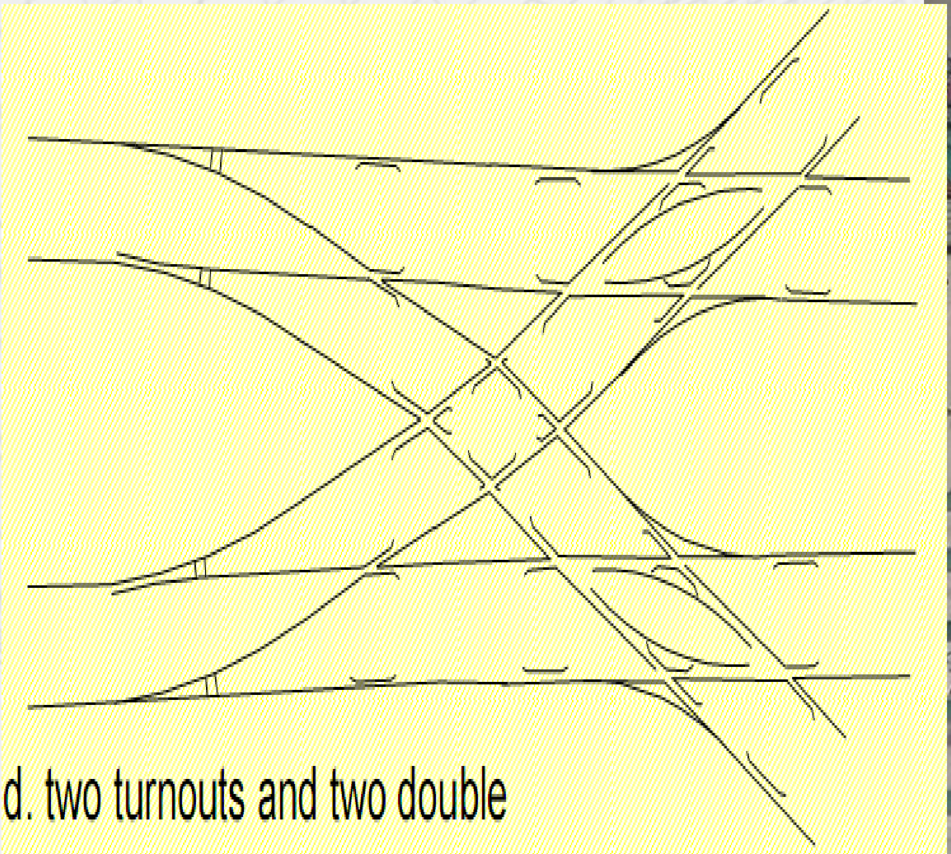
Curve diamond crossing



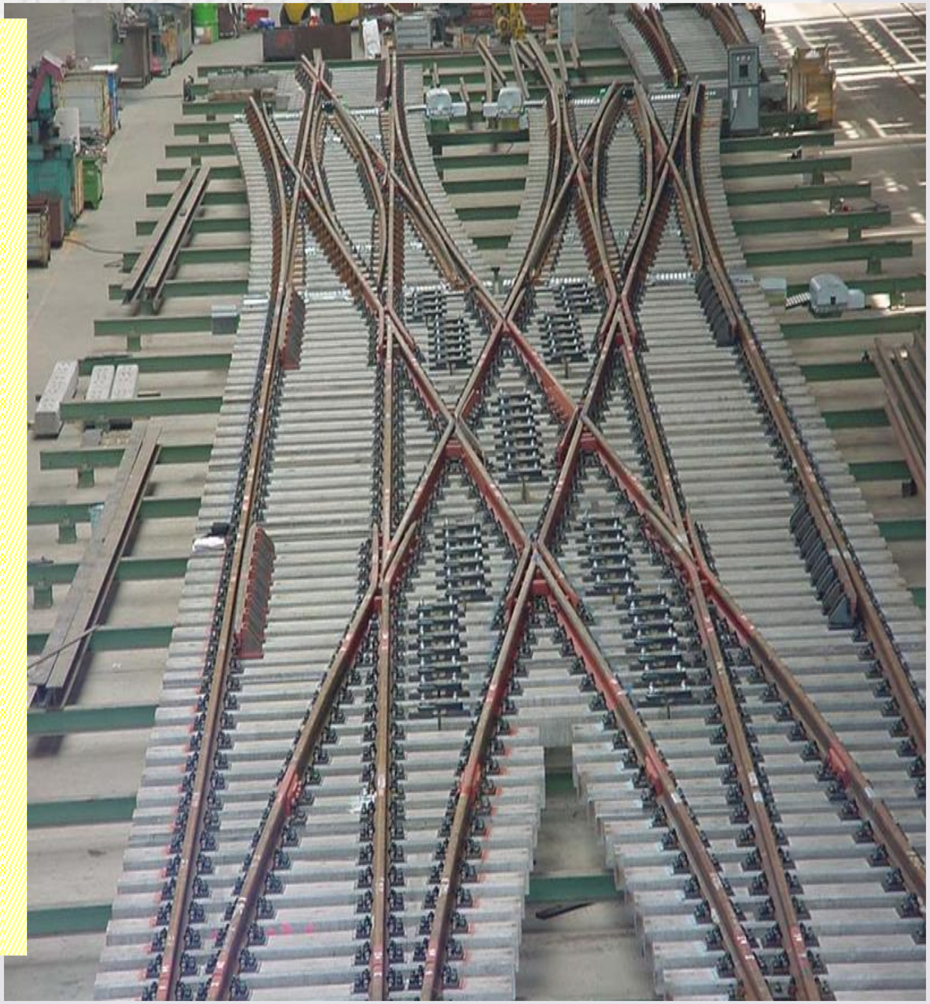
Two Intersecting crossovers with central diamond crossing

crossovers

Diamond crossings



d. two turnouts and two double slips with central diamond crossing



5.3 Components of a single switch

1. Switch proper: two Stock rails, two switch rails, rail fastening and switch machine (switch stand)
2. frog: frog centre, wing rails, appropriate rail fastenings. Movable frog, rigid frog
3. check/guard rails
4. Intermediate rails

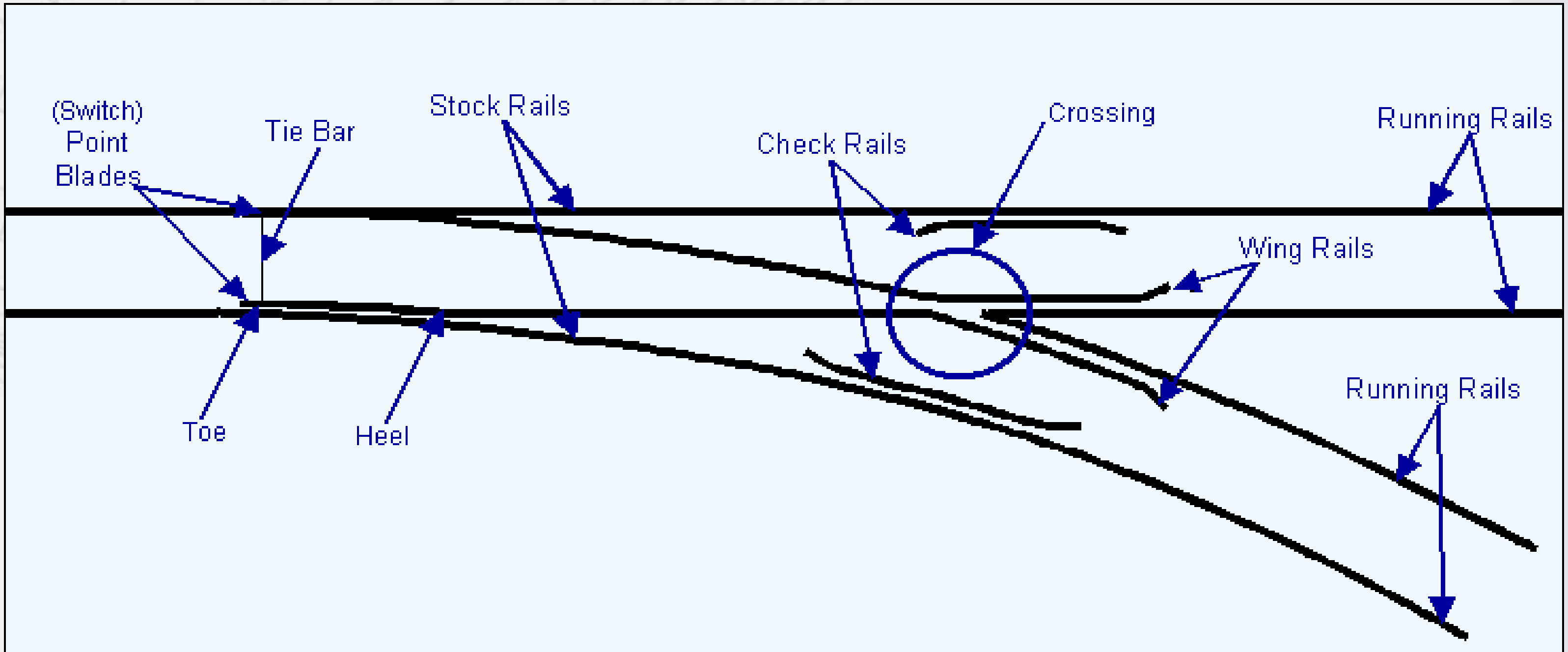


Diagram of simple turnout showing the names of the principal parts

5.4 Turnout

✓ Since the train usually needs to transfer from one line to another, the turnout is set to connect the lines

✓ Turnout is an important part of the rail, as its large quantity, short life, limited speed and low safety, it is called *the three big weak links with the curve and the joint.*

