METROPOLITAN TRANSIT AUTHORITY
OF VICTORIA

Feb. 1988.

Warren Doubleday BTPS.

This was prepared by M+MTB in 1928 and issued mid - 1987.

You will find it of interest I think. One of the chaps in here bound it to survive depot usage.

chris jacobson

METROPOLITAN TRANSIT

Inter Office Memorandum Date: 20th July 1987

To: CIVIL DESIGN DRAFTING STAFF

From: K.C. PAINTER

Subject: TRAMWAY PERMANENT WAY

During a recent discussion Stan Hewish reminded me of a series of lectures which were given to Permanent Way Inspectors, Sub-overseers and Gangers by the then M.M.T.B. in 1928. A set of the original papers has been found.

I thought you might be interested to receive a copy because many of the principles still apply.

Judging by the questions I have been asked recently, some of you will be interested also in the historic background of the development of the track structure in the Melbourne system.

K.C. Painter
20.7.87

K.C. PAINTER

KCP/KS

Mr Anderson

CIRCULAR TO TRACK INSPECTORS, SUB.OVERSEERS AND SENIOR GANGERS.

At the suggestion of one or two of the Inspectors, it has been decided to hold a number of voluntary classes for Inspectors, Sub-overseers, and Senior Gangers, dealing with the technical side of track work.

Meetings will be held on Monday evenings at 8 p.m. commencing 23 Jan. 1928 at Hawthorn Depot, and will occupy an hour. Each ~~officer~~ employee who attends will be paid an hour's pay at the ordinary rate (i.e. not special overtime).

At each meeting one of the Per. Way officers will give a brief talk on a branch of track work, and at least half an hour will be allowed for discussion and answering of questions.

In order that the scheme may be a success, it is desirable that all ~~officers~~ employees eligible to attend should do so, but attendance is by no means compulsory.

The committee consists of Messrs. O'Meara, Eakins, Bell and Gray, who will supply any further information needed.

Attached is a brief outline of the matters to be discussed, with dates.

Signed by T. P. Strickland

CHIEF ENGINEER.

OUTLINE OF A SERIES OF LECTURES TO PER. WAY INSPECTORS, SUB. OVERSEERS AND SENIOR GANGERS.

SERIES 1.

Period	Series of 10 lectures one per week.
Commencing	Monday 23. 1. 28
Time	8 p.m. to 9 p.m. - Lecture and Discussion
Place	Hawthorn Depot
Payment	To Inspectors, Sub. Overseers and Senior Gangers Ordinary time.
Lecturers	Per. Way Officers

S Y L L A B U S.

LECTURE NO. 1. Monday January 23rd - Mr. Eakins

Interpretation of Drawings.

Types
Scales
Units
Conventional symbols
Levels
Datum
Grades
Vertical Curves

LECTURE NO. 2. Monday January 30th - Mr. Gray

Alignment etc.

Marks on ground for straights and curves
Circular curves
  Minimum radii permissible
    " " for pressing
    " " " crowing
    " " " springing
  Deflection angle
  Tangents
  Tangent Points
  Secants
  Circular arc.
  Bending diagrams
  Super-elevation

LECTURE NO. 3 Monday February 6th - Mr. Fischer

Alignment continued and Special Work

Easement curves
  Cubic Parabola
  Spirals
  Switch spirals
Bending diagrams
Special work nomenclature
Switches
Crossovers
Junctions

LECTURE NO. 4 - Monday February 13th - Mr. Eakins

The drainage System

- Water entering the track structure
- Surface Water
- Subsoil water
- Effect of water
- Methods adopted to minimise damage
- Track drains
- Ashes
- Subsoil drains
- Side drains
- Spall drains
- Reasons for pits and necessity for inspection.

LECTURE NO. 5 - Monday February 20th - Mr. Gray

Concrete

- Materials
- Proportioning
- Water content
- Workability
- Mixing
- Placing
- Curing
- Testing

LECTURE NO. 6 - Monday February 27th - Mr. O'Meara

Rails and Fastenings

- Types
- Design
- Material and manufacture

LECTURE NO. 7 - Monday March 5th - Mr. Smith

Welding

- The meaning of the term "welding".
- The various types of welds.
- The general application of welding.
- Welding as applied particularly to Tramway construction and Maintenance.
- Electric Arc Welding
  - (a) Welding sets
  - (b) The use of various types of electrodes.
- Welding costs.

LECTURE NO. 8 - Monday March 12th - Mr. Fischer

Timber

- Suitable and available varieties
- Properties
- Production
- Treatment
- Spacing and Laying of
  - Sleepers
  - Timbers
  - Stringers
- Woodblocks

LECTURE No. 9 - Monday March 19th - Mr. Eakins

Paving and paving materials
Wood, asphalt and bituminous pavements

Binders
Bitumen

Source
Production
Grades and nomenclature
Necessity for various grades
Heating
Pouring.

Tar

Source
Production

Tar v. Bitumen

Stone
Suitable varieties
Properties
Common defects.

LECTURE NO. 10 - Monday March 26th - Mr. O'Meara

Track cross sections

First cost, life, maintenance, advantages and known defects of the following types.

Ballast foundation
Concrete " and sleepers
Concrete foundation and stringers.

- - - - - - - - - -

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD.

LECTURE NO. 1 - INTERPRETATION OF DRAWINGS.

A. TYPES.

B. SCALES

C. UNITS.

D. CONVENTIONAL SYMBOLS.

E. LEVELS AND DATUM.

F. GRADES.

G. VERTICAL CURVES.

A good drawing is a faithful picture. It generally has a clear title, a scale, and a signature.

Definitions required :-

A plane is a flat even surface with length and breadth but no thickness.

A horizontal plane is one which is parallel to the surface of still water, i.e. a plane which is always at the same distance from the water surface.

A vertical line is one at right angles to a horizontal plane.

A. Types of drawings are :-

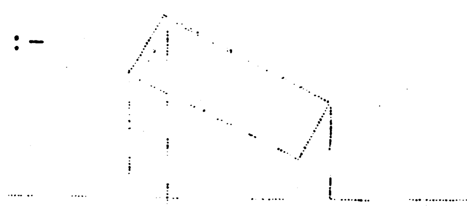
(1) Plans - shew the tracing made on a horizontal plane by a vertical line moving so as to pass successively through the various points and outlines of the objects concerned.

(2) Longitudinal Sections are a representation of what would be seen on a vertical plane through the centre line of a road, tramway, or railway.

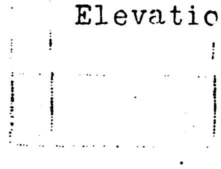
(3) Cross sections are a representation of what would be seen on vertical planes at right angles to the centre line.

(4) Detail drawings which shew more particulars of certain objects such as bolts, culverts, track drains. They may be plans, sections, or elevations. An elevation of an object is the heavy tracing made on a vertical plane by the end of a horizontal line at right angles to it, which moves so as to pass successively through the various points and outlines of the object.

Drawings of a match box inclined to the table would appear as under :-



Elevation



Plan.

B. Scales. The scale of a drawing is the key to the meaning of the lengths on it in relation to the objects drawn.

A scale of 1" = 40' means that a length of 1 inch on the drawing represents a length of forty feet on the ground, or a scale of 4' to 1" means that four feet on the ground are reduced to 1" on the drawing.

Our Per. Way drawings have the following scales in most cases:-

General plans and sections
Horizontal 1" = 40'.
Vertical 1" = 10'.

Track cross sections
Horizontal 1" - 10'.
Vertical 1" - 4'.

Details of curves.
Horizontal 1" - 10'
or 1" - 4'

Detailed cross sections
1" - 1'

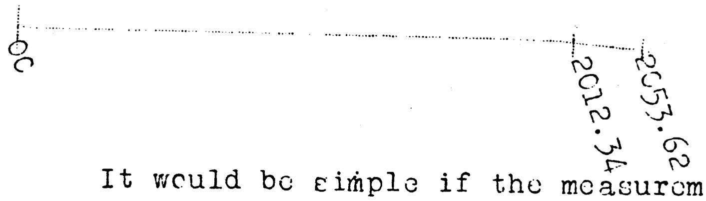
Track details and fastenings
Full size, half size or quarter size.

