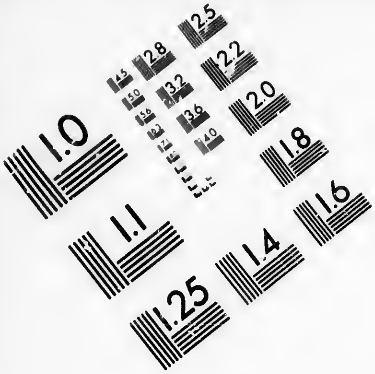

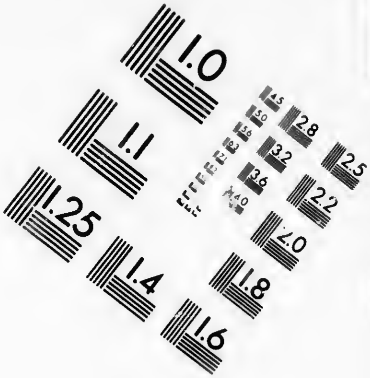

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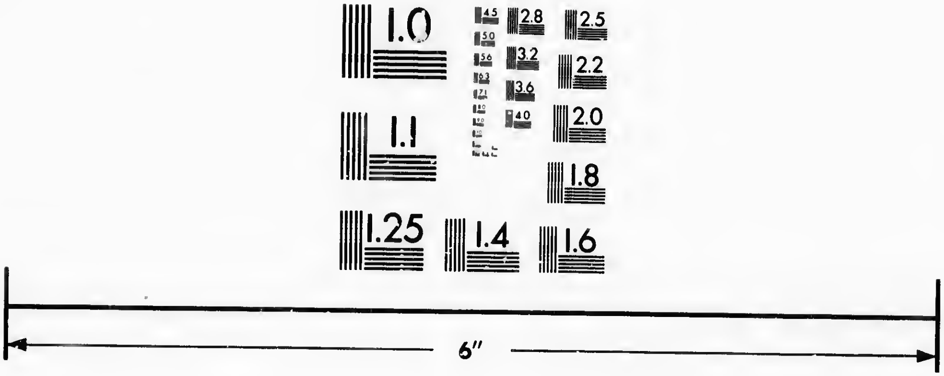

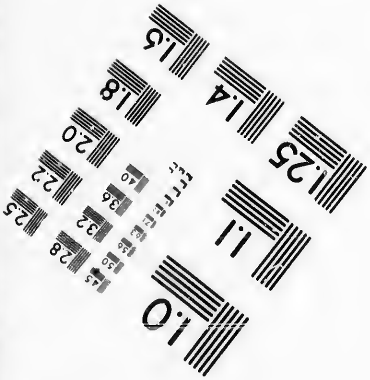

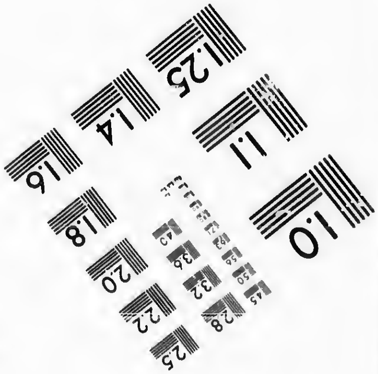

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INCORPORATED 1887.

## TRANSACTIONS.

# SPECIAL TRACK WORK FOR ELECTRIC STREET RAILWAYS, ESPECIALLY REFERRING TO THE MONTREAL AND TORONTO SYSTEMS.

By E. A. Stone, Ma.E., A.M. Can. Soc. C.E.

Special work is the general term applied to all track work not included in the ordinary straight track; its construction for electric railways has undergone great improvements during the last few years, and is still improving. The introduction of electric power for the purpose of city passenger traffic gave rise to the present substantially constructed cars, which, with their additional weight of motors, brought about radical changes in the construction of the track.

Besides electricity as used in the trolley system, other motive powers have been tried to take the place of the horse, such as gas and compressed air motors, cables, electric conduits and storage batteries; but up to the present time, the trolley system has demonstrated its practical superiority over all others.

The track which had answered all purposes for the old comparatively lightly constructed horse cars became utterly useless for the motor cars. As the special work is subjected to the greatest wear, and consequently requires the most frequent renewal, it changed form completely. The old cast-iron curves, with their short, lightly constructed switches and poor joints, had to give way to the heavier steel construction, bearing a greater resemblance to that of a steam railroad.

Special track work should be of good substantial construction, with the greatest care paid to the designing of the parts which wear most rapidly. It is most important that track, especially in the central parts of a city, should require renewal as seldom as possible, for such renewals are very expensive, apart from the actual cost of the new track work, as traffic is interrupted, causing great inconvenience and sometimes loss of business to the public, and generally demoralising a whole route of cars, and sometimes the greater part of the entire system. Special work should be made in such a manner as to cause the least possible obstruction to vehicles, no part rising above the level of the paving more than is unavoidable; the necessary recesses, grooves, etc., should be as narrow and shallow as possible, to prevent wheels of vehicles from catching. Flat surfaces should have a rough top, to prevent horses from slipping upon them. All pieces should be finished so as to facilitate the paving, no long, unnecessary projections being left on bolts, etc. The curves should be of as great a radius as the width of the streets will allow. The sharper the curve the greater is the wear on the track, and wheels of cars, the slower the rate of motion, the more power required to drive the cars, the more uneven the motion and the greater liability to derailment.

The track may be laid on longitudinal stringers, on cross ties, or directly on concrete with tie bars connecting the rails. The old tracks of strap rail were laid on stringers, and the rail generally called stringer rail. (Figs. 1 and 2.) The greater part of the new construction is laid on ties, and in many respects is similar to steam track work. A combination of these two methods, consisting of planks laid longitudinally on cross ties, in order to give a more even surface, has been tried, but the results do not seem to have been so satisfactory as were expected. In several streets in Montreal, where permanent paving has been laid, the rails have been laid directly on concrete, and bound together by flat tie bars with threaded ends and double nuts. This, with the concrete between the ties, and paving, makes a very solid bed; however, it does not seem to have so much elasticity as track laid on ties in macadam.