- Turns one track into two
- Three basic components

  Switch

  Closure Curve

  Frog
- ***Are designated by their frog number***

Standard turnout

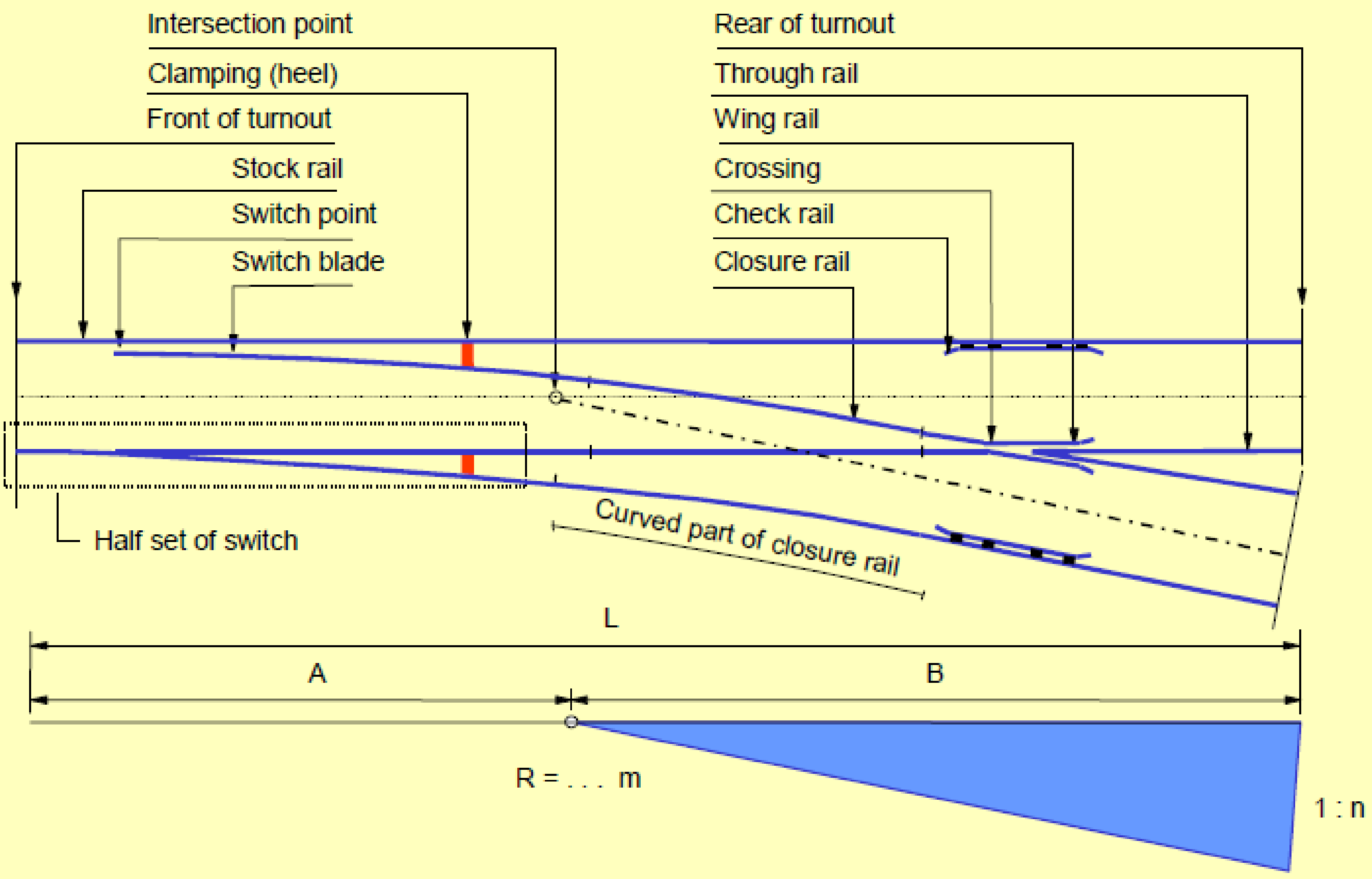
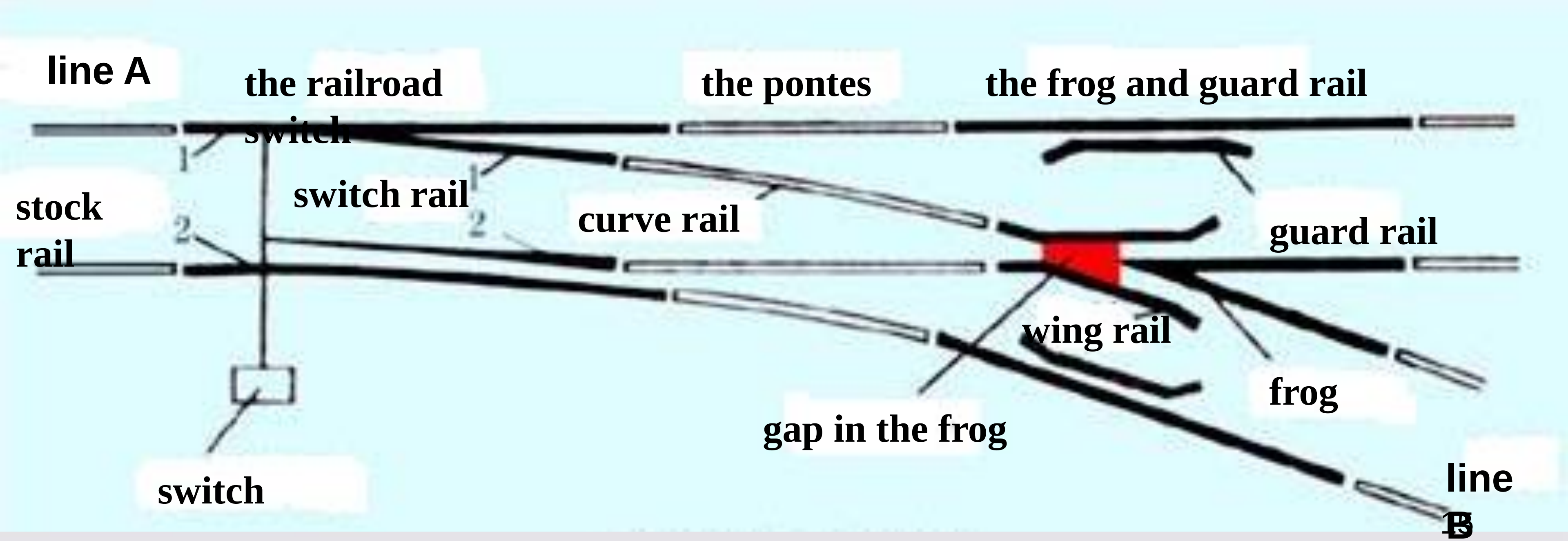


Figure 11.1: Standard right-hand turnout

Simple turnout

(1) components

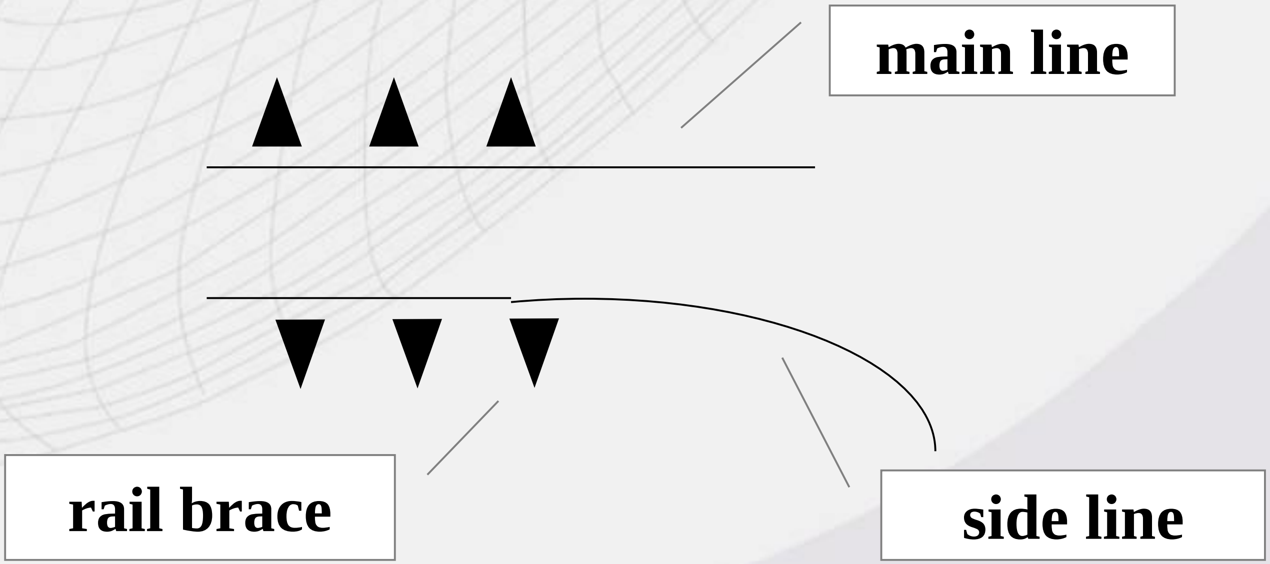
- **The railroad switch**: stock rail and switch rail- *to determine the opening direction of turnout*
- **The frog and guard rail**: wing rail, guard rail and frog - *to ensure the safety*
- **The pontes**: straight rail and curve rail- *to connect the line*



Simple turnout

Characteristic:

① main line is straight
② side line is curve
③ setting rail brace



Simple turnout

(2) the railroad switch

function: to guide the direction

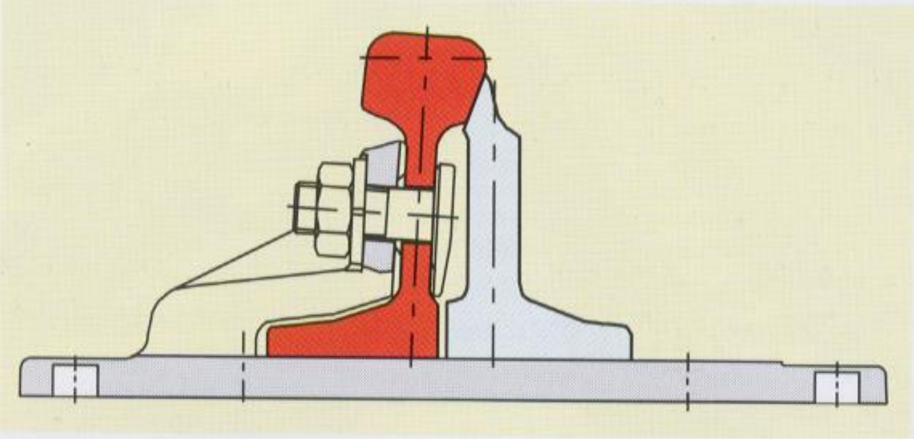
constitution: *two stock rails*, *two switch rails*, some union pieces and switch equipment.

Simple turnout

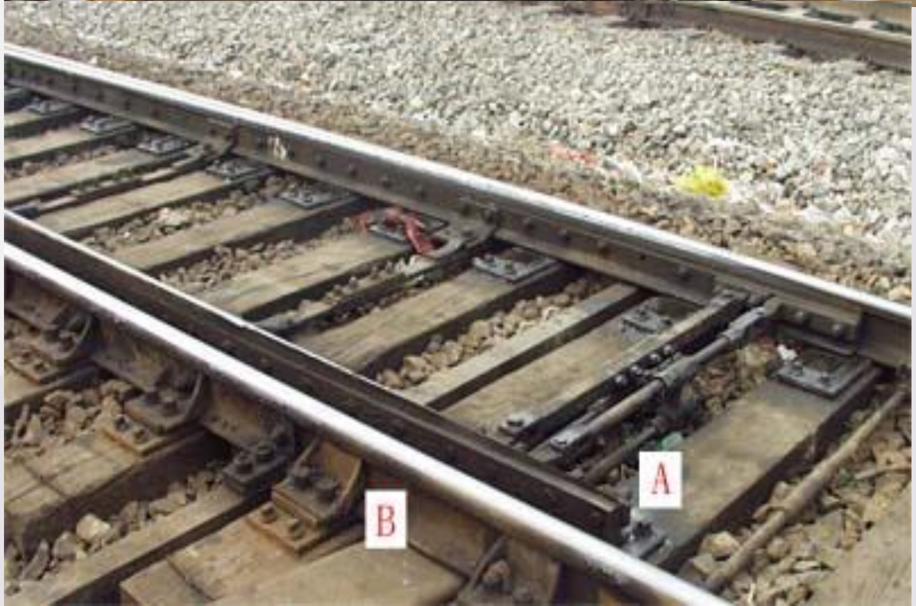
a) **Stock Rail :**usually with a length of 12.5m or 25m

