Basic French Technology for Crossings, Switches, and Special Trackwork

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ABSTRACT

A modern track has to cope with modern rolling stock and increasing load and speed and has to be cost-effective. This is why the French national railroads have developed continuous welded rails on their main lines. As a result, new techniques are being developed to weld or glue switches and crossings into continuous welded rail track. Also, it is essential to increase the resistance of the material to make it more cost effective (longer lifetime, less maintenance). The results of this effort to improve cost effectiveness and cope with increasing loads and speeds are tangent, constant, or continuously varying radius geometry; flexible, thick-web, solid switch points (high or low web); solid cast manganese steel frogs (glued or welded); movable point frogs; and concrete and very hard wood ties.

Turnouts and special trackwork provide the various route arrangements needed by railroad traffic. The speed requested on the diverted track and the comfort required for passenger trains determine the geometry. Increasing speeds and axle loads as well as the improvement of cost effectiveness require a constant effort to improve the design and the engineering of switches and crossings (e.g., flexible thick-web switch rails, solid cast manganese steel frogs, welded switches and frogs, movable point frogs, and resilient fasteners) are the result of this search for improvement.

Diverging and converging routes require turnouts (switches and crossings). Crossing routes simply require crossings. Single- or double-slip switcnes allow for diverging, converging, and crossing in small spaces. The components of a turnout are (a) the switch (points, stock rails, and braces), which splits the route into two, (b) the crossing (frog and guard rails), and (c) the closure and turnout rails. The components of a diamond crossing are (a) two obtuse frogs or central frogs and (b) two acute frogs or end frogs.

In most cases, the main line in a turnout is on a tangent run. If necessary, it can be curved, opposite the direction of the curve of the diverted track (contra-curved) or curved to the same direction as the diverted track.

Diamond crossings can also be curved (one track or both tracks). The proper use of turnouts and crossings allows setting up single and double crossovers, pocket tracks, sidings, classification yards, and so forth.

GEOMETRY OF TURNOUTS

The radius in the diverted track will depend on the required speed. On the curved run, the centrifugal acceleration is expressed as

$$\gamma = K V^2/R$$

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The acceleration is proportional to the square of the speed and inversely proportional to the radius. To avoid this transversal acceleration, it is necessary to superelevate the high rail. This is commonly done in running tracks. The superelevation never absorbs the complete lateral acceleration. Depending on required comfort for passenger trains, there is a certain cant deficiency. In special trackwork and especially in turnouts, it is impossible to set the running surfaces of rails at different levels at a proper superelevation for each route.

To maintain the centrifugal acceleration within reasonable limits in such conditions, it is necessary to set up a proper ratio between speed and curvature.

The Union Internationale des Chemins de Fer Français/Office de Recherches et d'Essais (UIC/ORE) have determined that the maximum centrifugal acceleration acceptable, with good comfort and maintenance cost effectiveness, is 0.067 g (or 0.667 millisecond^2). This acceleration is obtained with a cant deficiency of 4 in. and takes into account the break-off of the curvature at the end of the point, which generates a sharp acceleration that is twice higher than in the regular curve. This cant deficiency value complies with the needs for maintenance. Examples of minimum radius on diverted track with corresponding cant deficiency follow.

Cant Deficiency (in.)	Speed 62.5 mph	100 mph
3 1/6	R = 5,000 ft (1.16°)	R = 15,800 ft (0.37°)
4	R = 4,000 ft (1.46°)	R = 10,000 ft (0.58°)

Generally, the geometry of the diverted track is a constant radius [e.g., a turnout n.20 with a constant radius (1) on the diverted track will allow a speed of 62.5 mph] (see Figure 1).

In crossovers, the diagram of centrifugal acceleration is different. The two opposite accelerations in a short lapse of time, due to the short distance, are prejudicial to comfort and limit the speed in the crossover to a lower value than on the diverted track of a single turnout (see Figure 2).