The rails used in Toronto and Montreal are "Girder" rails. Those first laid have a height of 6½ in. with a flange of 4½ in., while those laid later are 6⅝ in. high with a flange of 5 in.; the web of the rail is not directly below the centre of the head as in the "Tee" rail, but nearer the gauge line, while a flangway 1¼ in. wide at the top is provided for by a projecting lip. These rails average 75 lbs. per yard. This type of rail (Fig. 3) is used on all straight pieces and outside rails on curves in the special work; the inside rails are made of a section very similar to this, the principal difference being that the lip is much heavier, being one inch in width at the top and rising 5-16ths in. above the level of the head of the rail; this provides an efficient guard for the cars in running round a curve, the groove is ¼ in. wider than in the ordinary girder rail. This rail weighs 84 lbs. per yard. (Fig. 4.) Another section (Fig. 5) is, however, coming into use, and will no doubt largely replace these sections for special work; it is the same as the guard rail section, except that the groove is filled up with solid metal to within 9-16ths in. of the top of the head, thus providing a double bearing for the wheels as both flanges and treads of wheels rest on the metal, so that the cars pass over all points without jolting, and the wear on the least durable parts of special work, viz., points, is greatly diminished. This section gives a rail of 89 lbs. to the yard. (Figs. 1 to 6.) The peculiar sections of these rails, with their thin flanges and webs, and much thicker heads, cause a variable amount of toughness in the section, the head having received the least amount of rolling proportionally and taking the longest time to cool is not so tough as the web and flanges. Tests on pieces taken from the guard rail (Fig. 4) have given the following results:—

Fig 1
STRINGER RAIL

Fig 2
STRINGER GUARD RAIL

Fig 3
GIRDER RAIL
ORDINARY SECTION

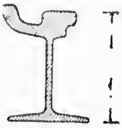


Fig 4
GIRDER RAIL
GUARD SECTION

Fig 5
GIRDER RAIL
SOLID FLOOR SECTION

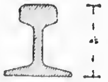


Fig 6
TEE RAIL
56 LBS

Head:—Tensile strength—64,300 lbs. per sq. in.

Elastic limit—75 per cent. of tensile strength.

Elongation on 4 in.—3½ per cent.; reduction in area—2 per cent., with an even and uniform whitish gray fracture, moderately fine grained.

Web:—Tensile strength—91,250 lbs. per sq. in.

Elastic limit—75 per cent. of tensile strength.

Elongation on 4 in.—27 per cent.; reduction in area—20 per cent., with a fine grained light gray fracture.

The necessity for the increase in the weight of the new rails over the old is made apparent when it is considered that the weight of a motor car averages about 6 tons, while the weight of the old horse cars averaged only about 2 tons, and whereas horse cars run at the rate of about 6 miles per hour, electric cars frequently have a speed of 15 miles per hour. Tee rail (56 lbs.) is also used lately for this work, but its use is generally confined to macadamised roads in the suburbs, as its height is not suitable for paving purposes (unless raised on chairs), although otherwise quite as efficient. (Fig. 6.) The girder rail being so high admits of block paving, and by the lip on the inside provides a good edge for the pavers to work to, whilst the narrow groove offers a very slight hindrance to vehicles.

In tee rail special work, the inside rail on curves is generally guarded by a second rail being bolted to it, the two rails being held apart by cast iron filling pieces; the space between these rails is afterwards filled with cement to within an inch from the top, so as to cause as little obstruction to traffic as possible, the guard rail is slightly elevated above the running rail. Frequently rails are used in paved streets of insufficient height to admit of a paving block between the ties and the head of the rail; when this is the case, the difference in height has to be made up by the use of chairs; this leads to rather complicated joints, and requires a longer time to lay than the method of direct spiking to the ties.

### MAIN DIVISIONS OF SPECIAL WORK.

Special work may be divided into four classes considered with respect to its use and its position when in place, viz.:—intersections, passing sidings, crossovers and turnouts, and miscellaneous combinations.

1. *Intersections.*—By the term intersection is meant the special work placed at the intersection of two or more streets, and may assume an almost endless variety of forms as regards number and direction of curves and the alignment of the main tracks. The work must be so constructed as to guide the cars in whatever direction required, without any other external assistance than the moving of the tongues in the switches by the motor men; the cars must ride as smoothly as possible, *i.e.*, there should be no jolting; in places where a groove is to be crossed that would cause the car to run unevenly, the floor should be raised so as to give a bearing on which the flanges may run. On double track lines the distance between tracks is usually from four to five feet, but in order that cars may pass one another on the curves, and not be obliged to wait at the ends, this distance is increased to about seven or eight feet to provide ample clearance, this extra width is obtained by striking the curves from different centres, *i.e.*, the curves are not concentric. The practice in Montreal and Toronto has generally been to make the inner and outer curves of the same radius when the apex angle has been nearly 90°; but when the angle varies greatly from a right angle, the outer curve has generally been made sharper than the inner when running round the obtuse angle. When the centre line of street changes direction, or has a "jog" at the intersection, necessitating a plain or reverse curve on the through tracks, the complications increase very rapidly.

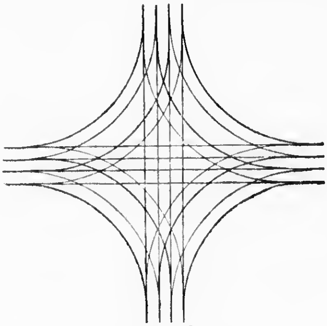


Fig 15

FOUR CONNECTING CURVES

2. *Passing Sidings.*—These are used on single track lines when cars run in both directions; they may be divided into two classes, viz.: diamond and thrown-over sidings.

Fig 16
DIAMOND SIDING

Fig 17
THROWN OVER SIDING

In the diamond siding (Fig. 16) the track diverges like a Y at either end, so that the centre line between the tracks in the sidings is on line with the centre line of the single track; this is the form usually adopted on single tracks running through narrow streets. If it is desired that cars shall run either to the right or left at these points, the switches of the sidings must be provided with movable tongues; but if the cars always run in the same direction, they may be guided in the direction required by a movable tongue held to the proper side by a spring, so that a car facing a switch is always guided to the same side, and a car trailing it compresses the spring, and passes on, the tongue of the switch falling back to its proper position. (See Plate Fig. B.) This guiding of the car in one direction, however, may be provided for much more simply by means of a switch without any movable part, commonly called a blind switch. One side of the switch is straight and the other curved, the front of the switch coincides approximately with the end of the curve of the switch, whilst the curve to the opposite side begins near the back of the switch, as shown in Fig. 18. If the cars always run to the right (as in Montreal and Toronto) the switch is made left hand, *i.e.*, the p. c. of the curve turning to the left is in front of the p.c. of the curve turning to the right by the length of the switch (approximately); thus a car approaching the siding travels straight along on the tangent past the point of the switch, and is then curved out of its path to the side by the curve in the rail behind, and when leaving the siding runs over the curve of the switch; this is the best arrangement for such sidings, as it is the simplest, most durable, and causes least delay to the cars.

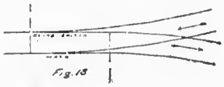


Fig. 18

In the thrown-over siding (Fig. 17) one track is continued straight through, whilst the other is thrown over to one side of it; this is suitable for single, track lines on a wide street, or in places where the track is on one side of the street. If cars are to be run to either side, switches with movable tongues are necessary; but if the cars always keep to the same side, the tongues must be provided with springs, or blind switches used; with the latter the problem is not so simple as in the diamond siding, and in order to solve it the main track has a slight reverse curve placed in it extending from the first of the switch to a short distance inside the curve cross; by introducing this, the general arrangement for the diamond siding holds good. (See Fig. 19.) The radius for the curves of passing sidings in Montreal and Toronto is 300 feet to inside gauge line.