b) **Switch rail**

switch blade and stock rail



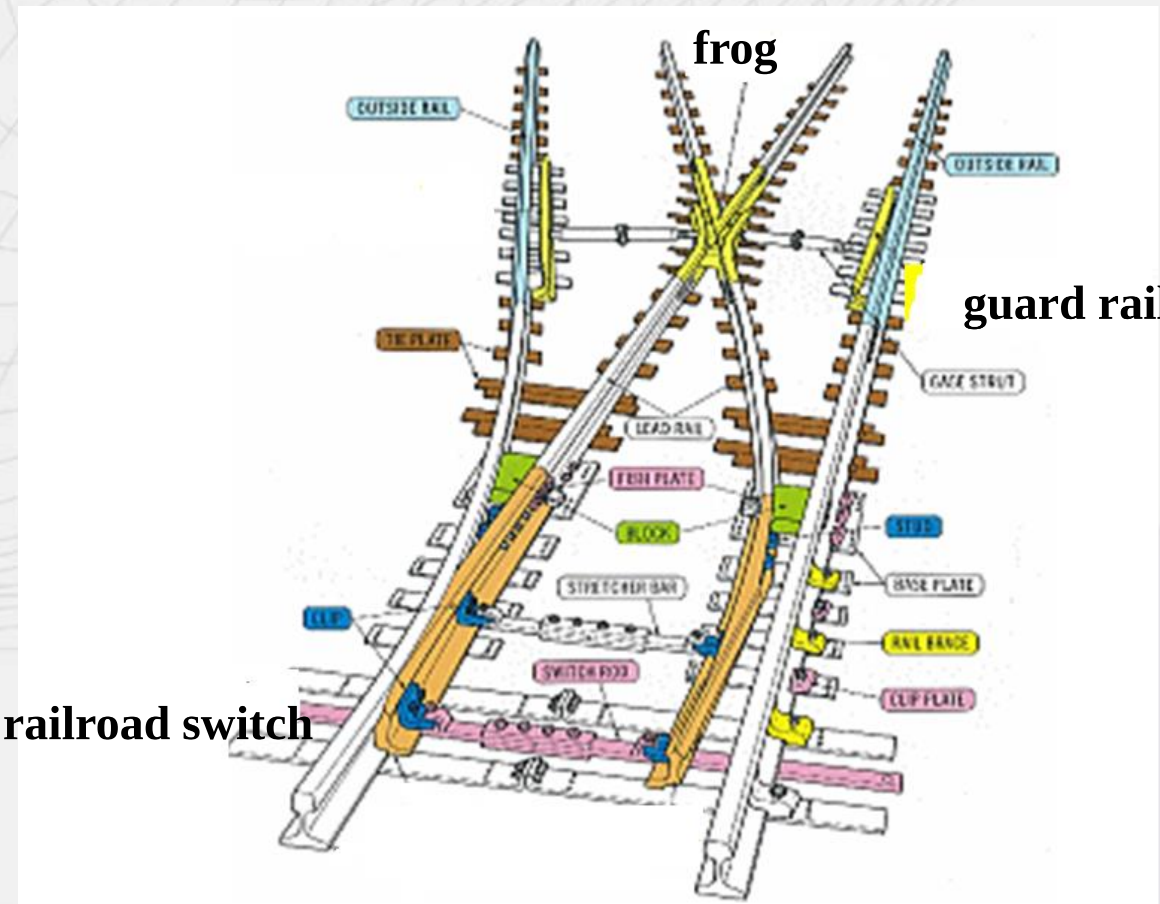
Cross-sectional drawing of T-rail switch blade



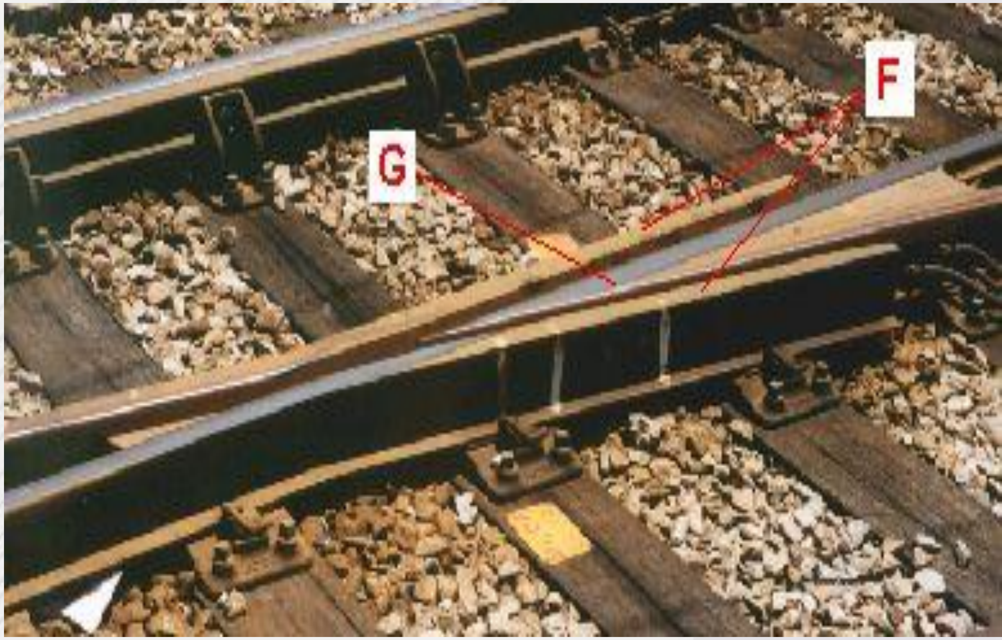
Simple turnout

(3) The frog and guard rail

consist of wing rail, guard rail, frog and some union pieces



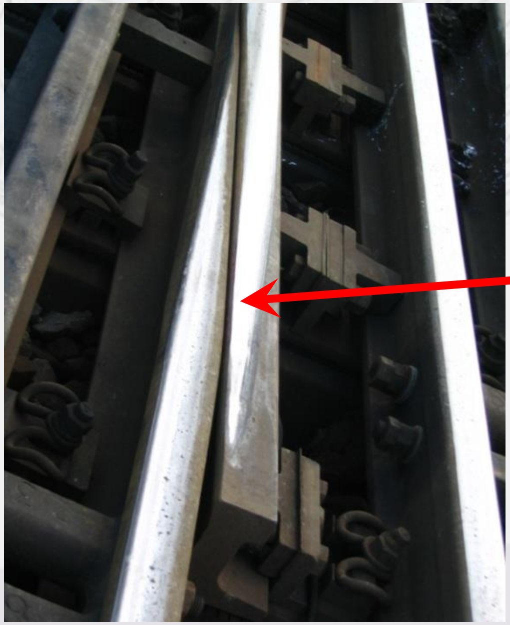
The frog

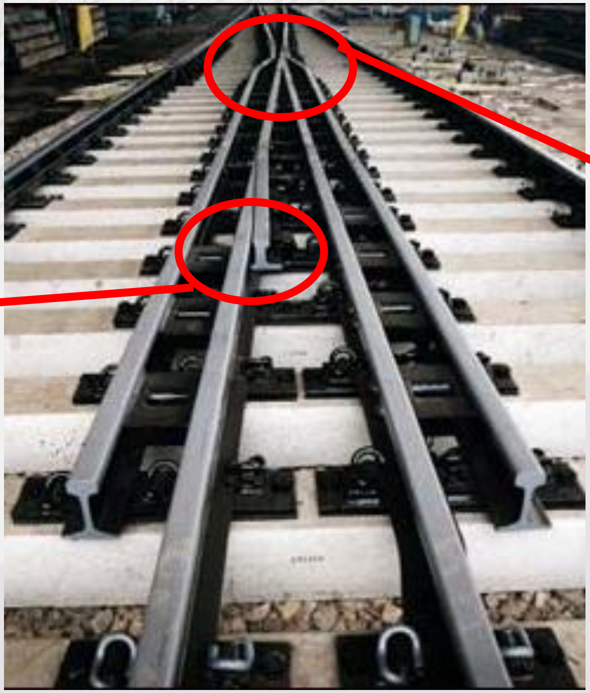


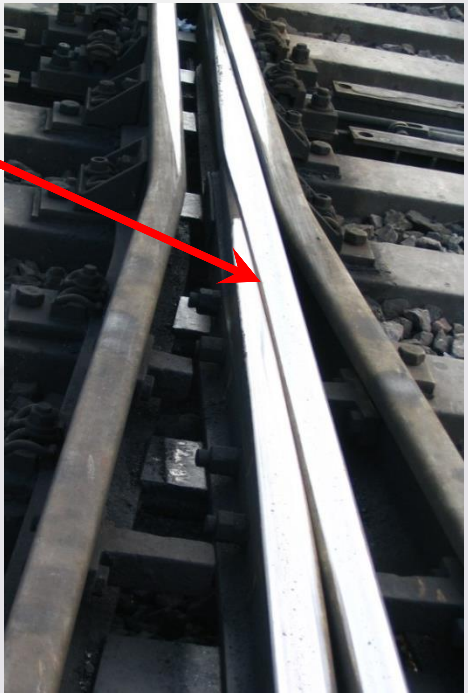
consist of wing rail and frog

There are two types of frogs

1. ***movable frog***
2. ***Fixed/rigid frog***



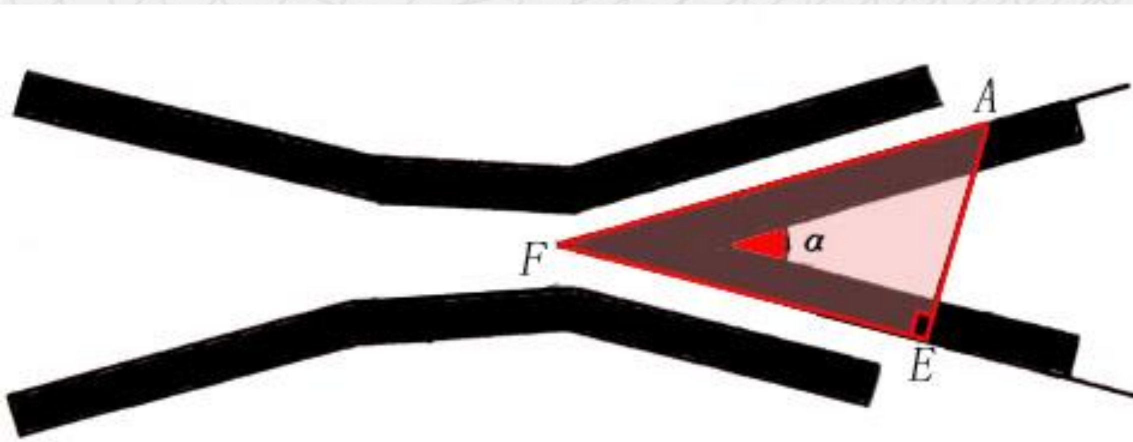




The frog

- Permit the wheel flange to cross over opposing rail in turnouts & crossings.

size of frog



$$N = ctg\alpha = \frac{EF}{AE}$$

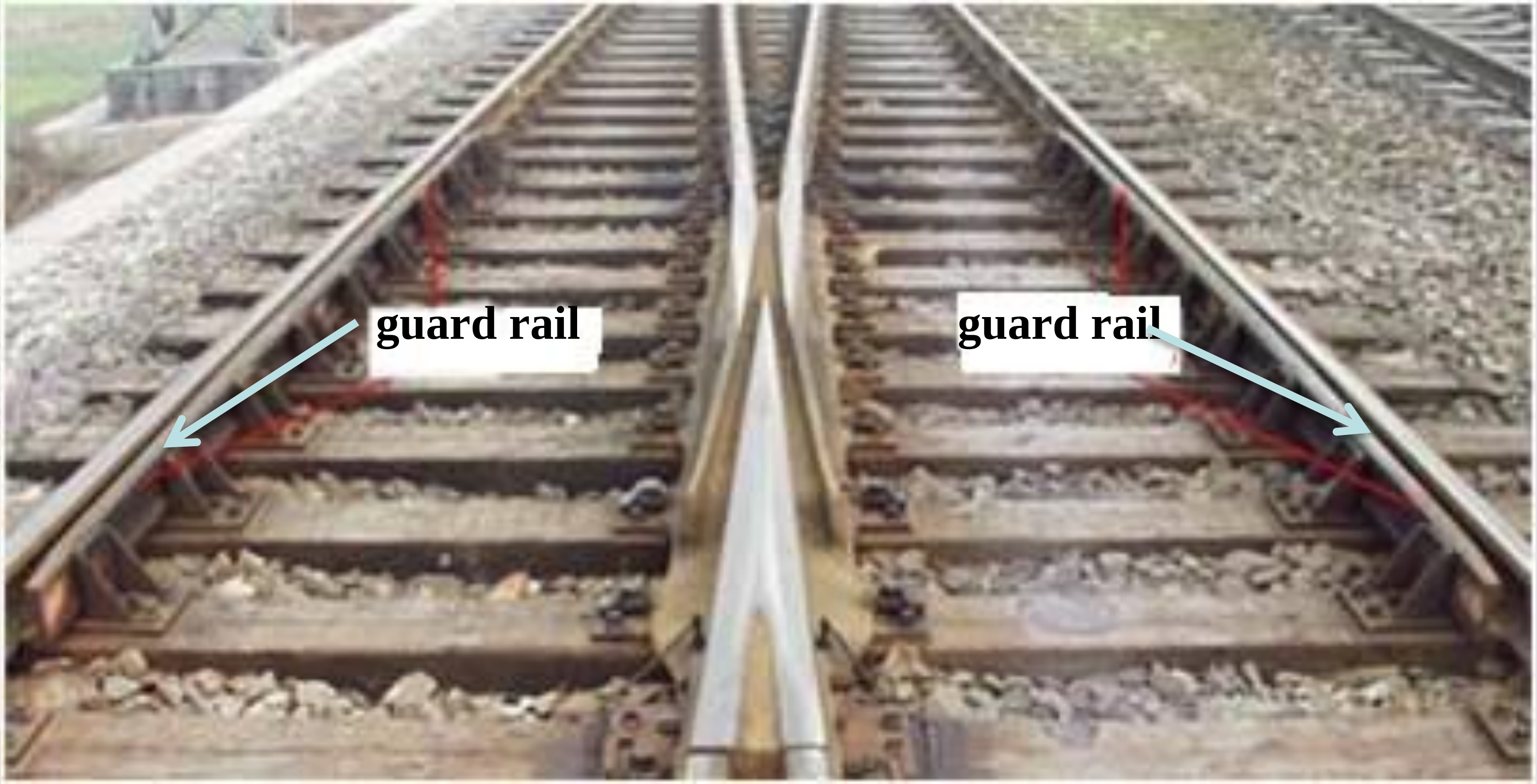
Rigid frog

The larger the size N is, the smaller the angle α it could, and the faster the allowable speed is.