It is necessary to establish a portion of tangent

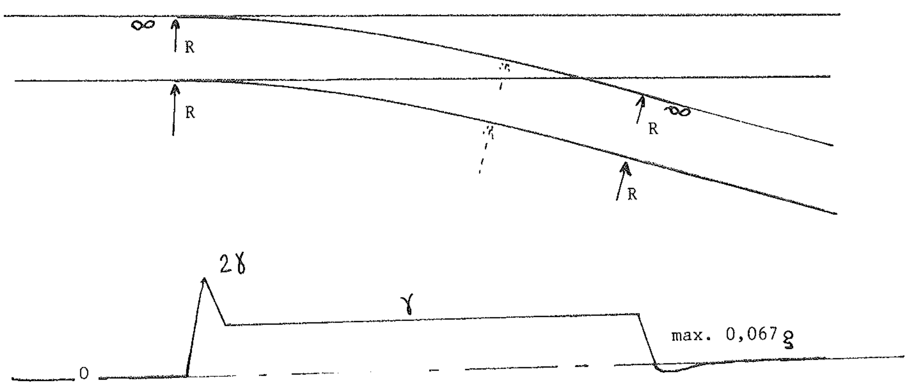


FIGURE 1 Diagram of centrifugal acceleration.

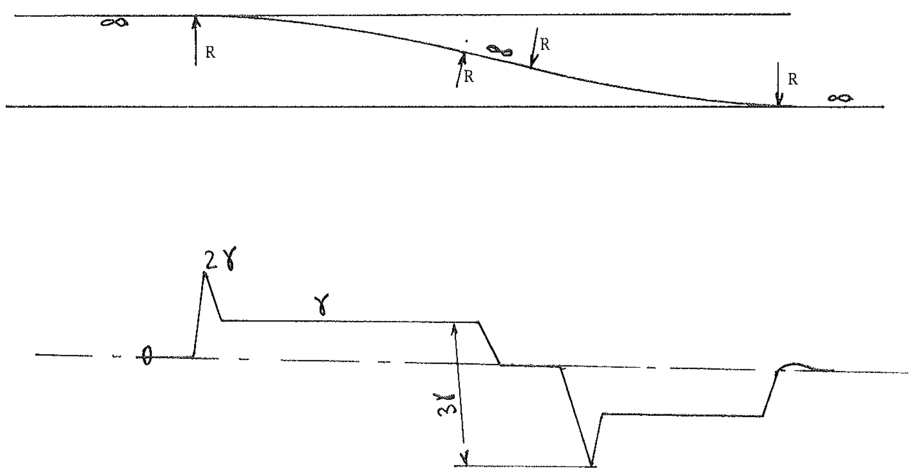


FIGURE 2 Diagram of centrifugal acceleration in a crossover.

track between the two opposite curves in order to allow the vehicles to stabilize (self frequency of vehicles is about 1 Hz). The required lapse of time is constant at 1 or 2 sec. The length of track required will thus depend on the speed. This may possibly have an effect on the distance between central lines on the two tracks.

In special conditions, such as high speed, parabola or curves with a constant variation of curvature can be used. The use of curves with constantly varying radius improves the performance of crossovers. For instance, on the Très Grande Vitesse (TGV) line, between Paris and Lyons, the Société Nationale des Chemins de Fer Français (SNCF) uses crossovers with parabolic curves with radii increasing steadily from their minimum value to infinite (see Figures 3 and 4).

Two turnouts have been developed by the SNCF for the Paris-Lyons high-speed line: (a) n.65 with a maximum speed of 138 mph on the diverted track, and (b) n.46, which is mostly used for crossovers with a maximum speed of 100 mph.