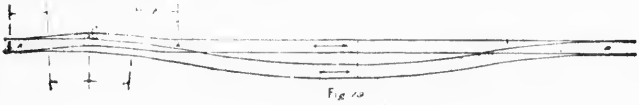


Fig 19
THROWN-OVER SIDING WITH BLIND SWITCHES

3. *Crossovers and Turnouts.*—Crossovers (Fig. 20), sometimes called connecting tracks, are used on double track lines for the purpose of transferring cars from one track to the other, and consequently are placed at the terminations of regular routes and at points which are made temporary termini to accommodate special traffic.

Turnouts (Fig. 22) are used when a double track runs into a single track, the centre line of the single track being on line with the centre line of one of the tracks of the double track line.

These crossovers and turnouts, as well as all special work, should change the direction of the car's motion from one line into another with the least amount of resistance possible consistent with the date given; those in Montreal and Toronto have 75 feet radius curve and about 25 feet of tangent, the latter varying with the distance between tracks; this gives a crossover of about 60 feet between extreme ends of switches. Crossovers and turnouts are said to be either left or right hand, according to the direction in which they curve from the track, as seen from the switch when looking towards the cross. Fig. 20 shows a right hand crossover. If a crossover of either hand is suitable at a certain point of the line, one of the same hand as the side to which the cars run should be chosen, *i.e.*, right hand crossovers are preferable for systems on which the cars run to the right and left hand, on those in which the cars keep to the left; this is on account of the fact that cars running always to the right will trail all switches of right hand crossovers and face those of left, so that they cannot possibly take the wrong track in the first case, while they may be suddenly thrown out of their course in the second, and accidents result.

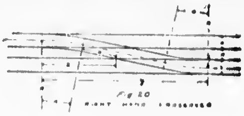


Fig 20

RIGHT HAND CROSSOVER

Fig 22

RIGHT HAND TURNOUT

In addition to permanent crossovers it is always necessary to have temporary ones during construction, which are laid directly on top of the paving wherever required. These are so constructed as to be easily and quickly laid in place and readily moved from one part of the line to another by a small gang of men.

4. *Miscellaneous Combination.*—Besides the work already mentioned, there are several kinds of diamonds made to fill various requirements. There are also special combinations for car houses, etc. The simplest kinds of diamonds are those used when electric lines cross electric lines, and only require the running rails. When an electric road crosses a steam road, the steam road track requires guard rails for greater safety, and the electric line should also be guarded either by an additional rail or plate.

### SUB-DIVISIONS.

Intersections, cross-overs, etc., are composed of several pieces, which may be divided into the following sub-divisions, viz.:—Tongue switches (single and double curve), blind switches, mates (single curve, double curve and combination), curve crosses (single curve, double curve and combination), diamonds (for electric and steam crossings), split switches, stub switches and lengths of rail (curved and straight). (See Pages 18 and 19.)

1. *Tongue-Switches.*—The tongue switch is perhaps the most important piece in any combination of special work, as it is subjected to greater and more frequent shocks than any other piece, its duty being to change the direction of the car's motion from one line to

another. When made of girder rail, it is constructed of the guard rail section to ensure the perfect guidance of the wheels. When made of Tee rail, a guard is formed either by bolting on another piece of rail, or by carrying up the casting on the side to form the required guard. The switch generally consists of four main parts, viz.:—the tongue, a casting and two pieces of rail. The tongue is made of steel, and should be of a substantial size, having a cross section near the point, proportioned to resist violent shocks: at the same time the point must be rather sharp to ensure the car "taking" it exactly; if blunt, the car may mount the tongue, and drop again, causing a severe jolt. If the top of the tongue rises above the level of the head of the rail, it is sloped at both ends so as to allow the rise and fall of the car to be imperceptible. The pin must be so placed as to make it impossible for a wheel to touch the tongue behind the pin, and so throw the switch before the back wheels have reached the point. If the tongue were made so long that the distance from the centre of the pin to the tongue point were greater than the wheel base of the cars (about 7 feet) this would be impossible; this method, however, would necessitate a too expensive switch, and the difficulty is easily overcome by rounding the back of the tongue and placing the pin sufficiently far back. The pin should also be placed so that the wheels do not run over it, and so cause it to become loose, and should be so fastened to the casting that the tongue may easily be removed at any time. The top of the casting on which the tongue slides and the bottom of the tongue should be truly even, as if not, dirt will collect between the two, and after a short time the tongue will tilt when a car runs over it, and may cause the tongue to throw to the opposite side, or the back wheel may strike the point, either of which may be sufficient to throw the car off the track. Single curve switches are those curved only on one side; double curve switches are curved on both sides.

2. *Blind Switches.*—The blind switch is used in place of the tongue switch when cars always run off the curve at that point and never enter it. It closely resembles the mate in general construction. In order that the guidance of the car facing the switch may not altogether depend on the fact that the car will naturally take the straight track in the direction in which it is moving, rather than turn into the curve, a ridge is left along the floor on the straight track which acts as a gauge line, to make it practically impossible for the car to enter the curve.

3. *Mates.*—The mate is the piece opposite the switch, on which the wheels of one side of the car run while the wheels on the other side are being pulled around by the switch: its sole use is to provide a surface for the wheels to run upon, and has nothing to do with the change in direction of the car's motion. It is made of two pieces of rail, and sometimes there is a casting. One piece of rail extends over the whole length, and is straight if for a single curve mate, and curved if for a double curved mate; the other piece is shorter and always curved, the head terminating in a point; this point should be so designed that the gauge at the point is quite slack, so that a wheel facing the mate may not strike upon it. The width of the point should not be less than ½-inch, as if made sharper it will wear to this. In girder rail the solid floor section makes the best mate, as it provides a wide floor for the wheels to roll upon, and the depth of the floor below the head of the rail being less than the depth of the flange of the wheel, it quickly wears so as to provide a double bearing for the wheels, so that the point is passed without the wheels dropping heavily upon it. If the mate is not made of the floor section, but of the ordinary girder rail as used on the straight track, or if of Tee rail construction, a steel casting is necessary to carry the wheels over the point from the long rail on to the short one; this casting is more efficient if carried up on the inside to provide a guard; for in case of the gauge being too slack, the tongue may have a tendency to jerk the car off the track. This casting must project considerably inside the gauge line of the short rail, the path of the rear wheels on a truck not coinciding with that of the front ones, but lying about ½-inch inside, as may be clearly seen on any worn mate.

4. *Curve Crosses.*—Curve cross is the name given in this work to the piece corresponding to the frog in steam railroad work; it differs considerably from the frog, however: one, at least, of the rails in a curve cross is generally curved to a very sharp curve, whilst the frog is straight on either track; the frog has wing rails, and a wheel crossing a frog runs from one piece of rail across the channel on to another rail, whilst in the curve cross a wheel generally runs the entire length of the cross on one piece of rail, the channel for the flanges being shaped out of the head of the rail. According as one or both rails are curved, the cross is said to be a single or double curve cross.