2) guard rails

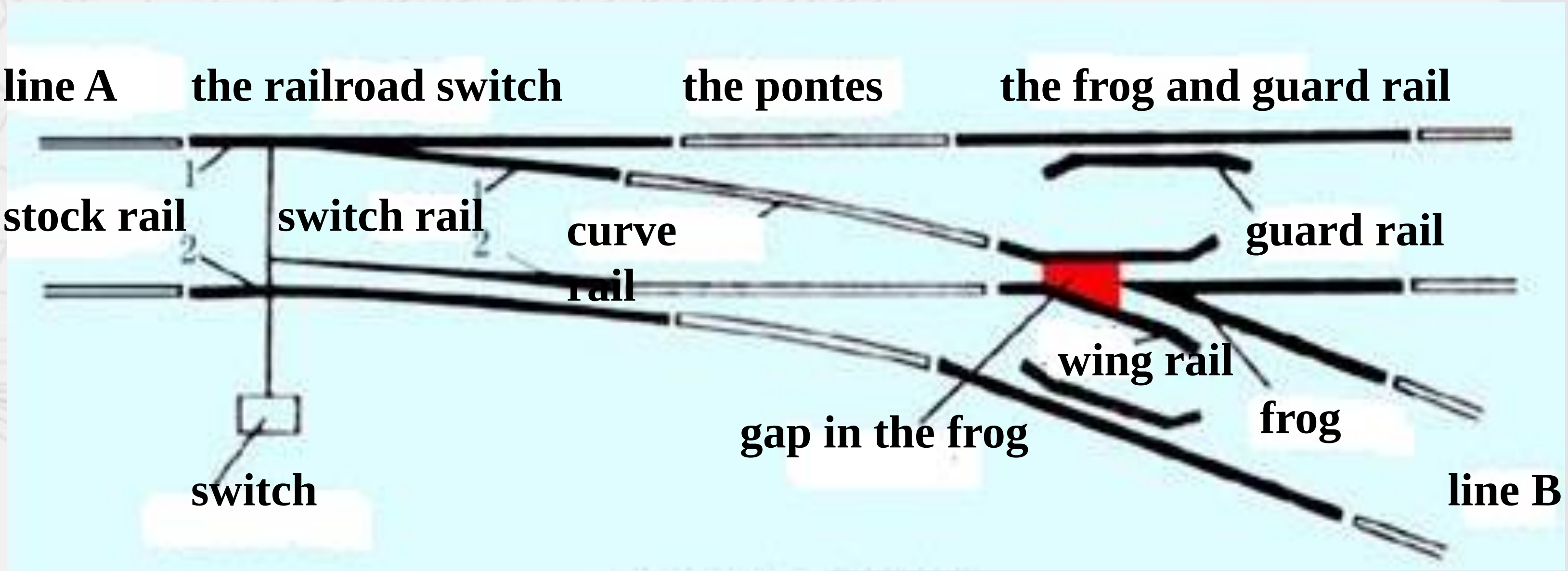
The function of guard rails are

- ***to counter act the dynamic force at the switch,***
- ***strengthen the stock rails,***
- ***prevent derailment wheel due to joints at the frog etc.***

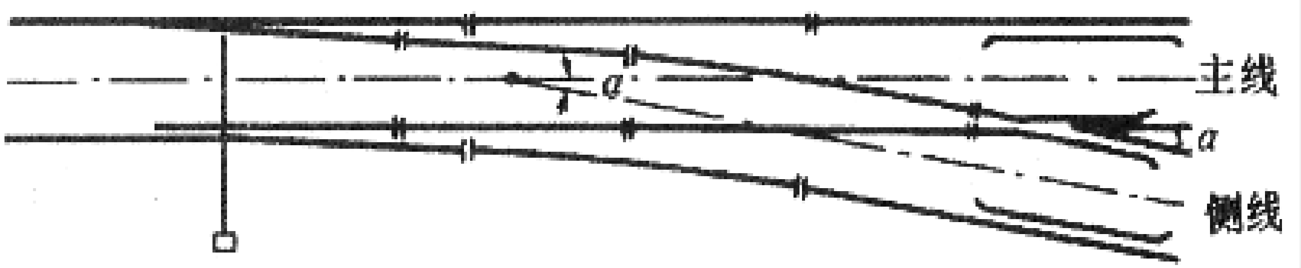


(3) the pontes

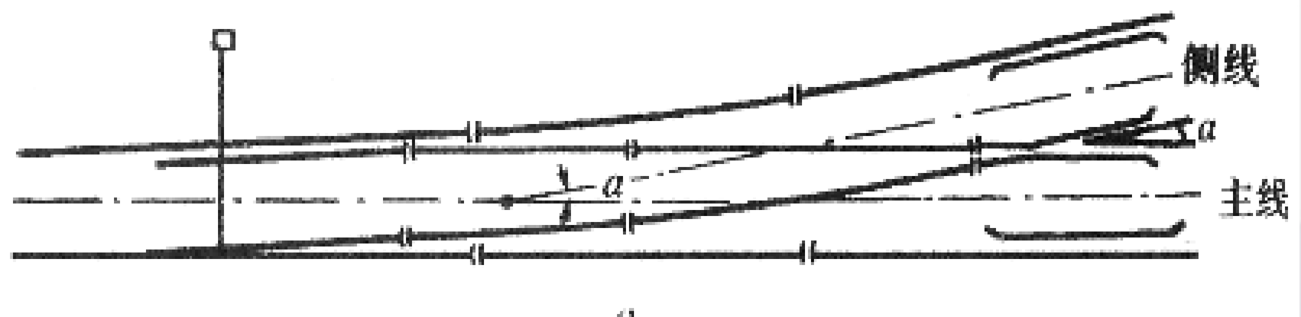
consist of straight rail and curve rail to join the switch area to the frog and guard rail



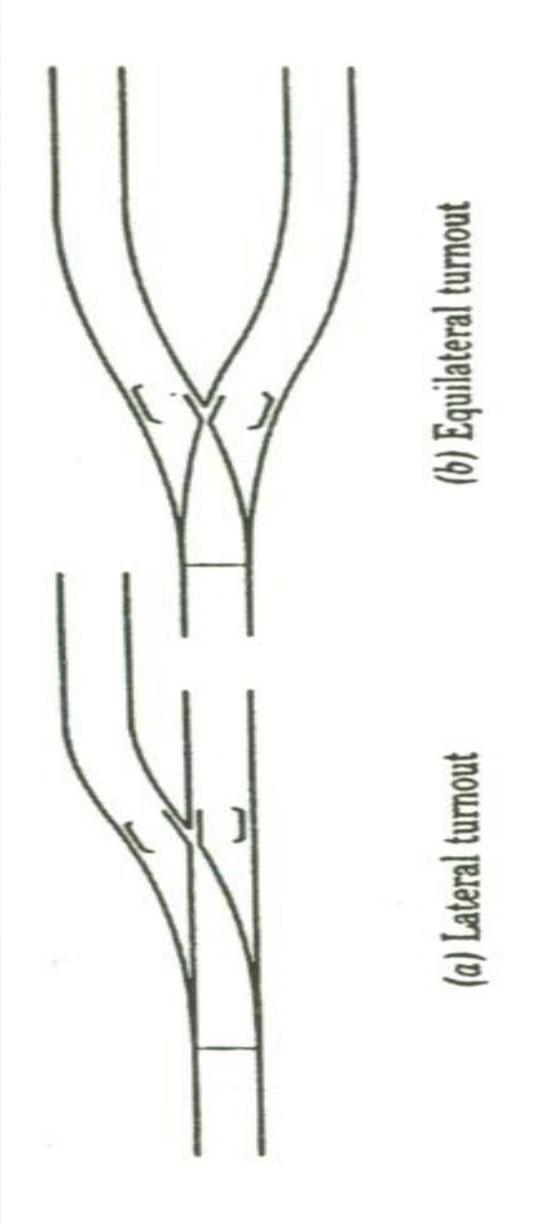
(4) Right and left turnouts



right-turnout



left-turnout



Symmetrical turnout

Symmetrical turnout increase the radius of curve rail, improve the speed and can shorten the length of the station

Characteristics:

① Both left and right lead curves shall be sidings with equal diameters, neither in straight nor side direction

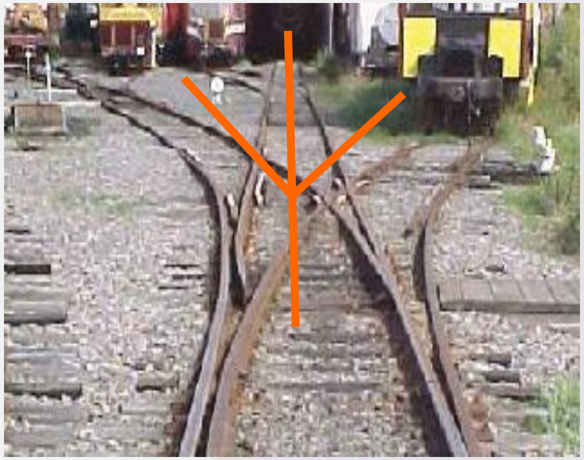
② It is able to increase the diameters of lead curves while reducing lengths of station yards.

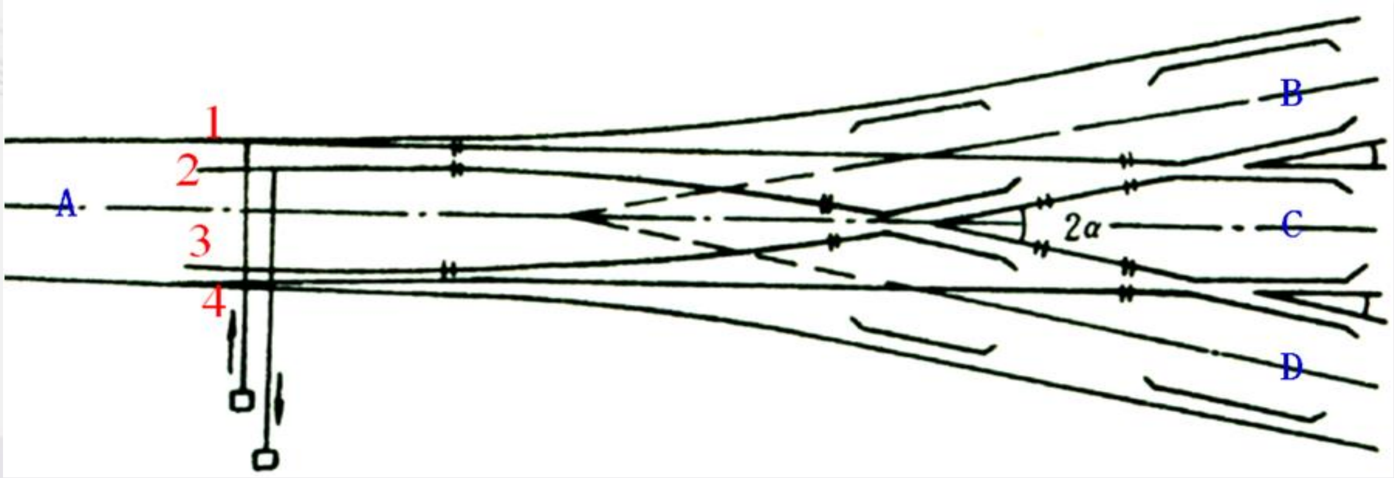
③ Suitable for locomotive depots, arrival yards, freight yards, etc.