It will be noticed that scales vertical and horizontal in the same sections are different. This has been found necessary as the vertical heights are generally too small compared to the horizontal lengths that even Callantina with the same scales for vertical and horizontal would appear a gentle rise.

1" in the detail plans represents a shorter length than 1" in the general plans, so that more room may be available for the showing of the details.

C. Units. The measurements of objects in the field is done by surveyors and chainmen. The measurements of length are read off in feet and hundredths, and so are the measurements of height. This brings us to the question of decimals.

A measurement to a peg such as 2012.34 ft. means that the length from a starting point is 2012 complete feet and 34 hundredths of a foot. This latter can be written 34/100. Now if we have another peg on the same line which measures 2053.62 ft. and wish to get the distance in between these two pegs we subtract the lengths



2053.62
2012.34
41.28.

It would be simple if the measurements were even feet. The difference would then be forty-one feet. Now for the hundredths. The farthest point is 62 hundredths further on than the even feet, while the nearer point is 34 hundredths on. Therefore the extra difference is sixty-two hundredths less thirty-four hundredths, that is, twenty-eight hundredths so that the total difference is 41'and 28 hundredths, written as 41.28.

Two places of decimals shew hundredths
One place " " shews tenths.

To change from hundredths of a foot to inches multiply the hundredths by twelve and divide by 100..

Example. Express .35' in inches.

.35 x 12 = 4.20 inches.

Now ¼" = .25 x 3/16" = .1875". Therefore the measurement is nearer 3/16" than 4/16", so is 4 3/16" correct to sixteenths.

D. Conventional Symbols. To save space and lettering certain abbreviations and signs are used :-

Full lines - Existing or new work on the surface.
Dotted " - Work to be removed or existing underground work.
Fine " - Either the centre line or the surveyors' run line.
○ - Represent pegs.
- Represent instrument sites.
- On the footpath represents verandahs.
C.T.P. - Common Tangent Point.
C. of A. - P.M.G. manhole
E.W.P. - Earthenware pipe.
E.L.P. - Electric light pole.
F.A. - Fire Alarm.
F.P. - Fire Plug.
G.I. - Galvanised Iron.
G.P. - Guard Post.
H.P.V. - Hydro Power Co. valve.
Hyd. - Hydrant.
I.C.S. - Interconnected switches.
I.P. - Inspection pit.
M.M.B.W.)
M.B.W.B.M.) M.M.B.W. bench mark.
M.C.C.E.S. - M.C.C. Electric supply.
M.G.C. - Melbourne Gas Co. valve
M.T.P. - Mean tangent point.
OHP - Overhead pole.
P.H. - Pillar hydrant.
R.C.P. - Reinforced concrete pipe.
S.W. - Storm water pit or inlet.drain.
S.W.I. - Storm water inlet.
S.W.P. - Storm water pit.
S.W.Mo.) -
S.W.MH) - Storm water manhole.
S.M.H. - Sewer manhole.
S.I.S. - Sewer inspection shaft.

SP - Silt Pit
Si P - Siphon pit.
T.D. - Track drain.
Tr P - Tramway pole.
T.P. - Tangent point.
Ver. - Verandah.
V.P. - Verahdah post.
W.P. - Water plug

E. Levels and datum. To fix the position of any point it is necessary to have measurements in a horizontal plane (e.g. in the plan) and also in a vertical direction.

The height of any point above a fixed starting point is called its reduced level. These heights are measured in feet and hundredths by means of levels and staves. The starting point is the datum. For levels around Melbourne the datum is a certain water level at Hobson's Bay. This datum is practically permanent.

Thus, if the R.L. of a certain peg is 186.14 this point is 186.14 feet above the datum.

Now if another point is R.L. 187.24, the difference in levels between these two points is 187.24 - 186.14, equal to 1.10 feet.

Now if the second point is the designed rail level at the peg this would mean that the rail level is 1.10 feet = 1 ft. 1.20 inches or 1 ft. 1¼ inches above the peg.

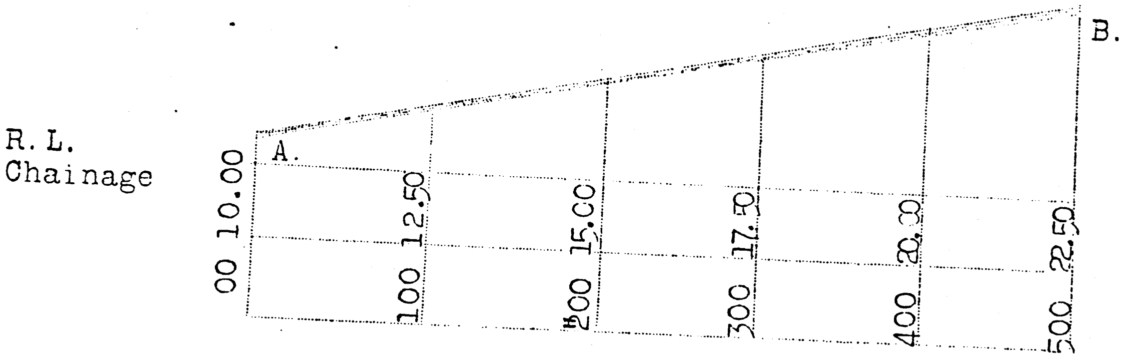
On the longitudinal section are given chainage, centre line, surface levels, North and South track levels.

At any chainage point the difference between surface levels and say North track level gives the depth below or height above the surface of that track.

More detailed information concerning levels of the street are given on the cross sections. These show widths of street and footpath, kerb and gutter levels, etc.,

F. <u>Grades</u>. A grade is simply a slope. In our work it is taken to mean a straight slope.

If we have a point A on a track and find that the track will bone through to a point B five hundred feet away, then the track AB is on a certain grade.



Now if B is R.L. 22.50 and A is R.L. 10.00

B is 22.50 - 10.00 = 12.50 feet above A and

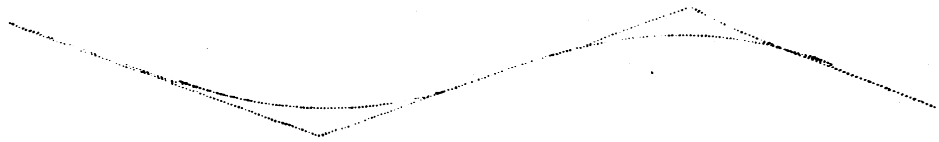
B is 500 ft. distant from A.

This means that in every hundred feet we rise $\frac{12.50}{5}$ feet or 2.50%.

There is another way of indicating grades. This way is to give the length in feet in which the grade rises one foot. In the case above if 2.50 ft. is the rise in 100 ft. then there will be one foot rise in 100/2.50 feet = forty feet. The grade is then called one in forty.

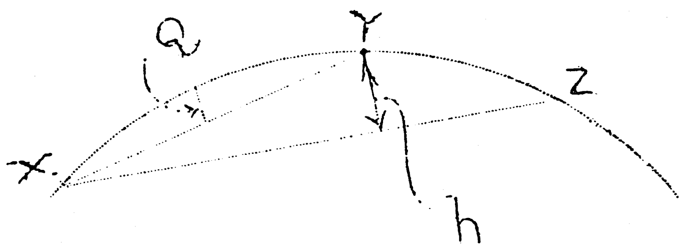
G. <u>Vertical Curves</u>. A track cannot be going up hill for ever, so that we have to change from one grade to another. To give the cars a smooth ride while doing this we join the grades by a smooth curve. As these curves are in a vertical plane they are called vertical curves.

Vertical curves are concave, i.e. the bend downwards or convex, the bend upwards.



The larger the difference between two grades the longer the vertical curve.

If three points X, Y, Z, are given on a vertical curve and these are not close enough for trimming the bottom, then intermediate points can easily be obtained.