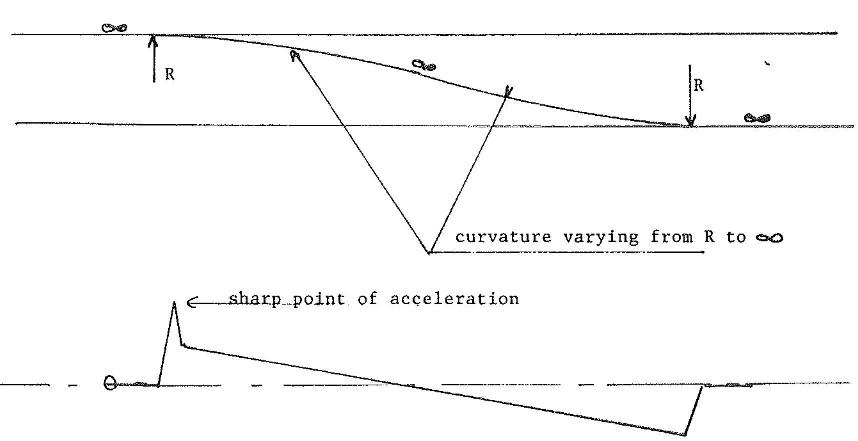


FIGURE 3 Diagram of centrifugal acceleration in a crossover with continuously varying radius.

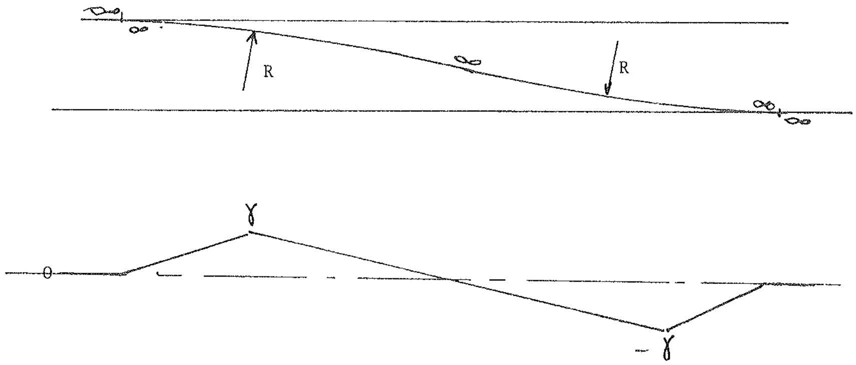


FIGURE 4 Centrifugal acceleration with double curvature variation.

POINT AND CROSSING TECHNOLOGY

Rails

The SNCF specifies UIC 60 rails (122 lb) with a 270 or 320 Brinell Hardness Number (BHN). The switch rails are machined in a special reinforced profile, called thick-web switch rail.

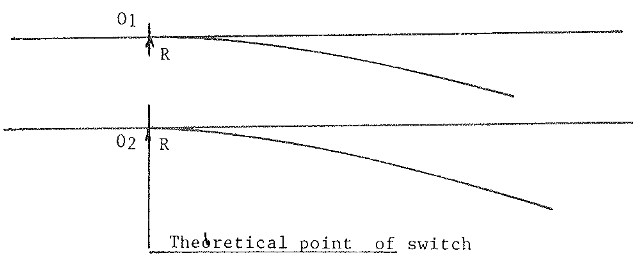


FIGURE 5 Theoretical point of switch.

Switches

In the previous section, the author mentioned the geometry where the diverted track is tangent to the main straight track at the point of the switch (see Figure 5). In fact, the physical point of the tongue is beyond the theoretical point of tangency, and the point of the curved tongue is straight when the thickness of the machined head is comprised between 3/32 and 7/32 in. (see Figure 6). Consequently, at the real point of the tongue, there is a small angle between the point and the stock rail (4.60 of a degree for an n.65). Nevertheless, this angle is small, and substantially inferior to the angles existing in straight switch points.

The gage on the diverted track is the same as on the main track, with the exception of small radii, or switches, or both, where low speed is acceptable on the diverted track. In such cases, two solutions can be used:

1. The theoretical point of the curved tongue is beyond the theoretical point of the straight tongue, the physical points of both tongues remaining square.