Three-throw turnout

- ✓ **It has three frogs and can lead to three directions**

✓ It can decrease the use of land; but the life of its switch rail is short and it has gap in frog without the guard rail.





Slip switch

- ✓ It can lead to four directions
- ✓ Though the connecting length is shorten, there exists gap in frog without guard rail

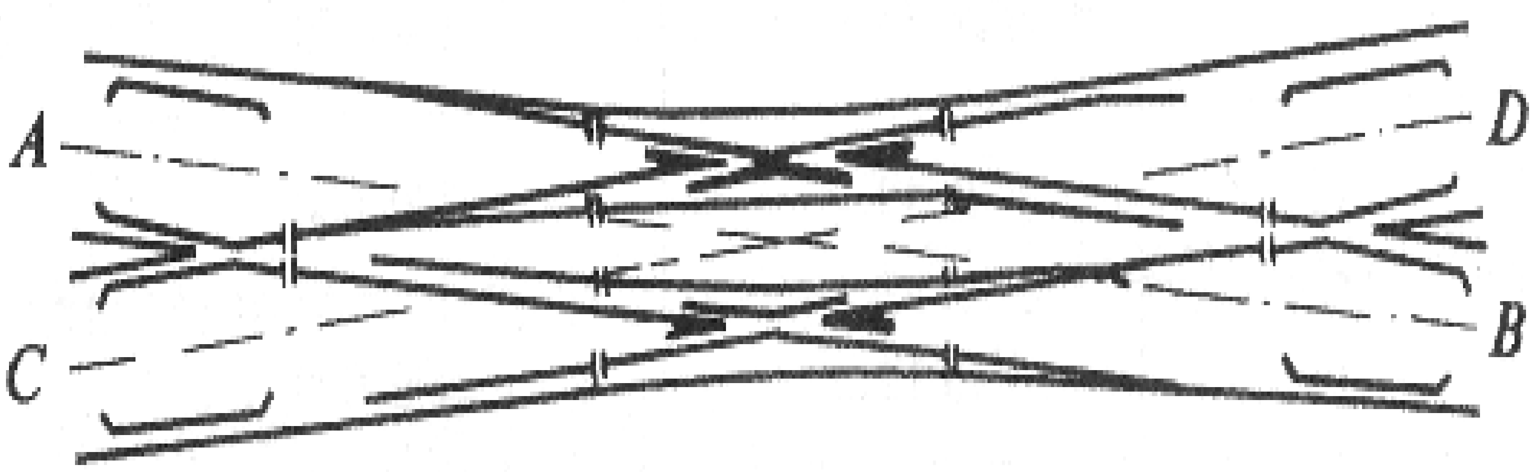
feature:

① Combination of two simple turnouts achieve the function of two turnouts.

② The connecting length of line is obviously reduced.

③ The structure and maintenance of turnouts are complicated, and the safety is poor.

④ It is applicable to the station restricted by landform.



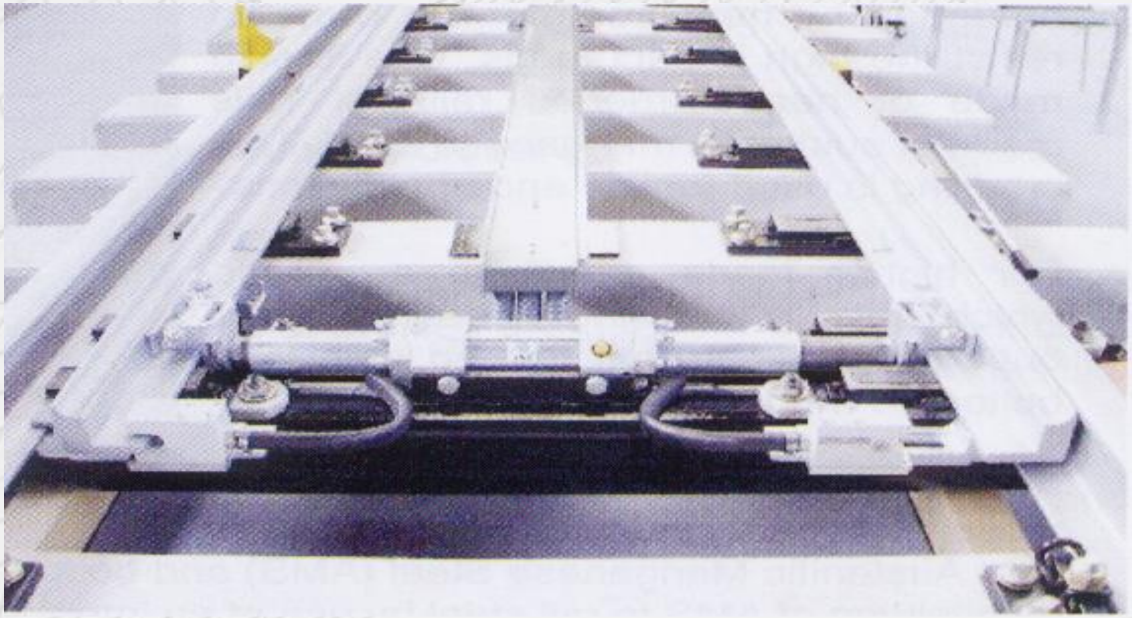
Slip switch

Slip switch

Special turnout

Cross equipment

Switch with integrated hydraulic setting and locking system



The locking system is integrated in a hydraulic setting cylinder. The principle of an integrated locking and switching machine enables the blades to move sequentially so less power is needed at the same time.

Design inputs and steps- Generalized

1. Select the following inputs

- *Rail type：50、60、75kg/m*
- *Frog size/angle: N=cot a (Based on speed and closure R)*
- *Sleeper type： wooden sleeper, concrete sleeper*
- *Frog type： movable frog, rigid frog*

2. Geometrical design of main dimensions

- switch proper geometry- (length of switch, stock rails)

- Lead curve geometry- superelevation & R(Rate of curvature)

- Frog and guardrail, wing rail geometry – attack angle, gap in frog

3. Consideration and check to the limit

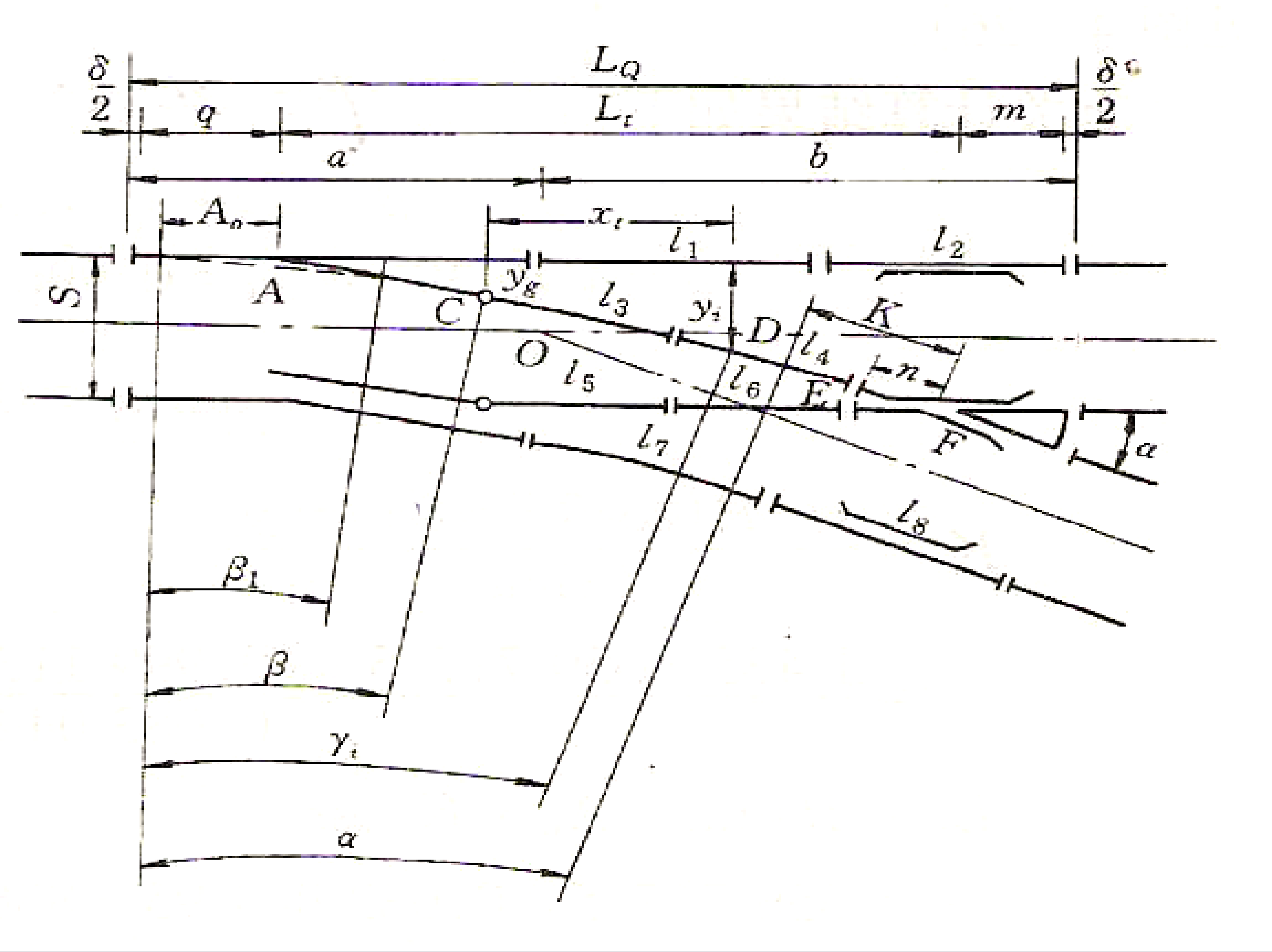
- kinetic energy rejection

- Rate of super elevation

- centrifugal force, $a= v^2/R$

4. Follow the design standard and iterate until economical, safe and suitable geometry for maximum speed operation

Layout of Turnout dimensions



Switch calculations and design

The relationship b/n

- **radius of curve, R**
- **crossing angle and**
- **speed, V**

Note: Straight crossing **d is less than gauge length s.**

The acceleration and speed can be related as;

$$a = \frac{V^2}{R}$$

$$d = R(1 - \cos\alpha)$$

in which:

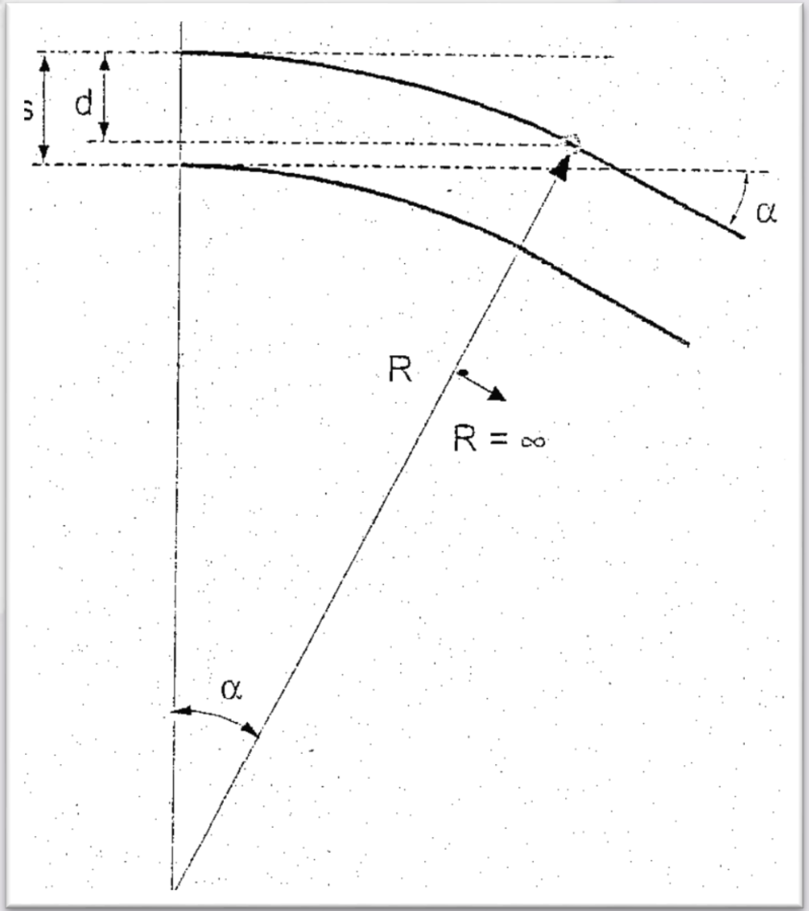
d = indicates transition point curve to straight track, depending on constructional requirements;

R = radius of curve part closure rail;

α = crossing angle.