Find the height of Y above the line boned through from X to Z; let this be **h**. Then Q on the curve half way between X and Y is $^h/_4$ above the line boned through between X and Y.

<u>CONCLUSION</u>.

Drawings are made by human beings and though checked may occasionally be found wrong or contradictory. But generally they are right and time spent in understanding them thoroughly at the start of a job will always save trouble later on.

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD.

LECTURES TO PER. WAY INSPECTORS, SUB-OVERSEERS AND GANGERS.

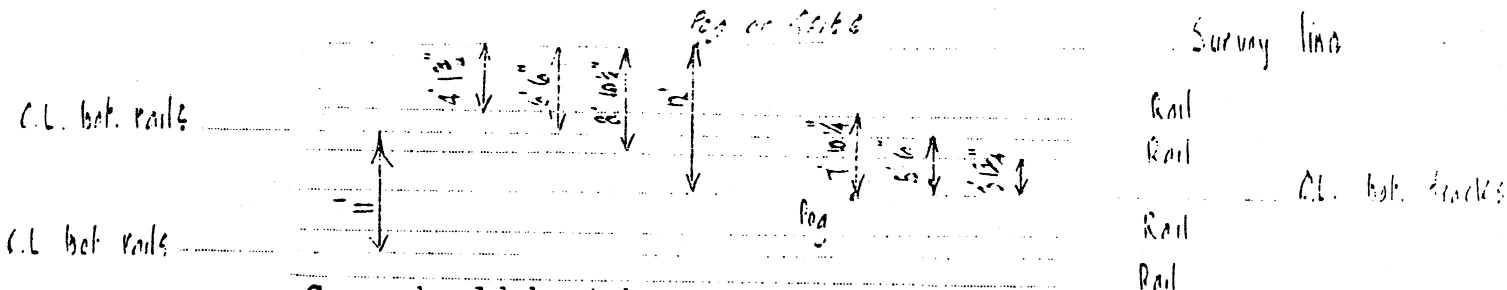
LECTURE NO. 2.

ALIGNMENT, ETC.

The alignment of the track as shown on the plans and explained in the first lecture is marked on the ground by means of wooden pegs with a nail driven in the top, dogspikes or nails with a hole drilled in them, or holes drilled in stones or iron frames in the roadway.

Straights.

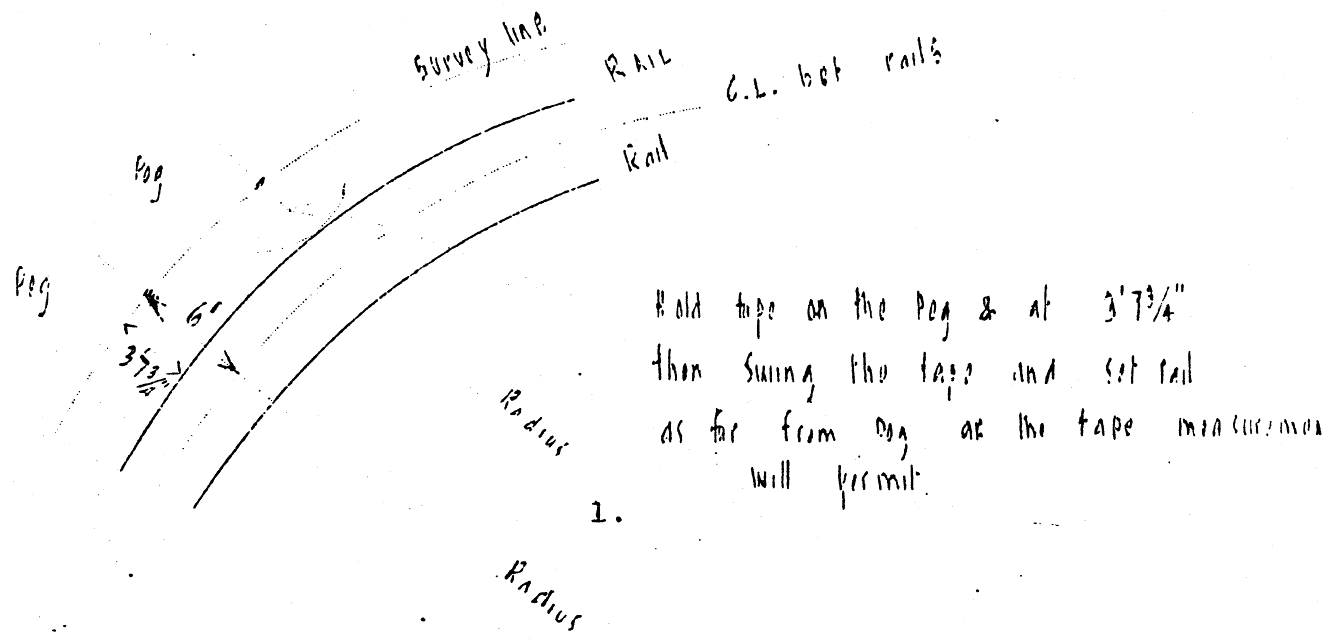
For straights, pegs or spikes are usually placed at 100 feet horizontal intervals, either on the centre line or at 12 ft. from the centre line giving offsets to the various rails for a track laid at 11' c.c. as under :-



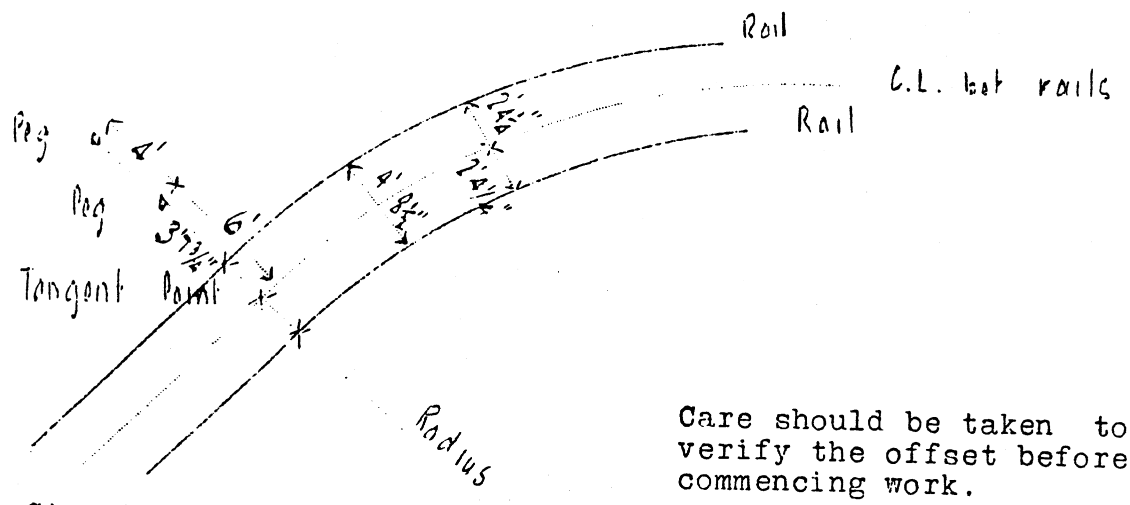
Care should be taken to verify the offset before commencing work.

Curves.

For curves pegs or spikes are usually placed at six feet from the centre line of each track, as shown below:-



At tangent points two pegs or spikes are driven on line with the centre and the tangent point and at 6' and 10' from the tangent point peg on the centre line of the curve.



Care should be taken to verify the offset before commencing work.

<u>Circular Curves.</u>

In order to change the alignment from one straight line to another the straights are joined by curves, in tramway work circular curves with easement (transition) curves at one or both ends are employed.

A <u>Circular Curve</u> is an arc of a circle joining two straight lines (the straight lines being called tangents).

<u>Angles</u> (L). Angles are measured for the setting out of curves by a theodolite in degrees, minutes, and seconds, there being 360 degrees in a full circle, 60 minutes in a degree, and 60 seconds in a minute and are written as under :-

Degrees	^{o}	e.g. half a right angle embraces	45^{o}.
Minute	'	e.g. half a degree embraces	- 30'.
Seconds	"	e.g. half a minute embraces	- 30".