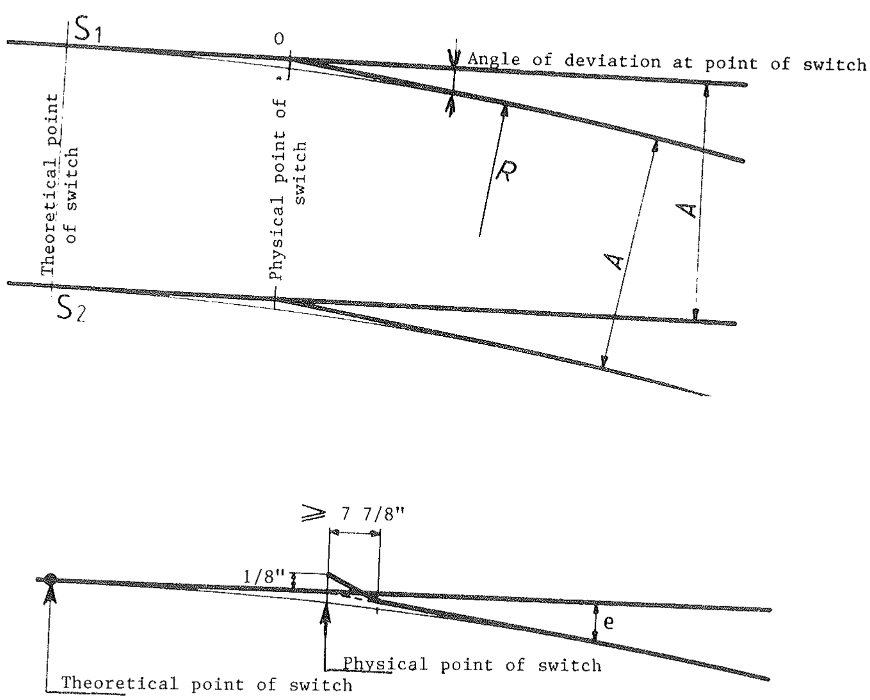


FIGURE 6 Angle of deviation at point of switch.

Consequently, the gage of the diverted track is wider, but there is a material swell at the gage line in the stock rail and at the point of the straight tongue (see Figure 7).

2. The theoretical point of the curved tongue remains beyond the theoretical point of the straight tongue, but, to avoid this drawback, it is wiser to cut the gage line of the straight stock rail with the gage line of the curved tongue. Consequently, the theoretical point of the curved tongue is beyond its physical point, which remains square to the physical point of the straight tongue.

This solution has the inconvenience to increase the value of the angle at the point of the curved switch. In any case, this value will be under 1 degree of angle (see Figure 8).

In the vertical plan, the points of switches are milled to avoid the wear by the wheel, in an area where the head of the tongue is thin. The undercutting and positioning of the point of the tongue under the running surface of the stock rail beyond the gage line guarantees that even sharp flanges will not force the point open.

The SNCF has generalized the use of flexible points for a long time. The movement of the tongue is allowed by the flexibility of the switch rail. There is no articulation or movement at the heel of the tongue, which is usually welded to the closure rail. It is also locked to the stock rail through a tightly bolted block and to the ties (see Figure 9). The minimum length of flexible switch point is 30 ft and the maximum driving effort is under 550 lb. The flexible switch points are milled in reinforced profiles with thick web, and heavier foot and head.