5. *Diamonds.*—Diamonds are made in various ways, according to the requirements they are to serve. A simple single track diamond for the crossing of two electric lines consists of two main parts, each part being made of five pieces of rail, one long piece with four short pieces butting up against it, two on each side; the long rail is usually made to form part of the track on the street having the greater amount of traffic. When an electric road crosses a steam road, the diamond is usually all made of tee rail, of the same section as the rail of the steam road. If the rails of the steam road are not to be cut, the diamond is made in three parts (Page 19, Fig. E), two outside and one inside the steam track, the whole being so constructed as to lift the street car before reaching the rails of the steam track on to the flanges of the wheels, and running across on them to the other side, and then dropping gradually to the ordinary level again, so that the only place where any jolt can occur to a car while crossing such a diamond is when it crosses the channel of the steam track rails, notwithstanding the fact that the rails of the steam track are not cut to the smallest extent to provide a passage for the flanges of the street-car wheels.

6. *Split Switches.*—Split switches are used to a comparatively small extent on this class of work. They are more especially adapted to suburban traffic when Tee rail is used, rather than crowded thoroughfares of cities. They are especially suitable when cars always run to the same side, when the switch may be made to work automatically by means of a spring, and in this way they have been found very satisfactory.

7. *Stub Switches.*—Stub switches are suitable for yard purposes and sidings only occasionally used; they are cheap, which is always a point in their favour. The use of a stand prohibits their use in city thoroughfares.

8. *Lengths of Rail.*—Rails for all special work should be accurately cut to the required lengths, and carefully bent to the proper template if for use on a curve, or accurately straightened if required for straight track. If part of a rail is to be straight and the remainder curved, the rail must not only agree with straight edge and template for the required lengths, but it must be tested, to determine whether the straight part is tangent to the curve, for if not, the piece will not fit correctly when placed in the work of which it forms part.

## THE DETERMINATION OF NECESSARY SPECIAL WORK.

Having laid down the routes of any street railway system necessary for the accommodation of the present traffic and that of the near future, the special work required becomes apparent. It is most important that curves likely to be required in a few years, but not necessary at the present, should be laid, if at all possible, during construction, as the addition of a single curve to an intersection in some cases necessitates the reconstruction of the greater part of the whole intersection.

## SURVEYS.

A careful survey must be made of the intersection of streets requiring special work, and all measurements of lines and angles taken which are necessary to plot with the greatest accuracy the centre lines of the proposed tracks together with the street and curb lines.

## PLOTTING.

These measurements are plotted to a suitable scale (say 10 feet to 1 inch), and the most suitable radii for the required curves determined, which are usually from 40 to 75 feet radius (45 and 50 ft. are most common in Montreal and Toronto).

The attempt is sometimes made to ease these curves as on steam railroad work; but when it is remembered that the length of most of the curves is about 80 ft., it will be seen how limited the space is in which to attempt anything of the kind; however, an improvement may be introduced by making the switches at the ends of curves of a longer radius than the main part of the curves, such as using 75 ft. radius switches on 45 ft. radius curves, this eases the curves for 10 ft. at each end and meets all practical requirements, any further steps in this direction would seem to lean towards "hair splitting."

It might here be mentioned that although these curves would appear very sharp to engineers accustomed to steam railroad work, yet there is a case on record of a 50 ft. radius curve on a trestle being used on a steam railway, and operated successfully, the speed on it being from 8 to 10 miles per hour. (U.S. Military Railway, Petersburg, Va.; see Trans. Am. Soc. C.E. 1878.) The Manhattan Elevated Railway in New York city has curves of 90 feet radius.

There should be, if possible, sufficient space between the inside rail of the curve and the curb stone for a vehicle to pass a car easily; this, however, requires very wide streets; if this cannot be done, the rail should be at about two feet from the curb stone at the corner, for if at say four feet, there would not be sufficient room for a car and vehicle to pass, but the attempt might be made and an accident ensue. The radii of the curves should also be determined with a view to sufficient room for the switches; if this is not looked to, special short switches may be required, which is not desirable. The intersecting points of the gauge lines should also be carefully observed, as by the slight alteration of a radius, combination pieces of complicated construction and of an unendurable character may often be avoided. The radii having been fixed, the gauge lines alone may be laid down to a large scale (say 4 feet to 1 inch), and the calculations proceeded with.

## CALCULATIONS.

The data on which the calculations are based are:—the gauge, distance between tracks, angle of intersection, radii of curves, and sometimes distances between apexes and deflection angles.

First, the tangents and lengths of all curves are found; next, the distances between the ends of the curves are determined.

In the case of a double track branch-off, with inner and outer curves of the same radius and equal central distances, this distance, $a$ (Fig. 25), is given by———distance between *P.C.'s*, $a = (\text{gauge} + \text{central distance}) \tan \frac{\text{centre angle}}{2}$

If the radii are equal, but the central distances on the two streets are unequal, the distances required may be found as follows:—

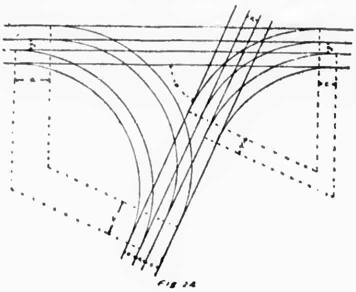


Fig 24

Let $G$ = gauge. (See Fig 24)

" $D$ and $D$ = central distances

" $a$ = angle of intersection

Since the radii of the inside and outside curves are equal, the tangents (for the same angle) are equal.

∴ distance between $P.C.$'s = distance between apexes.

(both measured parallel to gauge lines)

$$\therefore a = (G - D_1) \text{ cosec } a - (G + D_2) \cot a$$

$$b = (G + D_2) \text{ cosec } a + (G + D_1) \cot a$$

$$c = (G + D_1) \text{ cosec } a - (G + D_2) \cot a$$

$$d = (G + D_2) \text{ cosec } a - (G + D_1) \cot a$$

When both the central distances and radii vary, the distances between $P.C.$'s are found by adding and subtracting the lengths of the tangents, making allowance for the apex angle if differing very much from a right angle.

Next, the number of pieces into which to divide the intersection is determined, and the proper lengths for switches and mates fixed.

The points when the curves intersect the straight gauge lines are next formed; this may be done by either of the two following methods:

Taking Fig. 25 with distances as marked.