An angle of forty-five degrees, thirty minutes, thirty seconds, would be written thus 45^{o} 30' 30".

<u>Deflection Angle</u> (D.A.). The angle outside the tangents is called the deflection angle and is equal to the angle at the centre of the circle.

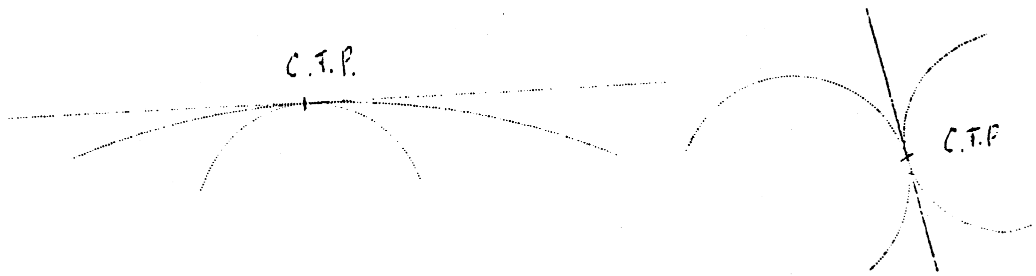
<u>Intersection Angle</u> (I.A.) The intersection angle is the angle between the tangents and is equal to 180^{o} minus the deflection angle.

Radius (Rad.) The radius of a circle is the distance between the centre and the circumference of the circle.

Tangent (Tang). The tangent is the line of the straight produced, and is the line which the curve just touches without passing across it.

Tangent Point (T.P.) The tangent point is that point of the tangent at which the curve just touches it; at this point the radius is at right angles to the tangent.

Common Tangent Point (C.T.P.) When two curves just touch, the tangent of one is the tangent of the other, and the tangent point of one curve is the tangent point of the other. This point is called the common tangent point.



Intersection Point (I.P.) The intersection point is the point where the two straight lines (tangents) meet.

Tangent length. The tangent length is the distance along the tangents from the tangent point to the intersection point.

Secant line. The secant line is the line joining the intersection point and the centre of the circle.

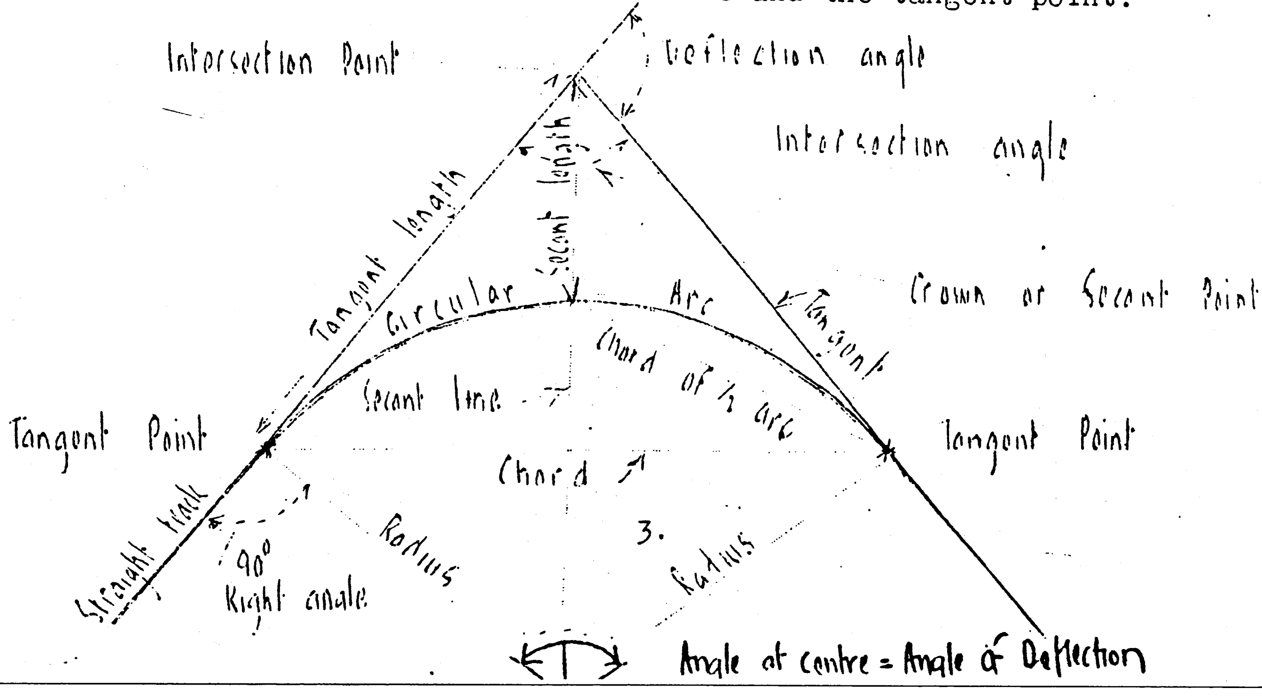
Secant Point or Crown. The secant point or crown is the point on the curve where the secant line intersects it and is on the curve midway between the tangent points.

Secant Length. The secant length is the distance along the secant line from the intersection point to the curve (at the secant point or crown).

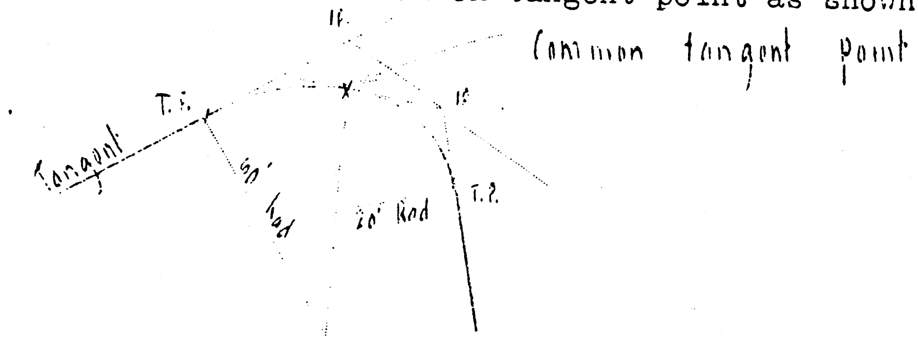
Circular arc. The circular arc is the length around the curve from tangent point to tangent point.

Chord. The chord length is the shortest distance between the tangent points.

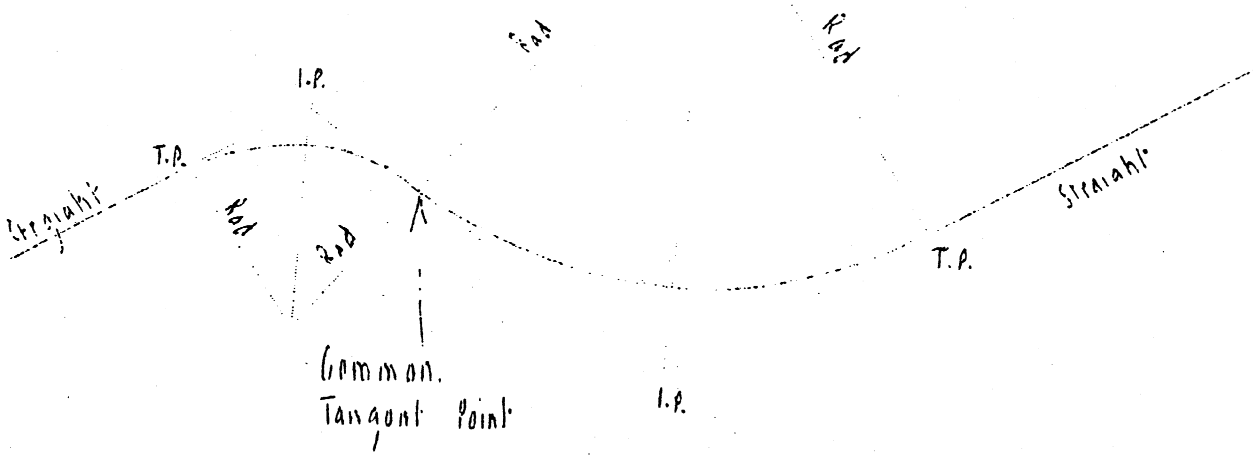
The chord of half the arc is the shortest distance between the secant point or crown of the curve and the tangent point.