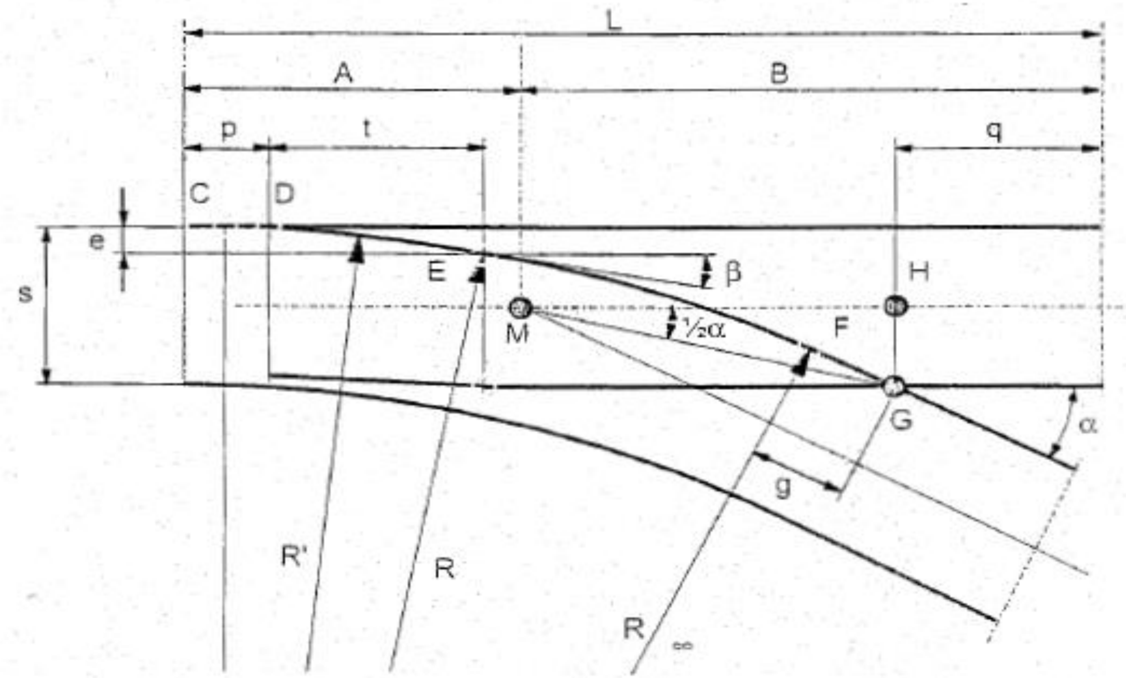
Note: for α<<1, then cosα = 1- ½ α² and

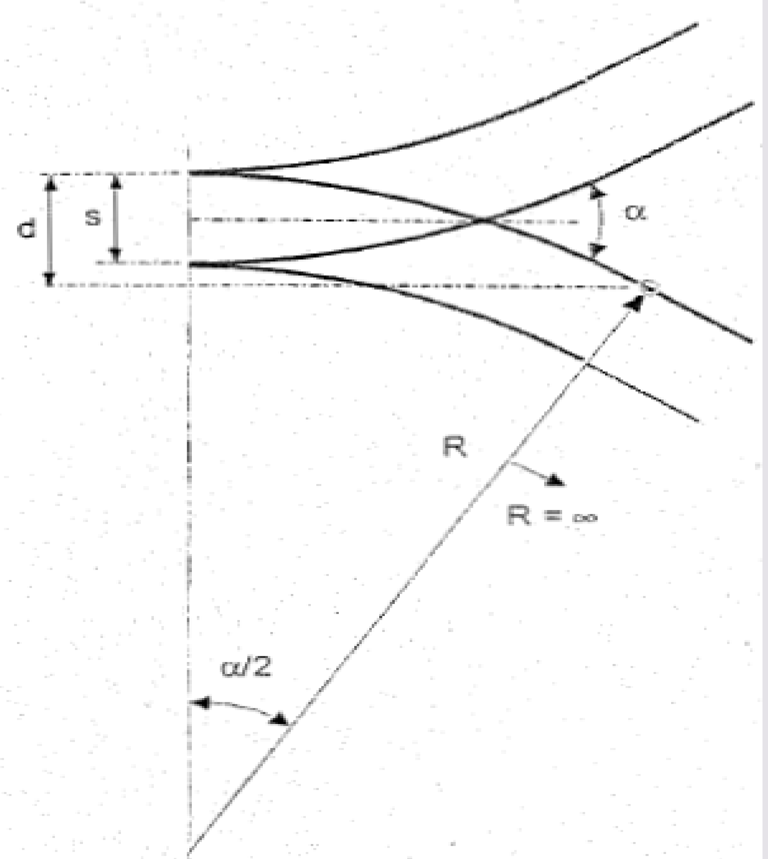
$$\alpha \approx 1{:}n$$



Switch calculations and design

Calculation of curve radius and length of normal turnout

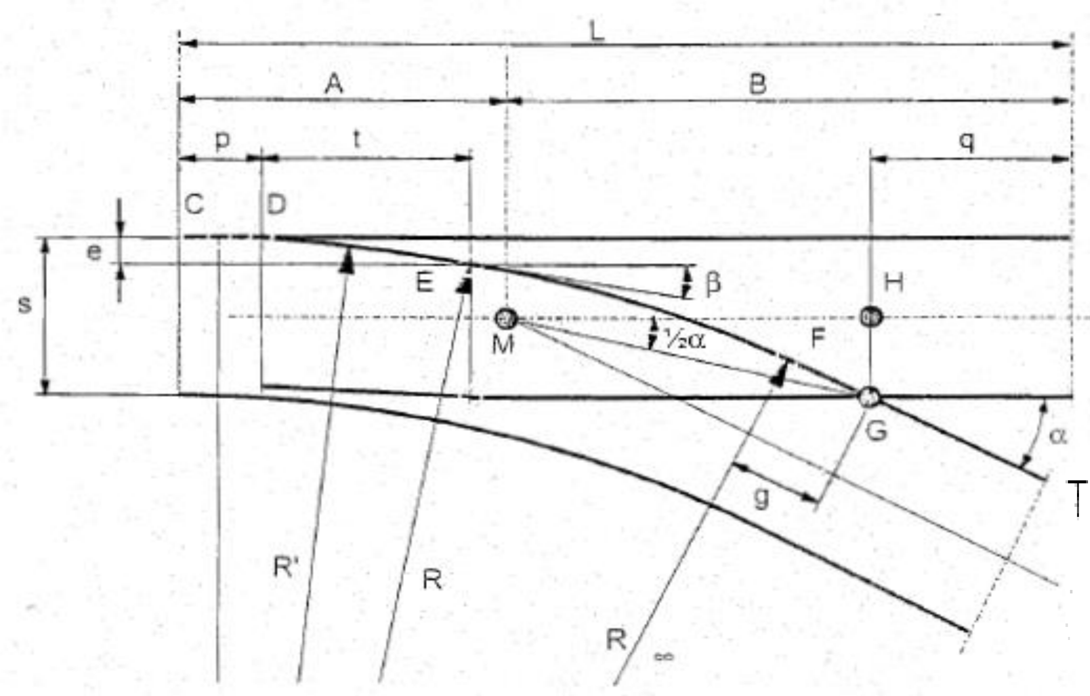




α = Crossing angle;
β = Angle of tangent line at the heel (point E);
s = Track gauge;
e = Position of heel;
g = Length of straight part before theoretical point G;
p = Distance from front turnout to beginning of switch blade (point D);
q = Distance from beginning of crossing to rear of turnout;
t = Length of switch blade (projection on stock rail).

Note: on curve crossing d is greater than gauge length s.

calculations of main dimensions



$$s = e + R(\cos\beta - \cos\alpha) + g\sin\alpha$$

$$R = \frac{s - e - g\sin\alpha}{\cos\beta - \cos\alpha}$$

The full length of the turnout can be calculated from:

$$L = p + t + R(\sin\alpha - \sin\beta) + g\cos\alpha + q$$

α = Crossing angle;
β = Angle of tangent line at the heel (point E);
s = Track gauge;
e = Position of heel;
g = Length of straight part before theoretical point G;
p = Distance from front turnout to beginning of switch blade (point D);
q = Distance from beginning of crossing to rear of turnout;
t = Length of switch blade (projection on stock rail).

Finally, the location of the mathematical point follows from:

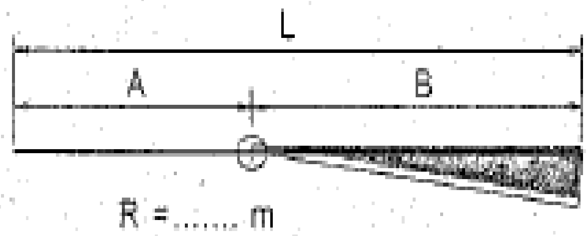
$$MH = \tfrac{1}{2} s \operatorname{cotg} \tfrac{1}{2}\alpha$$

calculations of main dimensions

$$B = MH + q$$
$$A = L - B$$

Assuming $\alpha = 1{:}n$

Common turnouts



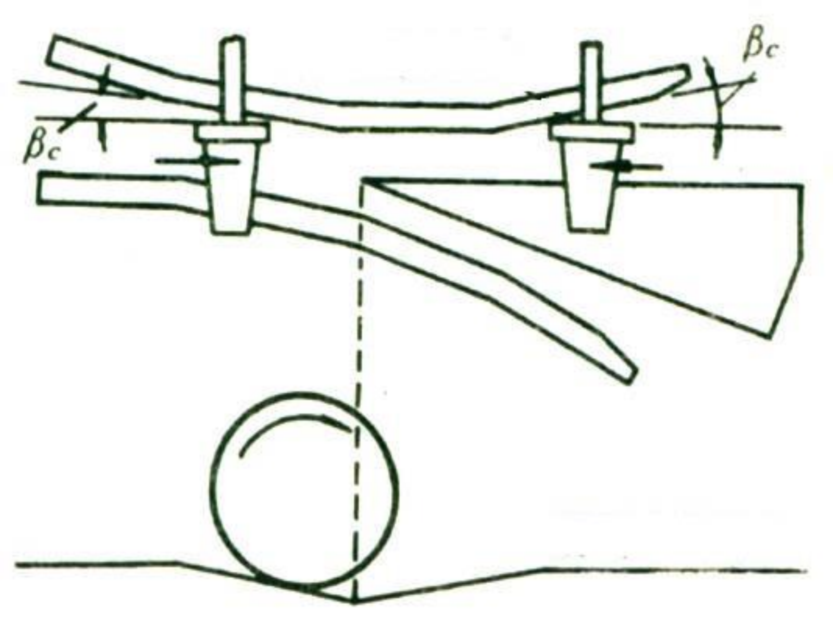
angle of intersection	construction	L [mm]	A mm]	B [mm]	R [m]	V [km/h]
1:34.7	UIC54 with movable crossing	99332	36878	62454	2300	140
1:15	UIC54 with curved crossing	47277	21221	26056	725	80
1:15	UIC54 with straight crossing	42706	16550	26056	600	70
1:12	UIC54 with curved crossing	38320	17420	20900	465	60
1:9	UIC54 with curved crossing	32185	14185	18000	260	40

Table 11.1: Survey of some common switches and crossings

Turnout Speed

Types:
straight turnout crossing speed ;
side turnout crossing speed.