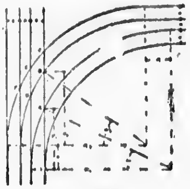


Fig 25

1st Method. Consider the point A,

$$H_1 = \sqrt{(R_1 + G)^2 - R_1^2}$$

$$= \sqrt{2 G R_1 + G^2}$$

$$sin\ a_1 = \frac{H_1}{R_1}$$

$$\therefore a_1 = sin^{-1}\left(\frac{\sqrt{2 G R_1 + G^2}}{R_1}\right)$$

Similarly for $B$, $H_2 = \sqrt{R_2^2 - (R_2 - D - G)^2}$

$$sin\ a_2 = \frac{H_2}{R_2}$$

$$\therefore a_2 = sin^{-1}\left(\frac{\sqrt{R_2^2 - (R_2 - D - G)^2}}{R_2}\right)$$

and so on for other points.

2nd Method.—For $A$, $vers\ a_1 = \frac{G}{R_1 + G}$ ∴ $a_1 = vers^{-1}\left(\frac{G}{R_1 + G}\right)$

$$H_1 = R_1 \sin a_1$$

For $B$, $a^2 = vers^{-1}\left(\frac{D + G}{R_2}\right)$

$$H_2 = R_2 \sin a_2$$

Similarly for other points.

At a distance $s$, the spread $w = 2\ s \sin \frac{a}{2}$ (See Fig. 26) which is

Fig 26

the distance between two points at a distance $s$ from the intersection point, one on the straight gauge line and the other on the tangent to the curve at the intersection point.

The straight lengths of the figure (Fig. 25), *i.e.*, the distances along the straight track between the points $A$, $B$, etc., are found by means of the lengths $H_1$, $H_2$, etc., and the distance between the $P.C.$'s. The arc to any point from the $P.C.$ is given by:—

$$\text{arc} = \text{radius} \times {}^{*}c.m.\ a.$$

So that the curved lengths, *i.e.*, the distances between the points $D$, $B$, - $F$, $E$, etc., are found by taking the differences between the arcs to these points, while the distances beyond $A$, $B$, etc., to the other end of the curve are found by taking the differences between the total lengths of the curves and the arcs to these points.

The following tables have been calculated by means of the preceding formulæ:—

| | Radius of inside gauge = 45′ 0″ Gauge = 4′ 8½″. Central distance = 4′ 0″ | | | | Radius of inside gauge = 50′ 0″. Gauge = 4′ 8½. Central dist. = 4′ 0″. | | | |
|---|---|---|---|---|---|---|---|---|
| Points as in Fig. 25. | Perpendicular from P. C. in feet. | Angle at centre subtended by arc to point. | Arc from P. C. to point in feet. | Spread at two feet. | Perpendicular from P. C. in feet. | Angle at centre subtended by arc to point. | Arc from P. C. to point in feet. | Spread at two feet. |
| *A* & *F* | 21.117 | 25° 08′ | 21.812 | $10\frac{7}{16}$″ | 22.204 | 23° 57′ | 22.863 | $9\frac{15}{16}$″ |
| *B* | 26.607 | 36° 15′ | 28.467 | $11\frac{15}{16}$″ | 28.196 | 34° 20′ | 29.995 | $14\frac{3}{16}$″ |
| *C* | 33.968 | 43° 06′ | 37.396 | $17\frac{3}{8}$″ | 35.889 | 41° 00′ | 39.144 | $16\frac{13}{16}$″ |
| *D* | 18.547 | 24° 21′ | 19.116 | $10\frac{1}{8}$″ | 19.596 | 23° 05′ | 20.137 | $9\frac{5}{8}$″ |
| *E* | 28.105 | 34° 26′ | 29.870 | $11\frac{1}{16}$″ | 29.614 | 32° 46′ | 31.293 | $13\frac{9}{16}$″ |

When the intersection has curves branching in both directions, as shown by Fig. 13, the points where the curves intersect as $K$, $L$, etc., have to be found, in order to determine the different lengths; the problem thus becomes "to determine the intersection point of two curves branching in opposite direction from parallel lines." This may be solved by either of the two following methods, the second of which is much the more readily applied. (See Fig 27.)

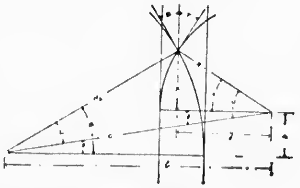


Fig 27

Let $R_1$ = radius of curve with upper $P.\ C.$
" $R_2$ = " " " lower $P.\ C.$
" $a$ = distance between $P.\ C.$'s measured parallel to gauge lines.
" $b$ = " " centres " perpendicular " "
" $c$ = " " " " in a straight line.
" $x$ = " of intersection point from upper $P.\ C.$ measured para. to gauge lines.
" $\theta$ = angle between a line perpendicular to gauge lines and line joining centres.
" $U$ = angle at upper centre between radius to intersection point and line joining centres.
" $L$ = angle at lower centre between radius to intersection point and line joining centres.
" $B$ = angle at centre subtended by arc between lower $P.\ C.$ and intersection point.
" $T$ = angle at centre subtended by arc between upper $P.\ C.$ and intersection point.

1st Method:—$x^2 + y^2 = R_1^2$.

---

[*] c.m. = circular measure.

$$\therefore y = \sqrt{R_1^2 - x^2}$$

$$(x + a)^2 + (b - y)^2 = R_2^2$$

$$\therefore x^2 + 2ax + a^2 + b^2 - 2\,b\sqrt{R_1^{\,2} - x^2} + R_1^2 - x^2 = R_2^2$$

which becomes

$$4\,x^2\,(a^2 + b^2) + 4\,ax\,(a^2 + b^2 + R_1^2 - R_2^2) = R_1^2\ (2b^2 - R_1^2 - 2a^2 + 2\,R_2^2)$$
$$+\ R_2^2\,(2\,a^2 + 2\,b^2 - R_2^2) - b^2\,(b^2 + 2\,a^2) - a^4$$

Corollary. When $R_1 = R_2 = R$

$$\text{then } x^2 + ax = \frac{1}{4(a^2 + b^2)}\left\{ b^2\,(4\,R^2 - b^2 - 2\,a^2) - a^4 \right\}$$

These formulæ are very labourious to use in practice ; however, as in the majority of cases $R_1 = R_2$, the corollary is the more frequently required.