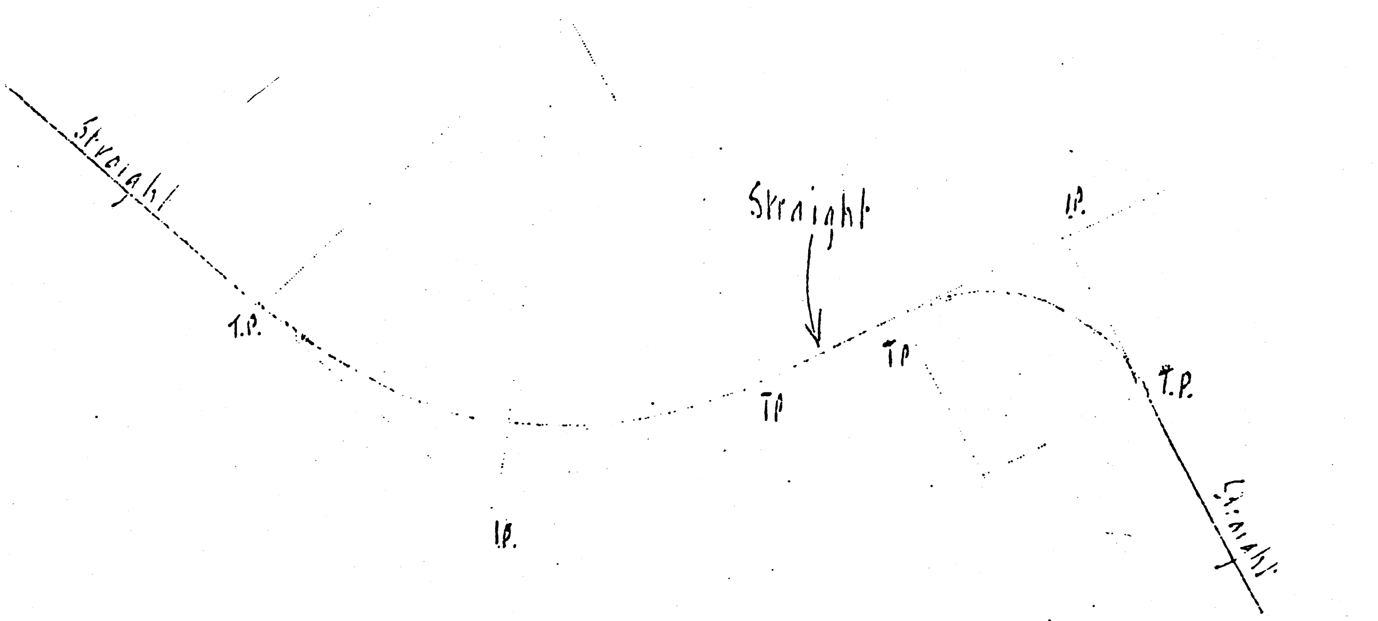


Compound Circular Curves. Occasionally, but never when it can be avoided, a change in direction is made by the use of compound circular curves with a common tangent point as shown.

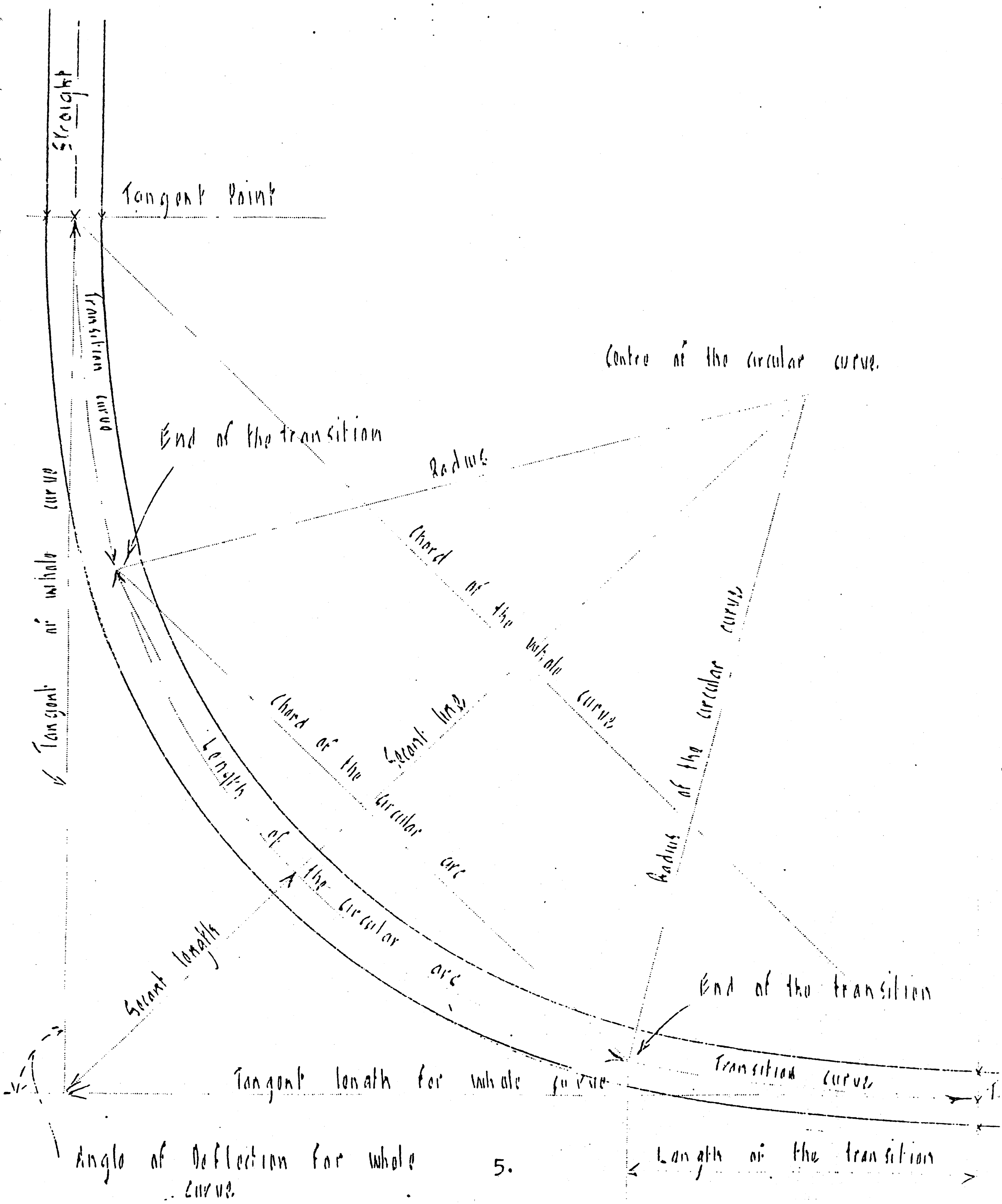


Reverse Circular Curves. When it becomes necessary to lay a reverse circular curve (goose neck) it ~~they~~ can be laid with a common tangent point as shown below on the first sketch, or by the more usual and better method of having a short length of straight between the tangent points, as shown on the second sketch.