- Determined by points and closure curve
- For curved points, must also consider the point of radius
- Self –guarded frogs are usually 15mph limit



Turnouts with Straight Switch Points (AREMA)

Turnout Number	Length of Switch Points	Speed in Miles Per Hour	
		Lateral Turnouts	Equilateral Turnouts
5	11'-0"	12	16
6	11'-0"	13	19
7	16'-6"	17	23
8	16'-6"	19	27
9	16'-6"	20	28
10	16'-6"	20	28
11	22'-0"	26	37
12	22'-0"	27	38
14	22'-0"	27	38
15	30'-0"	36	51
16	30'-0"	36	52
18	30'-0"	36	52
20	30'-0"	36	52

Turnouts with Curved Switch Points (AREMA)

Turnout Number	Length of Switch Points	Speed in Miles Per Hour	
		Lateral Turnouts	Equilateral Turnouts
5	13'-0"	12	17
6	13'-0"	15	21
7	13'-0"	18	25
8	13'-0"	20	28
9	19'-6"	22	30
10	19'-6"	25	35
11	19'-6"	28	39
12	19'-6"	29	40
14	26'-0"	34	49
15	26'-0"	38	53
16	26'-0"	40	57
18	39'-0"	44	63
20	39'-0"	50	70

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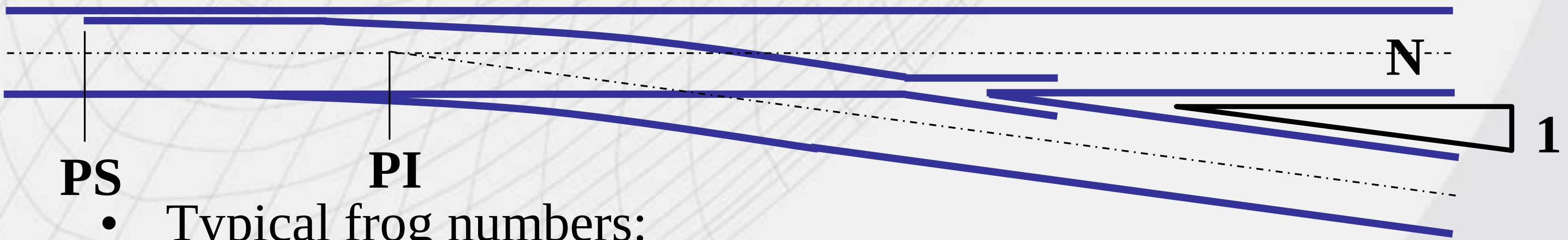
Turnout Speed

- Identified by “frog number”

 - Field identification of Turnout….**HOW???**



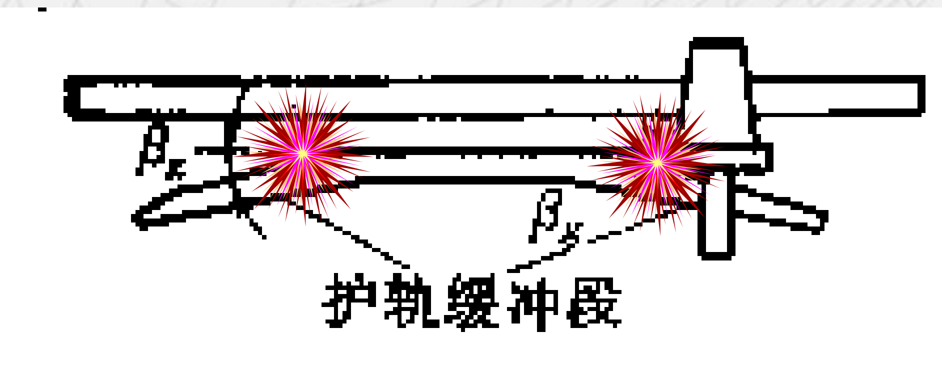
- Typical frog numbers:
  - Mainline No.20 or 24
  - Sidings No.15
  - Yards and Industry No. 11
- **Diverging turnout speed ~ 2 x N**

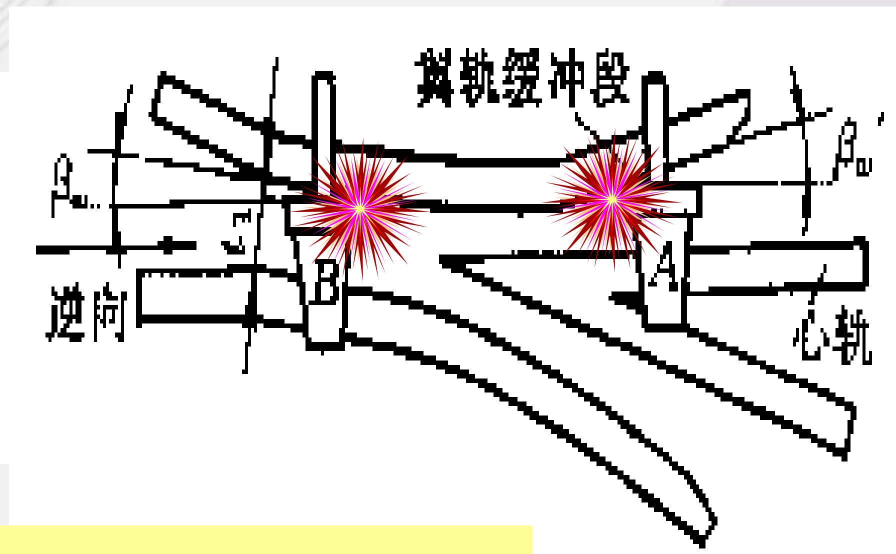
Factors restricting speed through switch main

（1）Attack angle of switch

Attack angle of guard rail

Attack angle of wing rail





Attack angle of guard & wing rail

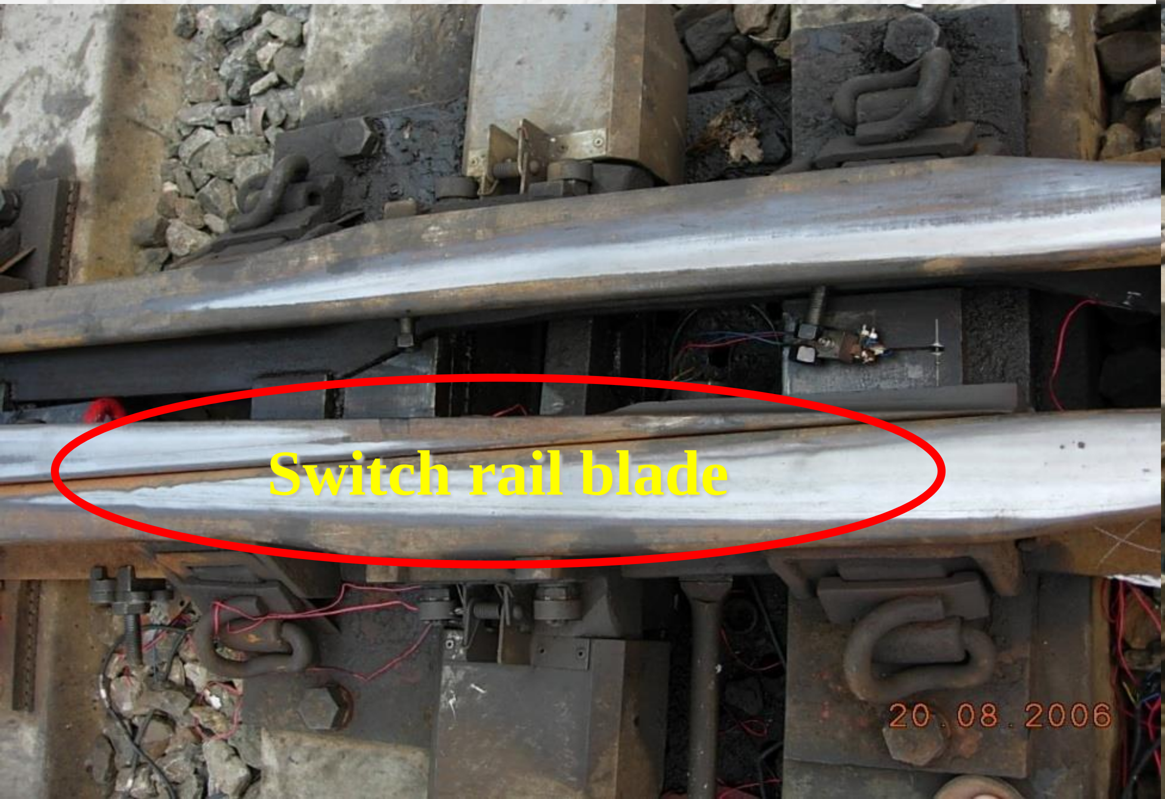
$$\sin\beta_g = \sin\beta_w = \frac{t_1 - t_w}{Nt_1}$$

Factors restricting speed through switch main

2) Structural un smoothness

Positions: *switch proper, frog*

Directions: *vertical, lateral*



Measures increasing speed through switch main

Two main measures：

- New structure

  Movable frog instead of rigid frog,
  Elastic bended switch rail instead of rail joint

- new material
  - **AT rail**
  - **Elastic guard rail**
  - **Wing rails with special section**

- Optimized structure layout and dimensions;

  Increase easement segment of guard rail and wing rail,
  Minimize the attack angle

Measures increasing speed through switch branch-general

- Using switches with big numbers(increasing the lead curve radius)
- Using symmetric switches, branch speed can be increased by 30～40%
- Improving layout design of switch, e.g. using curved switch rail, curved frog
- Strengthening the switch components, doing regularly maintenance
- Reducing attack angle

5.5 Railway clearance

Definition

To ensure the safety, all that buildings and equipments close to the line, must be kept their distance