There are two types of switch rail: (a) high web

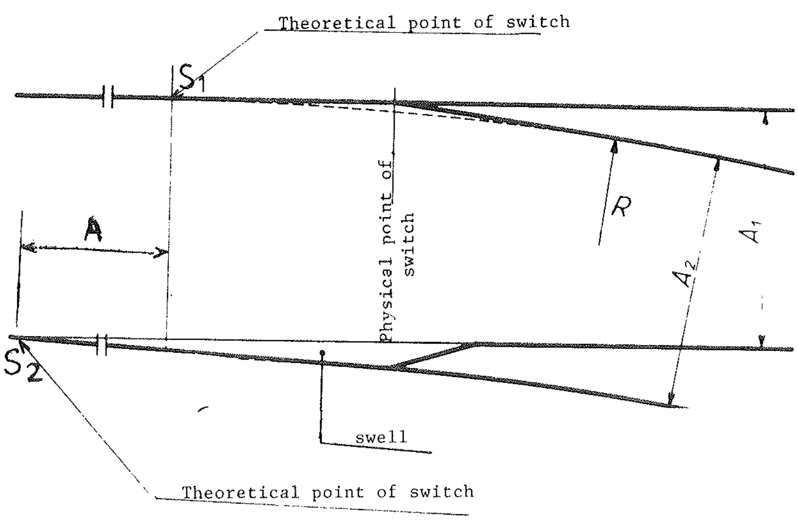


FIGURE 7 Gage widening on diverted track (Solution 1).

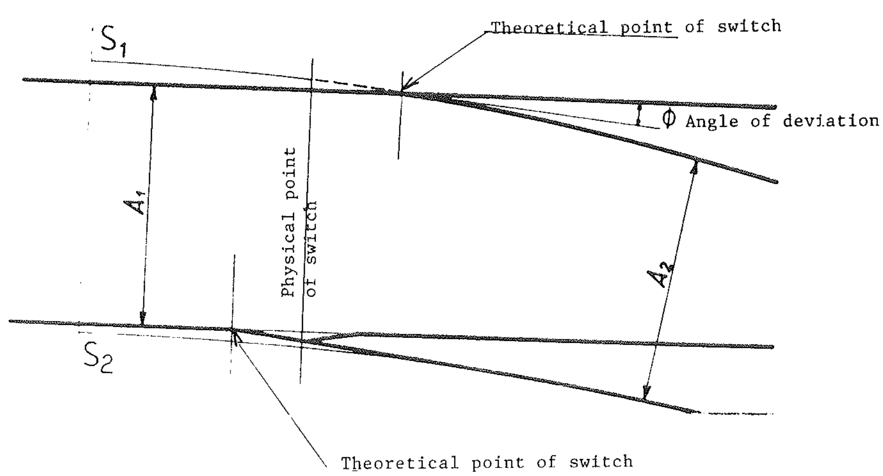


FIGURE 8 Gage widening on diverted track (Solution 2).

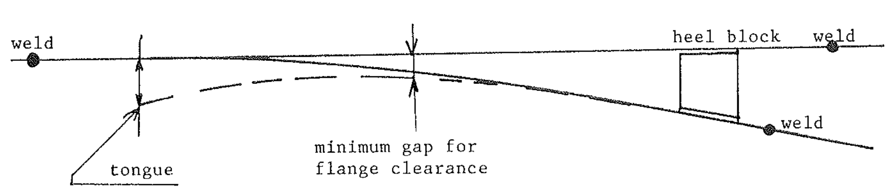


FIGURE 9 Diagram of a flexible thick web tongue.

(same height as the stock rail), and (b) low web (lower than the stock rail). In the high-web flexible switch point, both the switch and stock rails have the same height. The feet of both have to be machined to allow a proper contact. They are laid on flat sliding chairs, and the heel of the point is milled to the exact profile of the closure rail to allow easy field welding with standard equipment. Switch rails have also to be machined at the heel to increase the flexibility of the tongue (see Figure 10).

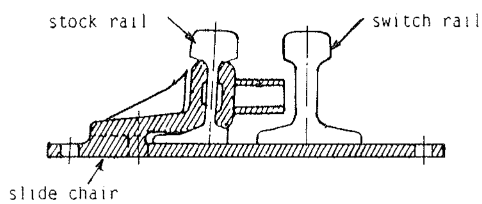


FIGURE 10 High-web switch rail.