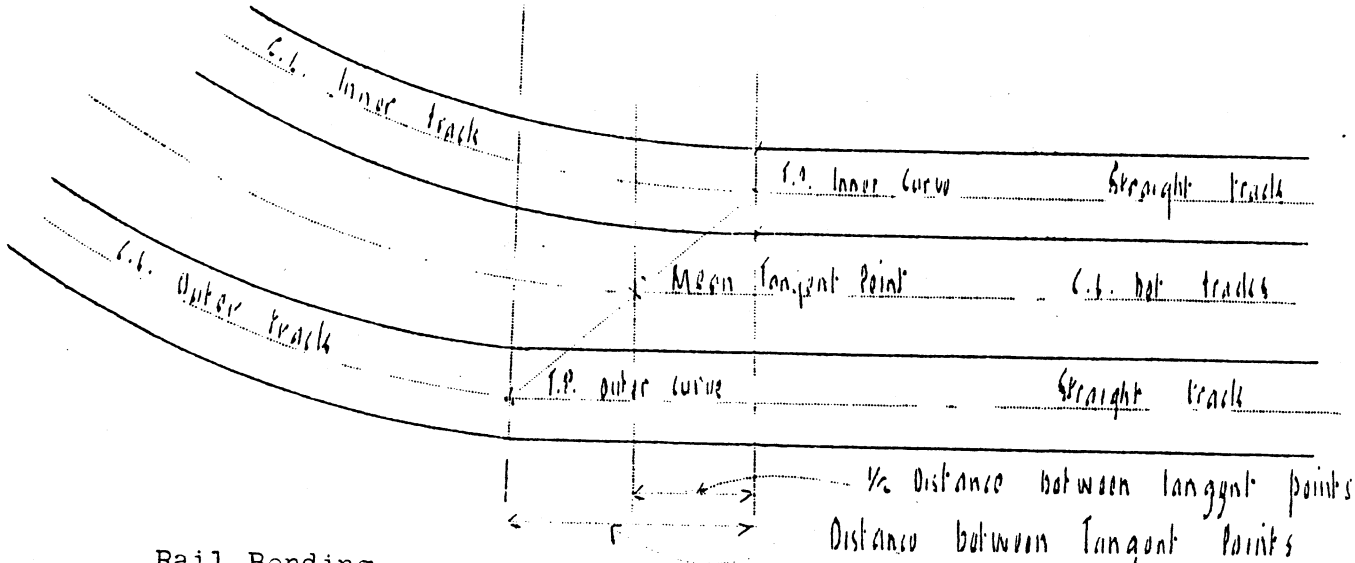




Complex Curves. In order to improve the car riding qualities of the track and thus increase the factor of safety and decrease Per. Way and Rolling Stock maintenance plain circular curves of small radii (less than 500 ft,) are seldom laid on tramway work nowadays. The general arrangement is to lay a plain circular curve with an easement (transition) curve at both ends as shown below. The application of super elevation to, and the combining of circular and transition curves, will be dealt with in the third lecture.



Mean Tangent Points. When a double track is laid around a sharp corner, curves of different radii are used in order to get clearance between cars swinging out while travelling round the curves. This use of different radii increases the distance between tracks and puts the tangent point of one track ahead of the other. The point on the centre line between tracks and midway between the two separate track tangent points is called the mean tangent point.



Rail Bending.

In order to lay straight rails round a curve they must be bent either by hammering, springing, crowing, or pressing.

Hammering. is bad workmanship, and should never be used.

Springing is almost as bad as hammering, but may be successfully used for the bending of rails to a radius of 5000 feet or greater, after the rails are linked up.

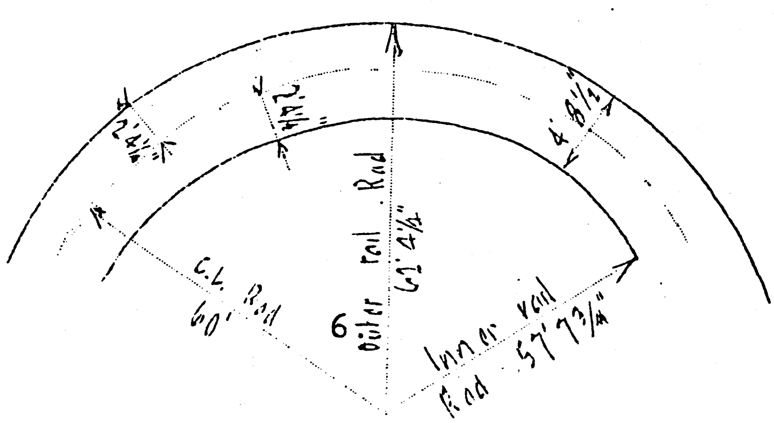
Crowing (with a bending crow only), should be used to prepare rails for curves from 150 feet to 5000 feet radius.

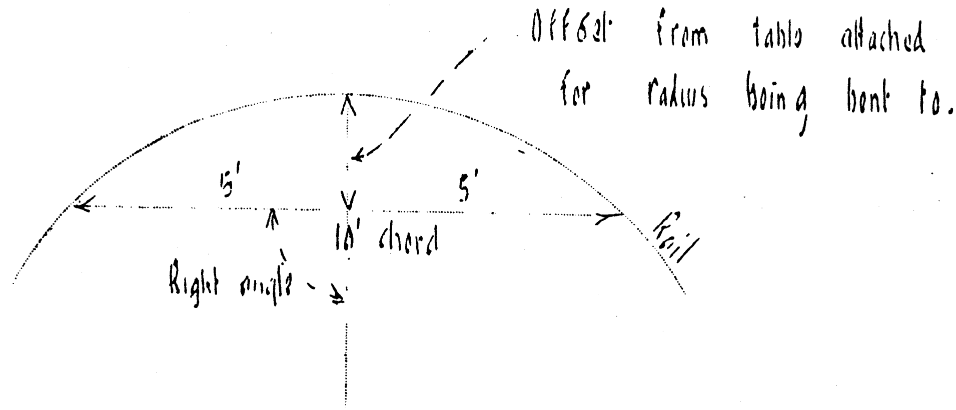
Pressing. In order to ensure that both the foot and head of the rail are bent equally and that the centre line of the web is at right angles to the bottom of the foot after bending, all rails for curves up to 150 feet in radius should be bent in a well-designed rail press using correctly shaped blocks.

General.

Bending with a press is superior to bending with a crow and should be used whenever possible. The legitimate work of a crow is to touch up rails "in situ" where a press cannot be applied.

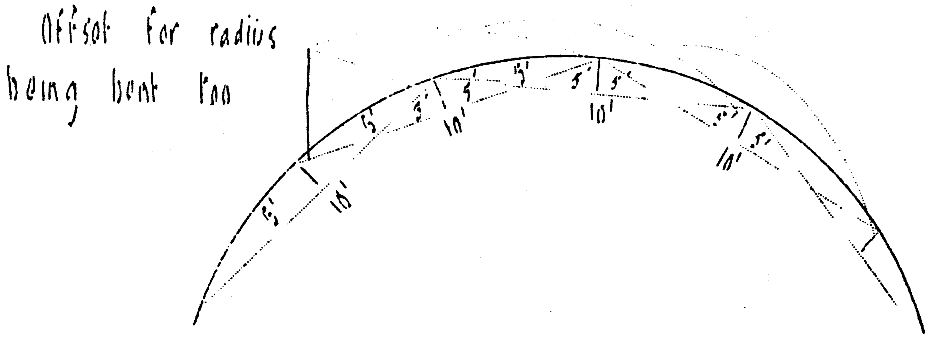
The radius of a curve is generally quoted as the radius of the centre line between the rails, so that the outer rail has a radius = the centre line radius plus 2'4¼", the track gauge being 4'8½".



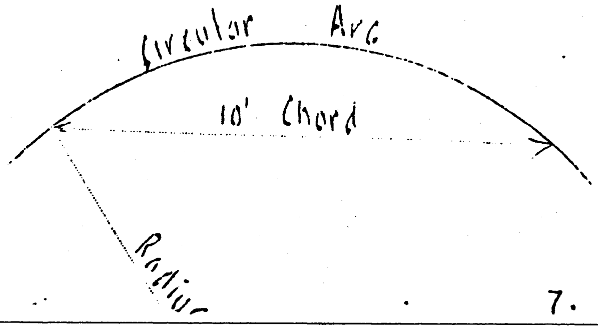


A table showing the centre line radius, together with the radii and bend in each ten foot chord for centre line radii from 40' to 4000' is attached.