There also have certain provisions for the train

Types

(1) the locomotive clearance

(2) the structure approaching clearance

(3) the max limited clearance for out-of-gauge freight

Clearance diagram

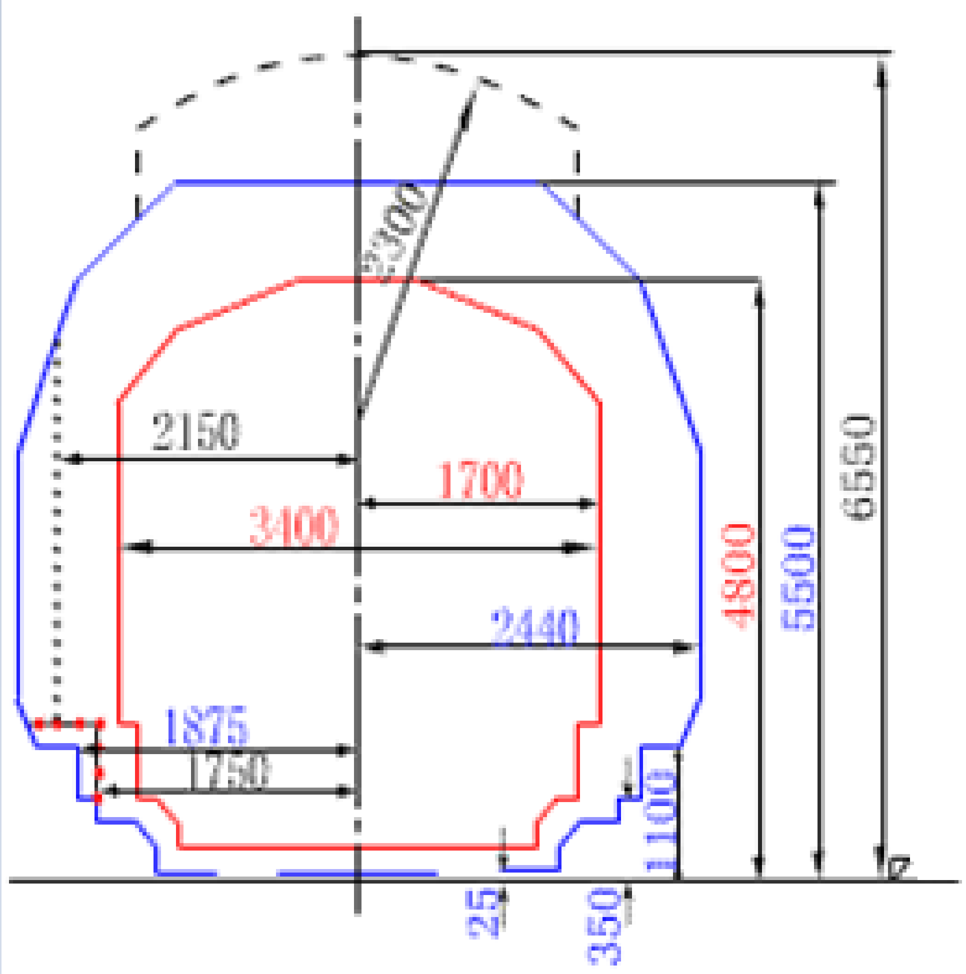
datum line:

vertical: rail surface

horizontal: center line of track

Railway clearance

The locomotive and structure approaching clearance

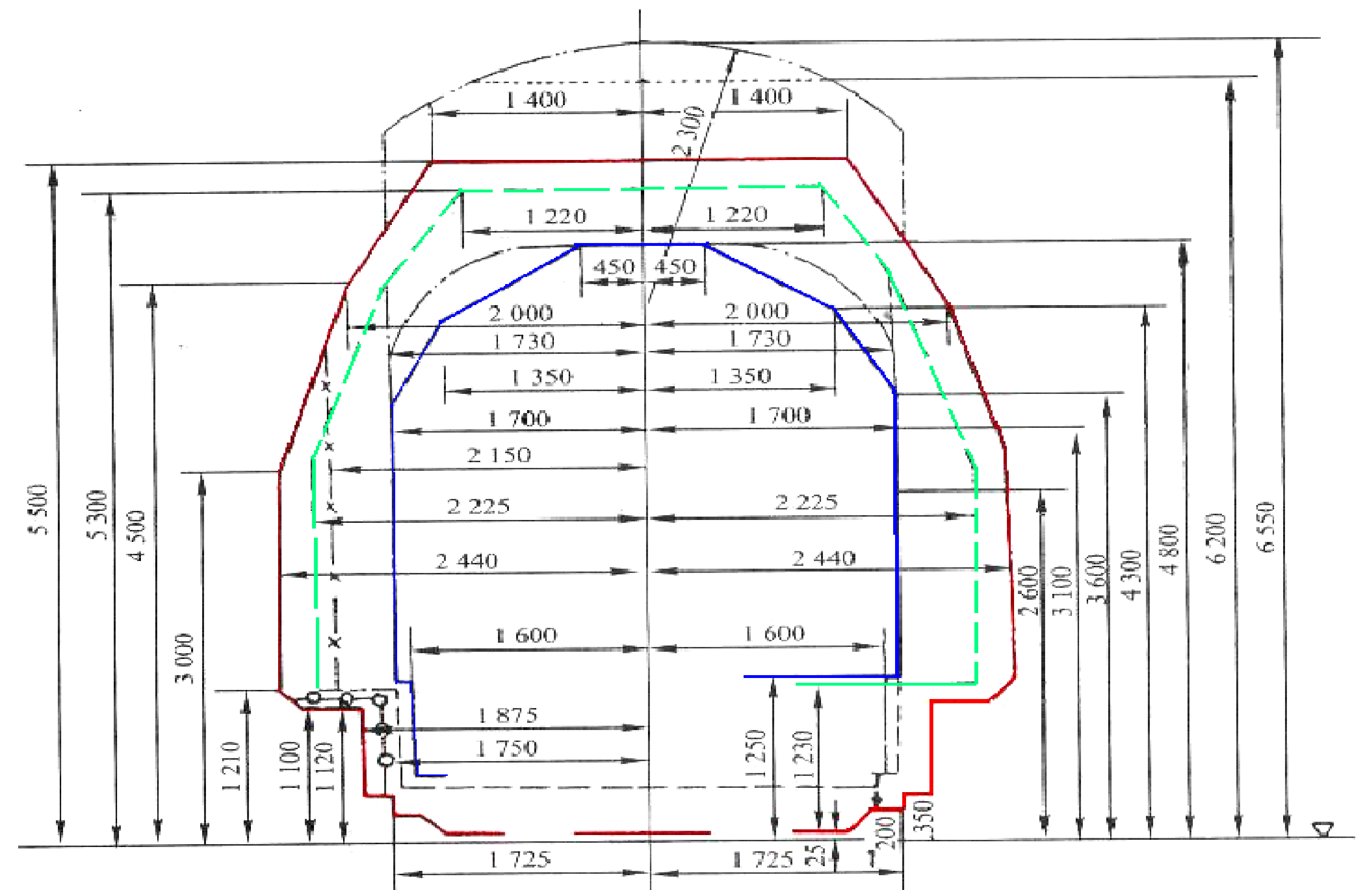


the structure approaching clearance

the locomotive clearance

Railway clearance

In order to ensure the safety of train operation, all the buildings and equipments close to the railway should keep a certain distance from the line. There are also requirements for the cross-sectional dimensions of the vehicles on the railway line. Those specified dimension are called gauges which include vehicle gauge and railway structure gauge.



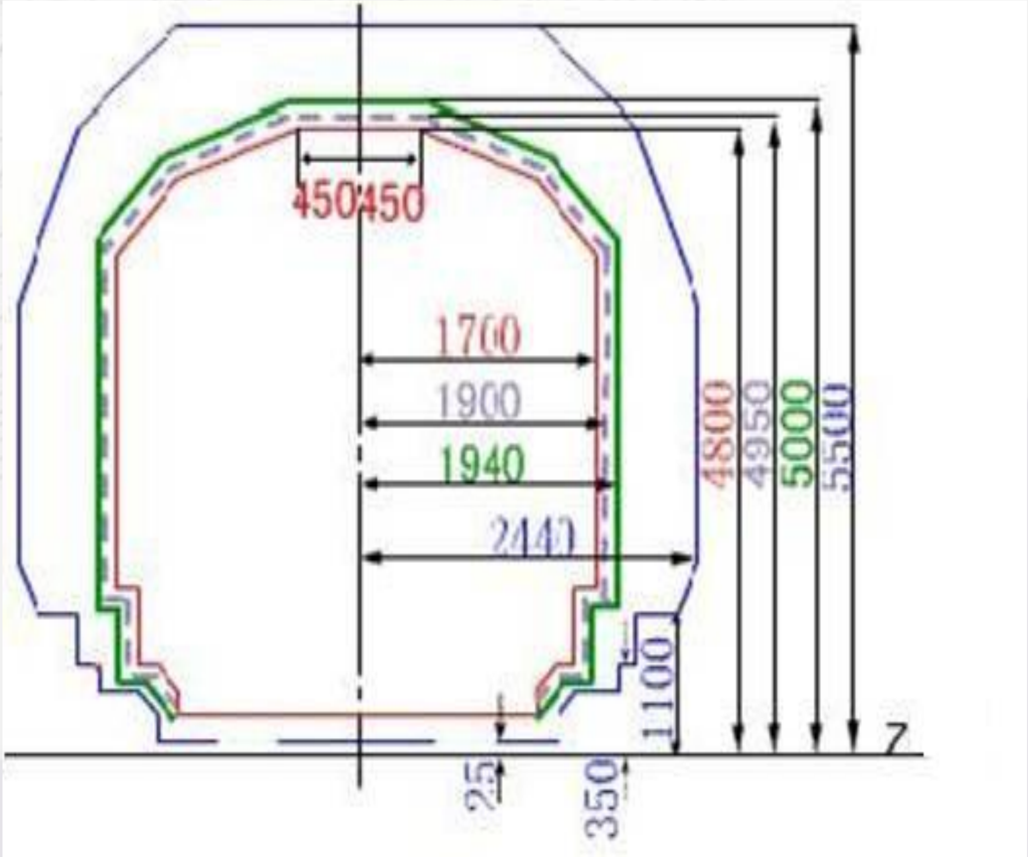
Railway clearance

<u>**out-of-gauge freight**</u>

When any part of the freight is beyond the locomotive clearance, it is called out-of-gauge freight.

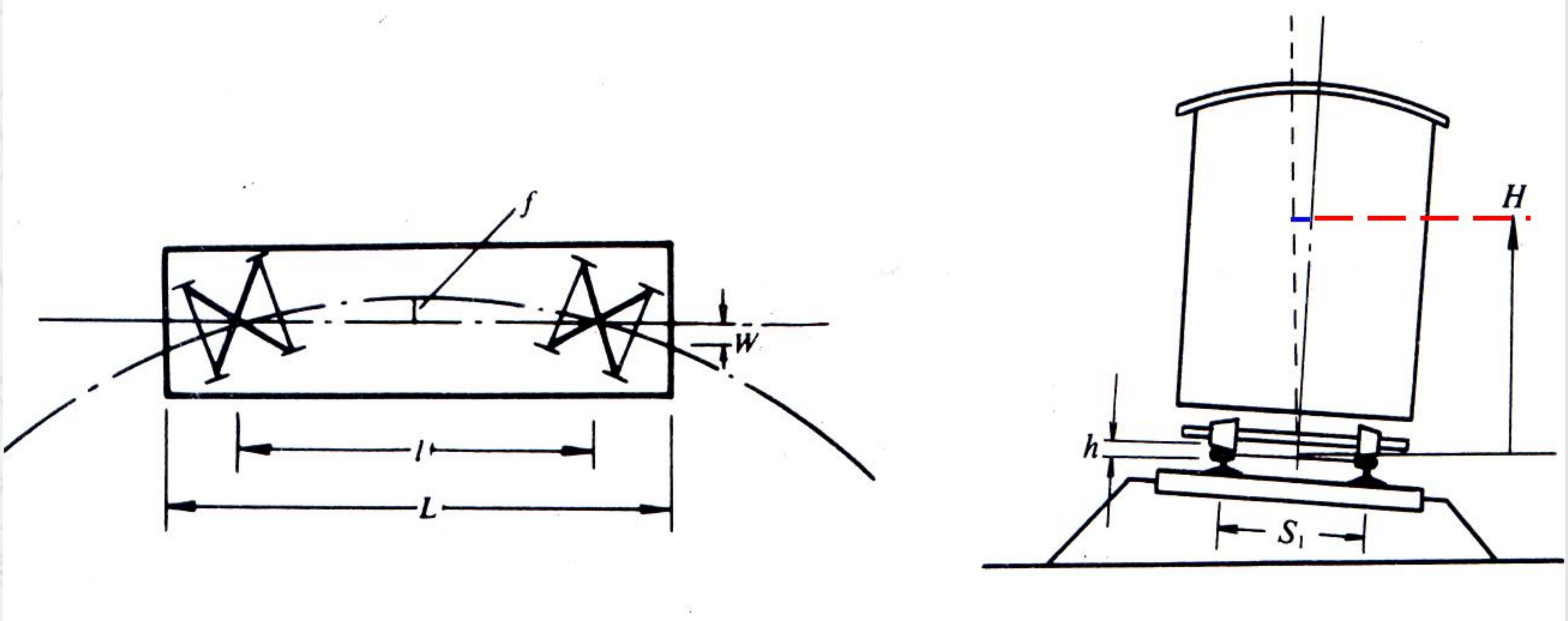
according to the degree, it is divided into three levels:

level Ⅰ, level Ⅱ and level Ⅲ.



Railway clearance

The locomotive clearance should be widen while on curve.



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Thanks!