Having found $x$, the angles $B$ and $T$ are given by

$$\sin B = \frac{x + c}{R_2}$$

$$\sin T = \frac{x}{R_1}$$

and the spread at a distance $s = 2\,s\,\sin\left(\frac{B + T}{2}\right)$

These formulæ apply also when the two curves branch off in the same direction, with the exception that the spread is given by

$$\text{spread} = 2s\,\sin\left(\frac{T - B}{2}\right) \text{ (see Fig. 28.)}$$

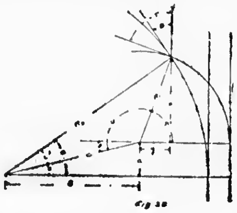


Fig 28

2nd Method :

$$\tan\theta = \frac{a}{b}$$

$$c = b\sec\theta$$

$$\cos U = \frac{c^2 + R_1^{\,2} - R_2}{2\,c\,R_1}$$

$$\cos L = \frac{c^2 + R_2^{\,2} - R_1^{\,2}}{2\,c\,R_2}$$

$$T = U - \theta$$

$$B = L + \theta$$

$$\text{spread} = 2s.\ \sin\left(\frac{B + T}{2}\right)$$

Corollary. When $R_1 = R_2 = R$

then $U = L$

$$\sec U = \sec L = \frac{2\,R}{c}$$

$$\text{spread} = 2s\,\sin U$$

When two curves branch in the same direction (Fig. 28) the above applies with the following exceptions :—

$$T = 180^\circ - (U - \theta)$$

$$\text{and spread} = 2s\,\sin\left(\frac{T - B}{2}\right)$$

Having fixed these points, the straight lengths are found as before by means of the perpendicular heights to the intersection points of the single curve crosses and the distances to the diamond by means of the tangents. The arcs to the intersection points of the double curve crosses are given by :—

For arc to intersection point on curve with upper *P.C.*,

$$\text{arc} = R_1 \; c.m. \; T$$

For arc to intersection point on curve with lower *P.C.*,

$$\text{arc} = R \; c.m. \; B.$$

so that the distances along the arcs between the points are given by taking the differences between the arcs.

In Fig. 13 it may be noted that when the radii of all the curves are equal, the angle $\theta$ for the points $L$, $N$, $O$ and $P$ = intersection angle $\sim 90^\circ$.

that for the points $K$, $L$, $M$ and $P$, $R_1 = R_2$

" " " $L$, $N$, $O$ and $P$. $a$, $b$ and consequently $\theta$ and $c$ are the same.

that the angle $U$ for the point $N$ = the angle $L$ for the point $O$, and *vice versa*.

that $L\,N = L\,O$, $N\,U = O\,R$. $O\,P = N\,P$, and $P\,T = P\,S$.

The following table has been calculated by the preceding formulæ from the following data:—(refer to Fig. 13) $D_1 = 4'\,9''$, $D_2 = 4'\,0''$, $a = 86^\circ\,33'$, gauge $= 4'\,8\frac{1}{2}''$, radius of inside gauge line of all curves $= 45'\,0''$.

| Points (Fig. 13). | Perpendicular from upper *P.C.* ($x$). | Angle at centre subtended by arc branching to left. | Angle at centre subtended by arc branching to right. | Spread at 2 feet. |
|---|---|---|---|---|
| *K* | 5.31 | 21° 21′ | 6° 08′ | $12\frac{5}{8}''$ |
| *L* | 10.394 | 20° 15′ | 13° 21′ | $13\frac{7}{8}''$ |
| *M* | 13.104 | 15° 17′ | 19° 50′ | $14\frac{1}{2}''$ |
| *N* | 16.851 | 29° 19′ | 19° 49′ | $19\frac{15}{16}''$ |
| *O* | 17.162 | 26° 43′ | 22° 25′ | $19\frac{15}{16}''$ |
| *P* | 22.165 | 33° 23′ | 26° 29′ | $23\frac{15}{16}''$ |

Note:—$2\,(90^\circ - 86^\circ\,33') = 6^\circ\,54'$

= difference between left and right angles of $L$ and $P$

= " " " of $N$ and right angles of $O$

= " " right of $N$ and left of $O$

To determine the *P.C.* of a branch-off curve from a curve main track:

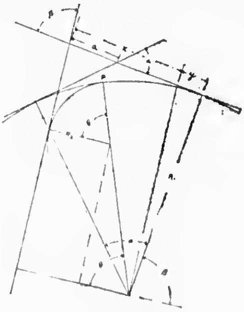


Fig 29

Let $a$ = deflection angle of main track tangents

Let $\beta$ = angle between one of these tangents and tangent to branch-off curve.

Let $\theta$ = angle between line joining centres and perpendicular from centre of main track curve to tangent of branch off curve.

Let $a$ = distance between apexes.

Let $R_1$ = radius of main track curve.

Let $R_2$ = " " branch-off "

It is required to determine the point $P$.

Taking $x + y$ as shown by Fig. 29:

$$x = a + R_1 \tan\frac{\alpha}{2} - y$$

$$= a + R_1 \tan \frac{a}{2} - R_1 \cot \beta$$

$$= a + R_1 \left(\tan \frac{a}{2} - \cot \beta\right)$$

$$\text{and } \cos \theta = \frac{x \sin \beta - R_2}{R_1 \mp R_2}$$

$$= \frac{\left(a + R_1 \tan \frac{a}{2}\right) \sin \beta - R_1 \cos \beta - R_2}{R_1 \mp R_2}$$

$R_1 - R_2$ when curves branch in the same direction as in Fig. 29.
$R_1 + R_2$ " " " opposite directions.

This determines the point $P$ with respect to either *P.C.*

To determine the intersecting points of the gauge lines when the main track curve lies wholly between the *P.C.* of the branch-off curve and the nearest intersecting points.

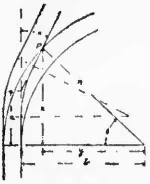


Fig. 30

$P$ is the point to be determined (Fig. 30), taking lengths as marked.

$$x^2 + y^2 = R^2$$

$$y = b - (x - a) \tan a$$

$$\therefore x^2 + \{b - (x - a) \tan a\}^2 = R^2$$

which becomes

$x^2 \sec^2 a - 2x \tan a (b + a \tan a) = R^2 - b^2 - a \tan a (2b + a \tan a)$

when the main track curves in the opposite direction to that of the branch-off, this equation becomes

$x^2 \sec^2 a + 2x \tan a (b - a \tan a) = R^2 - b^2 + a \tan a (2b - a \tan a)$

$$\theta = \sin \frac{x}{R} \text{ for both cases.}$$

and spread $= 2s \sin\left(\frac{\theta - a}{2}\right)$ when main track and branch-off curve in same direction

or spread $= 2s \sin\left(\frac{\theta + a}{2}\right)$ when main track and branch off curve in opposite directions.

If the distance ($h$) from the *P.C.* of a curve is known, the deflection ($d$) to the curve at that point is given by

$$d = r - \sqrt{r^2 - h^2}$$

or $d = r \operatorname{vers}\left(\sin^{-1} \frac{h}{r}\right)$ (See Fig. 31)

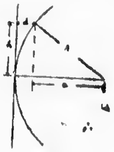


Fig 31

In order to make templates to which the rails are bent, calculations are necessary for flat curves (over 60 ft.); but those of a shorter radius may be trammelled out. To calculate these templates, the deflections at every 3 inches from zero up to half the length of the required template are calculated by one of the above formulæ. These deflections are laid off on a board, a curve is drawn through the points so found, and the board is then cut to the curve. Of course the trammelling process is preferable whenever practicable.

*Calculations for Crossovers.*—Taking lengths as shown by Fig. 20.

$$2\ R\ vers\ a + tangent\ sin\ a = D + G$$

First, a length may be fixed upon approximately as desirable for a tangent; with this length, solve for $a$ (most easily done by trial), having found $a$ approximately, assume an even value for it (say to nearest 10 minutes) for simplicity, and with this value solve the equation again for the length of tangent, determining it exactly, which will be very close to tho desired length (practically the same).