Now by referring to the table for a curve, with a centre line radius of 60', the inner rail has a radius of 57' 7¾" and requires a bend of 2 19/32" in 10' while the outer rail has a radius of 62' 4¼" and requires 2 13/32" bend in each 10 feet.



Since with a chord of ten feet on radii up to 100' there is a small difference between the length of the arc around the rail and the chord length (see sketch below), the lengths measured around the rail to give a 10' chord after bending should be slightly increased for different radii as shown by the attached table, but as the differences are so small compared with the errors in bending they can generally be neglected.

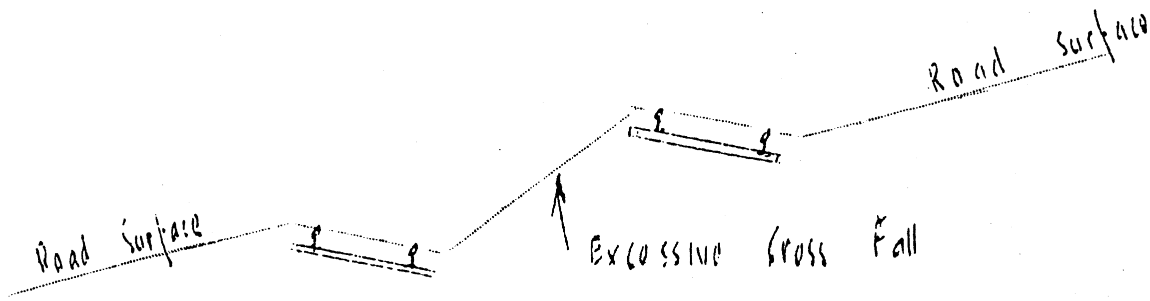


C.L. Rad.	Chord	Arc
40	10'	10'0⅜"
45	10'	10'0 5/16"
50	10'	10'0¼"
55	10'	10'0¼"
60	10'	10'0 3/16"
65	10'	10'0 3/16"
70	10'	10'0 3/16"
75	10'	10'0⅛"
80	10'	10'0⅛"
85	10'	10'0⅛"
90	10'	10'0 1/16"
95	10'	10'0 1/16"
100	10'	10'

Super-elevation or Cant. The object of canting a track or applying super-elevation to the outer rail is to counteract the centrifugal (flying off) force of the tram, and thus increase the safety and good riding qualities of the track and decrease the permanent way and rolling stock maintenance.

The best method of applying the cant is to run the inside rail on the designed grade and lift the outside rail, but as the outer rail of the straight and curve on the outside is sometimes fixed by the road level it is then necessary to reverse the process and lay the outer rail of the outer curve to grade and depress the inside rail.

Care must be taken to see that the lifting of the outer rail of the inside curve and the lowering of the inner rail of the outside curve does not put an excessive cross fall between tracks.



Sketch Only

NOTE. As all lengths shown on the plans are calculated with reference to the horizontal plane, slight discrepancies will occur between these and the actual measurements on the ground. Care must be taken to hold your tape horizontal when taking measurements or setting out offsets, and allowance made in rail lengths when the ground is not level. The length measured on sloping ground is always greater than that on the horizontal, whether the ground be rising or falling.

RAIL BENDING.

TABLE OF OFFSETS FROM 10' CHORDS TO NEAREST 1/32".

℄ Rad.		Offset	℄ Rad.		Offset	℄ Rad.		Offset
40'	37' 7¾"	3 7/32"	135'	132' 7¾"	1⅛"	750'	747' 7¾"	3/16"
	42' 4¼"	3 9/16"		137' 4¼"	1 3/32"		752' 4¼"	3/16"
45'	42' 7¾"	3 17/32"	140'	137' 7¾"	1 3/32"	800'	797' 7¾"	3/16"
	47' 4¼"	3 7/16"		142' 4¼"	1 1/16"		802' 4¼"	3/16"
50'	47' 7¾"	3 5/32"	145'	142' 7¾"	1 1/16"	850'	847' 7¾"	3/16"
	52' 4¼"	2 7/8"		147' 4¼"	1 1/32"		852' 4¼"	3/16"
55'	52' 7¾"	2 23/32"	150'	147' 7¾"	1 1/32"	900'	897' 7¾"	5/32"
	57' 4¼"	2⅝"		152' 4¼"	1"		902' 4¼"	5/32"
60'	57' 7¾"	2 19/32"	160'	157' 7¾"	31/32"	950'	947' 7¾"	5/32"
	62' 4¼"	2 13/32"		168' 4¼"	15/16"		952' 4¼"	5/32"
65'	62' 7¾"	2 13/32"	170'	167' 7¾"	29/32"	1000'	997' 7¾"	⅛"
	67' 4¼"	2 7/32"		172' 4¼"	⅞"		1002' 4¼"	⅛"
70'	67' 7¾"	2 7/32"	180'	177' 7¾"	27/32"	1100'	1097' 7¾"	⅛"
	72' 4¼"	2 1/16"		182' 4¼"	13/16"		1102' 4¼"	⅛"
75'	72' 7¾"	2 1/16"	190'	187' 7¾"	13/16"	1200'	1197' 7¾"	⅛"
	77' 4¼"	1 15/16"		192' 4¼"	25/32"		1202' 4¼	⅛"
80'	77' 7¾"	1 15/16"	200'	197' 7¾"	¾"	1300'	1297' 7¾"	⅛"
	82' 4¼"	1 13/16"		202' 4¼"	¾"		1302' 4¼"	⅛"
85'	82' 7¾"	1 13/16	250'	247' 7¾"	19/32"	1400'	1397' 7¾"	3/32"
	87' 4¼"	1 23/32"		252' 4¼"	19/32"		1402' 4¼"	3/32"
90'	87' 7¾"	1 23/32"	300'	297&7¾"	½"	1500'	1497' 7¾"	3/32"
	92' 4¼"	1 ⅝"		302' 4¼"	½"		1502' 4¼"	3/32"
95'	92' 7¾"	1 ⅝"	350'	347' 7¾"	7/16"	1600'	1597' 7¾"	3/32"
	97' 4¼"	1 17/32"		352' 4¼"	7/16"		1602' 4¼"	3/32"
100'	97' 7¾"	1 17/32"	400'	397' 7¾"	⅜"	1700'	1697' 7¾"	3/32"
	102' 4¼"	1 15/32"		402' 4¼"	⅜"		1702' 4¼"	3/32"
105'	102' 7¾"	1 15/32"	450'	447' 7¾"	11/32"	1800'	1797' 7¾"	3/32"
	107' 4¼"	1 13/32"		452' 4¼"	11/32"		1802' 4¼"	3/32"
110'	107' 7¾"	1 13/32"	500'	497' 7¾"	5/16"	1900'	1897' 7¾"	1/16"
	112' 4¼"	1 11/32"		502' 4¼"	5/16"		1902' 4¼"	1/16"
115'	112' 7¾"	1 11/32"	550'	547' 7¾"	9/32"	2000'	1997' 7¾"	1/16"
	117' 4¼"	1 9/32"		552' 4¼"	9/32"		2002' 4¼"	1/16"
120'	117' 7¾"	1 9/32"	600'	597' 7¾"	¼"	2500'	2497' 7¾"	1/16"
	122' 4¼"	1 7/32"		602' 4¼"	¼"		2502' 4¼"	1/16"
125'	122' 7¾"	1 7/32"	650'	647' 7¾"	¼"	3000'	2997' 7¾"	1/16"
	127' 4¼"	1 3/16"		652' 4¼"	¼"		3002' 4¼	1/16"
130'	127' 7¾"	1 3/16"	700'	697' 7¾"	7/32"	4000'	3997' 7¾"	1/32"
	132' 4¼"	1 ⅛"		702' 4¼"	7/32"		4002' 4¼"	1/32"

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD

LECTURE NO. 3.
FEBRUARY 13TH, 1928.

ALIGNMENT (CONTINUED) AND SPECIAL WORK.