The low-web flexible switch point is mostly used for long points. Because the switch rail is smaller than the stock rail, there is no need to machine the feet of both switch and stock rail. The foot of the switch rail comes over the foot of the stock rail, sliding on a two-level slideplate. The heel of the point is forged and welded to a piece of running rail to allow field welding to the closure rail (compromise weld) (see Figure 11). Flexible thick web points (low or high) allow for the elimination of the joint at the heel of the point and of the reinforcing bars with holes, bolts, and rivets.

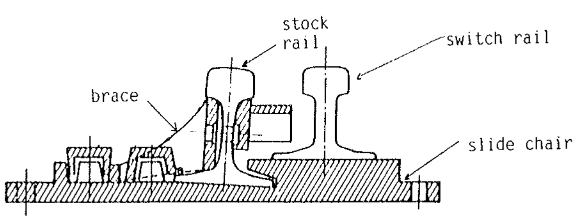


FIGURE 11 Low-web switch rail.

Crossings

Fixed-Point Frogs

The SNCF uses solid manganese steel frogs exclusively. The casting temperature is 1450°C. The longest units are 40 ft long. The thickness varies between 3/4 and 1 in. Heat-treated Hatfield steel with a manganese rate of 12 percent is used. The hardening is done on track by the vehicles and reaches an average value of 450 BHN. (Note that the French manufacturers are also able to preharden either by explosion or hammering.)

The running surfaces, the surfaces in contact with the ties, and the joint barring area are systematically milled, and holes are drilled.

Solid manganese steel frogs represent the large majority of frogs used on SNCF lines. They have proved to be highly reliable and long-lasting with low maintenance costs.

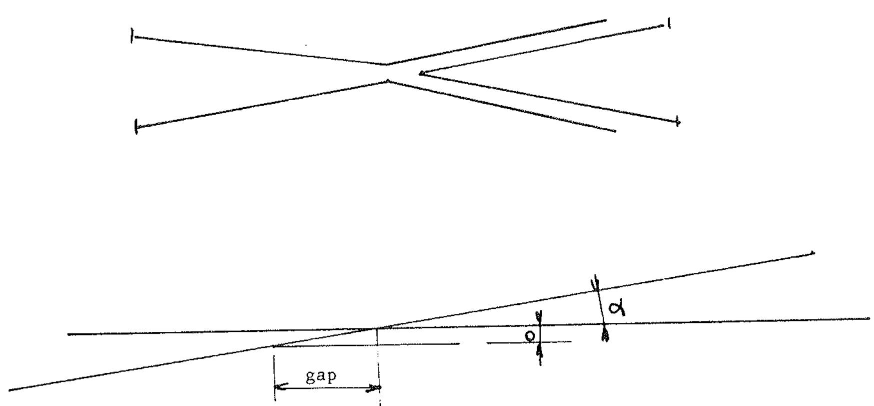
Movable-Point Frogs

The basic problem with crossings is the gap inherent to all frogs (see Figure 12); the lesser the angle, the longer the gap. The answer to this basic problem is the use of the movable-point frog, especially with heavy haul and high speed--that is, whenever it is necessary to suppress the gap and the shocks it generates.

The point of such frogs is generally milled in thick-web switch rail. It is machined, assembled, and adjusted to a solid cast manganese steel cradle. In cases like n.65 frog for the TGV, this cradle is assembled and bolted together in three pieces. The point moves in the cradle in coordination with the switch points. Interlocking between the switch and the movable point of the frog is necessary. The heel of the movable point is tightly locked to the cradle and the movement of the point is allowed by the flexibility of the rails (like flexible switch points).

Guard Rails

With convenient frogs, it is necessary to use guard rails to guide the axle through the proper track,



θ = flange clearance
α = crossing angle

$$\text{gap} = \frac{\theta}{\sin}$$

if α ↘ gap ↗

FIGURE 12 Gap value.

and to protect the frog point. There is no need for guard rails with movable-point frogs (see Figure 13). The SNCF has developed an interesting profile for guard rails, easily adjustable and replaceable, and with no link with the turnout rail. It has proved to be far more efficient than standard rails fixed to the turnout rails with blocks and bolts.