The distances from centre $P.C.$ to intersecting point of inside gauge is given by

$$x = D\ cosec\ a - \left(R - \frac{G}{2}\right)\ tan\ \frac{a}{2}$$

The total length between extreme end $P.C.$'s is given by

$$y = 2\ R\ sin\ a + tangent\ cos\ a$$

The distance from end $P.C.$, to nearest intersecting point measured along main track is given by

$$Z = \left(R - \frac{G}{2}\right) sin\ a + x\ cos\ a$$

$$= D\ cot\ a + \left(R - \frac{G}{2}\right)\ \left(sin\ a - 2\ sin^2 \frac{a}{2}\right)$$

By making tangent $= 0$, the conditions for a reverse curve are given

$$2\ R\ vers\ a = D - G\cdot$$

$$\text{and } y = 2\ R\ sin\ a$$

When a crossover is required for a width between tracks, $D_1$, the only charge necessary in a crossover designed for a width $D$ is in the length of the taugent which is changed by a length $= (D_1 \sim D)$ $cosec\ a$.

To determine a reverse curve (short tangent between curves) between two tangents not parallel, at an intersection.

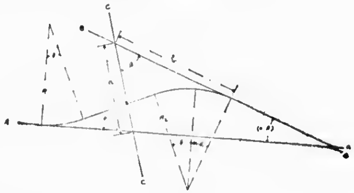


Fig 32

$A.A.$ and $B.B.$ are the two tangents not parallel, representing the centre lines of a street with a deflection at the intersection of another street, the centre line of which is represe[illegible]d by $C.C.$

Take distances as shown in Fig. 32.

Fix upon a point which will be convenient to form one end of the curve, and let its distance from an apex be $b$.

Then, $R_1\ vers\ \theta + tangent\ \ sin\ \theta + R_2\ vers\ \theta = a\ \ sin\ a - b\ \ sin\ (a - \beta) + R_2\ vers\ (a - \beta)$, as in the ordinary crossover calculations, fix $\theta$ by trial and then solve for the tangent,

$$\text{tangent} = \frac{1}{sin\ \theta} \left\{ a\ \ sin\ a - b\ sin\ (a\ - \beta) + R_2\ vers\ (a - \beta) - vers\ \theta\ (R_1 + R_2\ ) \right\}$$

Having determined upon the angle $\theta$, and found the tangent the other lengths are easily found.

*Calculations for Diamond Siding.*—Consider end $A$, Fig. 16.

$$\text{vers } a = \frac{D + G}{4R}$$

total length between extreme $P.C.^s = 2R \sin a$

$\cos$ angle at centre subtended by arc from right hand $P.C.$ to intersection point $= \dfrac{R - \frac{1}{2}(G + D)}{R - \frac{1}{2}G} = \cos \beta$

angle of curve cross $= 2\beta$

distance from right hand $P.C.^s$ intersection point $= (R - \frac{1}{2}G) \sin \beta$.

These calculations apply when the curves begin at the same point to branch to either side as in Fig. 16; but when the curves begin at different points (for blind switches) as in Fig. 18, the intersecting point does not lie on the centre line, and may be found as follows:—(Fig. 33.)

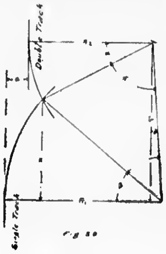


Fig 33

$$\tan \theta = \frac{R_1 - R_2 - a}{b}$$

$$\cos \pi = \frac{R_2{}^2 + (b \sec \theta)^2 - R_1{}^2}{2 R_2 b \sec \theta}$$

$$\cos \phi = \frac{R_1{}^2 + (b \sec \theta)^2 - R_2{}^2}{2 R_1 b \sec \theta}$$

$$a = 90° + \theta - \pi \quad \text{and} \quad \beta = 90° - \theta - \phi$$

$$x = R_1 \sin \beta \qquad \text{and spread} = 2s. \sin\left(\frac{a + \beta}{2}\right)$$

*Calculation for thrown-over siding with blind switches.*—The calculations are generally similar to those already described for crossover and diamond sidings, except for the curves in the main track; these are solved as follows:—(See Fig. 19, end A)

$$a = (R + \tfrac{1}{2}G) \text{ vers } a + \text{width of switch at back}$$

$$\text{vers } \beta = \frac{a}{2R}$$

Total centre angle for curve adjoining switch $= a + \beta$.

### WORKING DRAWINGS.

Having completed the calculations for an intersection, the detail drawings for each piece are made, and sent to the shop, together with a print showing the whole intersection with the distinguishing marks of all pieces and lengths of the connecting rails. A drawing is also made for assembling the work in the street, showing all necessary measurements for laying out the work together with the position and marks of the various pieces.

### SHOP WORK.

A bill of the rails required and the necessary new prints and references to old ones having been obtained from the Drawing Office, the manufacture of the work may be proceeded with. The bill of rails required (made out so as to give a minimum amount of scrap) is given into the hands of the man in charge of the rail saw, who proceeds to cut up the rails into the required lengths, marking the length of each and whether required straight or curved upon the web. The rails next with few exceptions, go to the rail bender, to be either curved to the required radius, or straightened; they next proceed to the "marker off," who carefully marks the necessary lines for all machine work required to be done upon them, he also stamps the rails on the end with their distinguishing marks; the rails afterwards pass on to the machines (milling machines, slotters, shapers, planers, etc.) suited to the work required; they then go to the fitting shop to be assembled according to the drawings.

In a tongue switch the long rail has to be properly curved, and slotted or bent for the tongue to fall into place. The tongue is made of hammered steel, and the turned pin is shrunk in; this is dropped into place, and all measurements checked before being considered ready for the track.

In the blind switch and mate, one rail is planed so as to leave a long notch on one side, while the other rail is planed to a point which fits into the notch; the two are strongly bolted or rivetted together and sometimes finished on a planer.

The curve crosses have usually two pieces of rail, one of which has the upper part so shaped at the crossing point as to allow the second one to drop down on the first, and fit accurately into the place allowed for it; while the second has the lower part shaped so as to allow the first rail to pass through, the two rails jointing neatly into one another. Great care is necessary in the fitting to have the angles of intersection exactly as required; in order to obtain the correct angle, the drawing shows the spread, $w$, at a fixed distance, together with the deflections, $d_1$ and $d_2$ of the curves at that point; so that this distance is measured along the rails from the intersection point and the deflections marked from the gauge line, the spread is then measured between the points so marked. (See Fig. 26.)