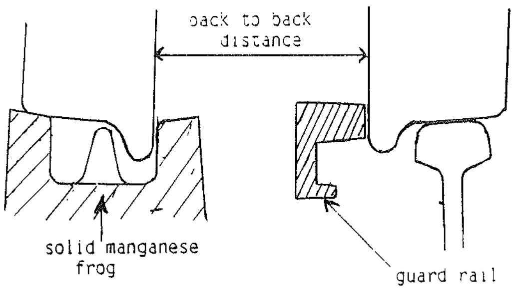


FIGURE 13 Guard rail.

Glued Frogs

Generally, frogs are glued into the continuous welded rail track (insulating glued joints), which allows for the necessary insulation related to track circuits. This also provides a continuous rolling surface with no gap and no risk of looseness. For the last 17 years, the SNCF has systematically welded turnouts into continuous welded rails. On main lines, expansion joints were suppressed with the exception of long bridges (movable ends).

It is necessary to anchor the turnout and junction rails into the ballast through the ties with resilient fasteners. Those fasteners have to avoid the canting and the creeping of the rail.

Ties

The SNCF prefers to use ekki wood ties under special trackwork. This African wood has a density of 1.2 and is far superior to oak as far as weight, hardness, and lifetime are concerned. In performance, it is more comparable to concrete ties than to soft or even hard wood.

Motors and Heating

Most switches are motorized and equipped with a locking or controlling system located on the stock rails. Both points move together since the motor is directly linked to the center of a rod located between the two points. When the length of the tongue is more than 30 ft, the motor is linked to two or more rods to ensure that the proper clearance between the open tongue and the stock rail is obtained. Also, additional control systems may be used to check that it is at this proper position. (Note that all these control and locking devices are linked to the signalling system. If anything goes wrong, the lights turn red to stop the train.)

The SNCF uses both gas and electric heating, depending on the situation of the track. Gas is cheaper but needs more maintenance, and is mostly used in stations and classification yards. Electric heating is more expensive but hardly needs any maintenance, and is used in remote places on main lines.

Diamond and Right-Angle Crossings, Double- and Single-Slip Switches

Central frogs (obtuse), end frogs (acute), and right-angle frogs for diamond and right-angle crossings are solid manganese steel, just like standard frogs for turnouts. Double- and single-slip switches are also designed and manufactured according to the same principles as the turnouts (i.e., solid cast manganese steel frogs and diamonds, thick-web flexible switch points, etc.). In some very special cases, solid manganese steel jump frogs are used.

CONSTRUCTION

Originally, most of the machining of the rails and cast manganese steel was done on conventional planing machines. Modern computerized planing machines are still used, but computerized milling machines are taking over. They are faster, more flexible, and more accurate; and allow long tables for the longest machining (120 ft for the switch point of the n.65 turnout of the TGV) with a tolerance of less than 0.01 in. The precutting and drilling of the rails is also done by computerized equipment. Timbers are preadzed and predrilled on computerized machines. They are thus ready for preassembly in the workshop before shipping to the site whenever this is necessary.

WELDING OF SPECIAL TRACKWORK INTO CONTINUOUS WELDED RAILS

Joints may be the main weakness in a track: the rolling stock and the wheels suffer, rail ends are beaten down, joint bars get loose, ties are stamped, and the ballast requires more frequent tamping. All this means shorter lifetime and heavier maintenance for both rolling stock and track: costwise, joints are a real nuisance. This is why, for more than 17 years, the SNCF has generalized continuous welded rails on its main tracks.

The key to welded track is the total rigidity of the rail/ties structure, and its fixed anchoring into the ballast (i.e., the fastening of the rail to the tie must remain square and restrain all creeping). The ladder structure of the rails and ties must be tightly anchored to the platform by a proper ballasting including high and heavy shoulders.