### CHECKING.

When an intersection has been made, it is sometimes advisable to have it assembled as a final check before shipping; for this purpose a large piece of ground, as level as possible, is required, and much more than is actually occupied by the work when in place should be available; the tangents of the intersection should be laid out, and a sufficient number of points fixed to accurately check the end of each curve. Having laid out the ground, the pieces are assembled, and any errors observed may be corrected; this last step ensures the work being absolutely correct, and is the best check on the work that can be adopted.

### ASSEMBLING IN THE TRACK.

In laying an intersection, it makes a great deal of difference whether the whole space required is graded at once and all traffic stopped, or if only part of the intersection is graded, leaving part undisturbed so as not to interrupt traffic. When the work has to be performed in the latter way, great care is necessary in placing the work, so that the remaining part when laid may fit up to and line in accurately with the first part. If it is necessary to lay out a curve, it is generally most easily performed by tangent and chord deflections or by ordinates from a chord. In grading a corner when an important intersection is to be laid, care should be exercised in excavating to the correct depth and having the grading done evenly, for if the track has to be lifted say six inches after being laid, it means very much more than the same lift on ordinary track, as the weight of rail is sometimes enormous as compared with the extent of ground it covers; also, if the work has been carelessly done, and presents a very uneven bed, much more time is necessary to couple up the joints than would have been required had the grading been properly performed. The spacing of the ties for this work should receive more attention than is sometimes given to it, as it is a very important matter. The ties should be the very best available, and spaced more closely than those on the straight track.

The center lines of tracks for both streets are accurately fixed, and if there is no diamond, the ends of the curves must be found; otherwise, this is not essential. If there is a diamond in the intersection, this is laid first, bolted up and lined accurately. The other pieces having been scattered about in their approximate positions are next drawn to place and bolted together. The rails are then securely spiked to gauge, and lifted (if necessary) to grade, when the intersection may be paved and so completed. If there is no diamond to lay, an end of a curve may be taken as the starting point. To lay the intersection so as to have the through straight tracks in perfect alignment requires great care, as the joints are usually very close together.

An idea of the amount of rail that may be used is a single intersection, and the consequent amount of labour required to make one, may be formed from the following figures, for one laid at the intersection of St. Lawrence Main and St. Catherine streets, Montreal (same as Fig. 15). It is built of 75 lbs. and 84 lbs. girder rail (Figs. 3 and 4). It contains 2,150 feet of rail, and has a total weight of about 26 tons. There are 86 built up pieces (switches, mates and curve crosses), and 78 lengths of connecting rails, making a total of 164 pieces in the complete intersection. The extreme length between ends and opposite switches is about 110 feet. The radius of the inside gauge lines of all the curves is 45 feet, and the distance between tracks varies from 4 ft. to 8 ft. 6 in. This intersection, as well as all others in Montreal and Toronto, was made by the Canada Switch Manufacturing Co., Lim., of Montreal.

Such work, when properly constructed and laid, represents a large amount of capital, and deserves much more attention and care than the old cast iron work; but, unfortunately, it seems sometimes to be treated no better. The curves at intersections are necessarily very sharp, and in order to diminish the amount of power required and the wear on the rails (as well as on tires), they require oiling at least once a day for heavy traffic, while the rate at which cars run over special work should be strictly regulated to a low speed. The groove of the rail and the tongue switches require to be constantly cleared of the dirt which inevitably collects, and if not removed causes great inconvenience. The life of such work may be appreciably prolonged by such attention, and when one considers the cost of renewal and the consequent interference to traffic while doing so, it will be readily seen that it pays in the end.

# TEE RAIL SPECIAL WORK

Fig A
TONGUE SWITCH

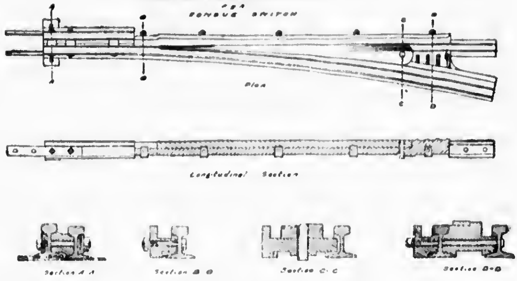


Fig B
TONGUE SWITCH WITH SPRING

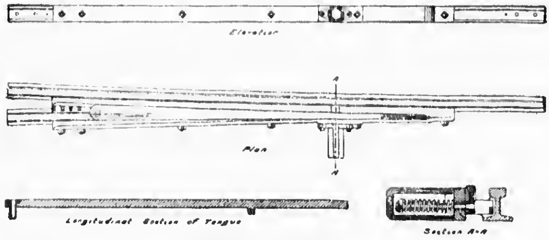


Fig C
MATE

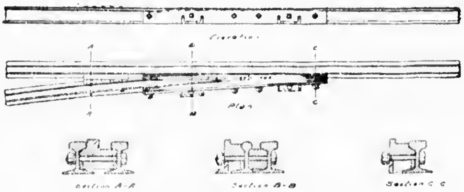


Fig D
CLAVE CROSSES

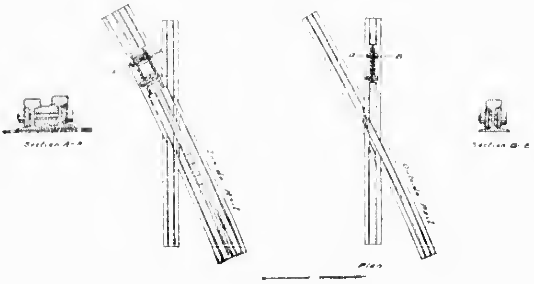
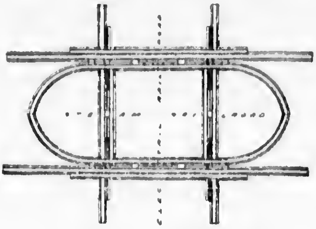


Fig [illegible]
Diagram for crossing of electric and steam railroads



## GIRDER RAIL SPECIAL WORK

Fig A
Tongue Switch

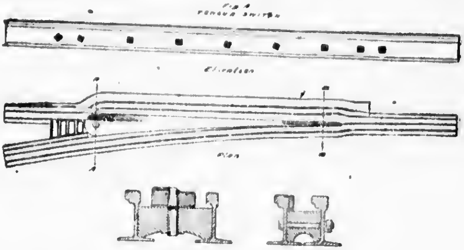


Fig B
Blind Switch

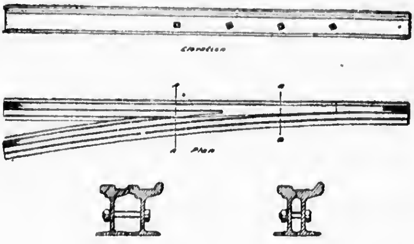


Fig C
Mate

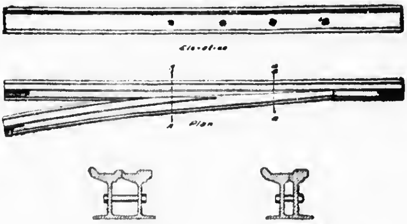


Fig D
Curve Cross