Forces in the closure rails are transferred to the turnout rails with increasing strengths at the switch heel. These increased strengths are restrained by longitudinal movements of the track skeleton in the ballast bed (see Figure 14).

With resilient fasteners, proper ties, and heavy ballasting, the experience of the SNCF railroads is such that the lateral forces are restrained, and the maximum longitudinal movement of the switch heel of ± 1/5 in. is perfectly acceptable.

NEW DEVELOPMENTS

Welded solid-cast manganese steel frogs have been on track for testing on SNCF main lines for several years. Several standard turnouts laid on prestressed concrete ties are also on track for testing under high-speed traffic (100 mph on the main track, 37.5 mph on the diverted track). The unique crosstie section has been studied so that the positive bending moment under the rail seat and the negative moment between rail seats support the dynamic efforts, whatever the position of the rails is. The unique cross section supports the highest bending efforts.

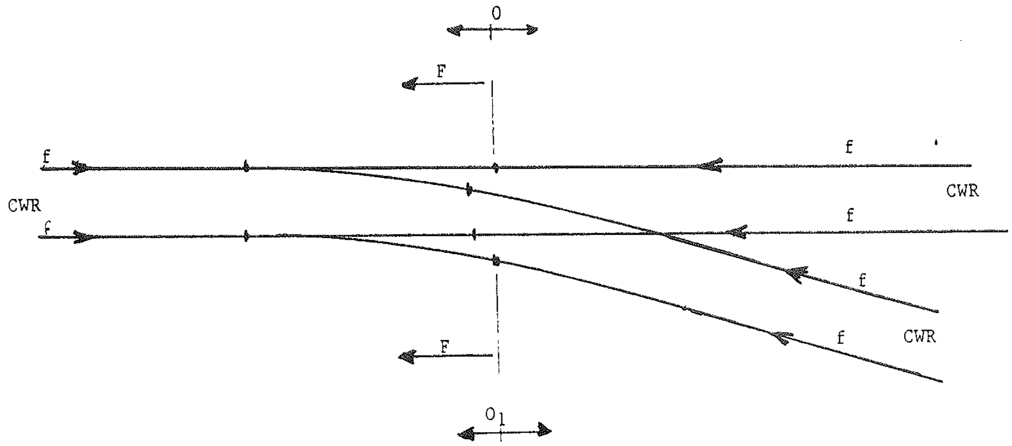


FIGURE 14 Welded turnout.

These turnouts are equipped with indirect fixation: a plate with a polyethylene high density pad underneath is first bolted into a plastic dowel anchored into the tie. The rail is bolted to the plate with another rubber pad in between, and with a resilient elastic fastener. The weight of the concrete ties is about twice the weight of creosote-treated oak ties. The concrete ties require a thickness of ballast of 10 in. minimum underneath. So far, turnouts equipped with concrete ties prove to have better stability and to require less leveling. The plastomere anchoring system and the rubber pads insulate the track.

CONCLUSION

The basic French technology for crossings, switches, and special trackwork has been described briefly. This technology results from constant studies to keep pace with this sensitive part of the track, while speed and axle loads have increased. Important factors such as safety and reliability have also been kept in mind. Both technology evolution and reduction in maintenance costs are necessary. Constant efforts have also been made to implement special trackwork maintenance as cost-effectively as possible, by means of mechanization and welding.

This special attention from the railroad engineers allows a wide range of applications such as

- Heavy loads of 30 gross tons or more (steel industry),
- A combination of high-speed (120 mph) passenger and freight trains, which is illustrated by the major part of the French network fixed plant,
- Commuter trains, rapid transit systems,
- A very high-speed dedicated line between Paris and Lyons (175 mph).

The French technology is the result of progressive engineering and permanent efforts to improve competition in coping with the demands of the transportation market.

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