EASEMENT CURVES :-

- SPIRALS
- SWITCH SPIRALS
- CUBIC PARABOLAS
- BENDING DIAGRAMS

SPECIAL WORK NOMENCLATURE

- SWITCHES
- CROSSOVERS
- JUNCTIONS.

EASEMENT CURVES.

It can be easily understood that if we had a sharp curve finishing directly on to a straight, we would be compelled to place only a small amount of super-elevation in the curve near the tangent point (T.P.), or to have a difference of rail level in the straight. In both of these cases there would be not only excessive strains and incidently excessive wear in the rails and tramcars, but it would also be somewhat dangerous. To overcome this diffiuulty, however, we use what is called Easement or Transition Curves.

A Transition Curve is really a curve of varying radii, being fairly flat near the T.P. and gradually becoming sharper until it is of about the same radius as the circular curve at the end of transition. (See Fig. 1.) This curve enables us to gradually apply the super-elevation.

The main reason for a transition in tramway practice is to do away with the shock and chance of derailment which is present, for instance, on cable curves.

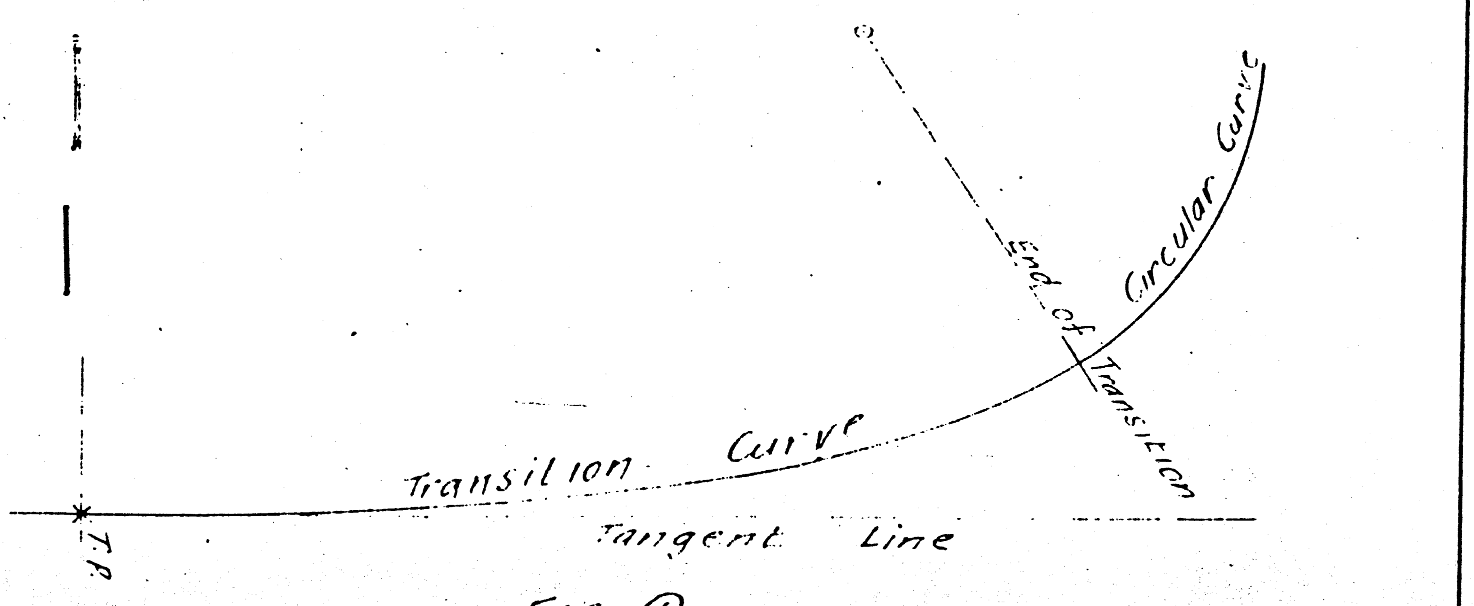


FIG. 1

It is the practice of the Board at present to employ transitions on all circular curves up to 500' radius.

Transition Curves can be classified under the following 3 headings :-

Plain Spiral
Switch Spiral
Cubic Parabola.

<u>Plain Spiral</u>. The plain spiral is simple and can be easily understood. It consists essentially of a curve of comparatively large radius near the T.P. and decreasing in radius at definite regular intervals until it reaches its minimum radius at the point of contact with the circular curve.

There are several different kinds of plain spirals but they are all based on the same principle. The one most commonly used, however, is Lorain's Standard No. 3 Spiral Transition and is shown in Fig. 2 below.

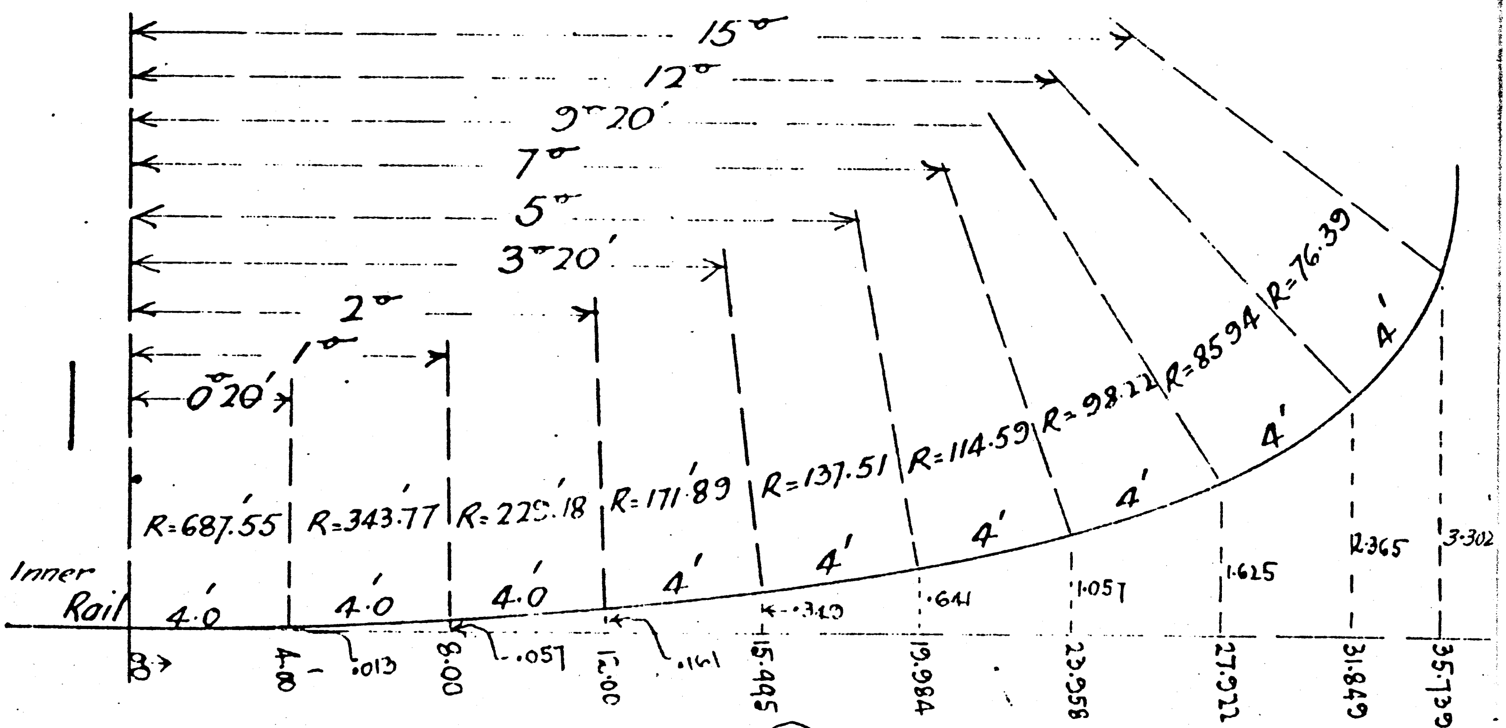


FIG (2)

As the curve of the spiral at the end of transition must not be less than that of the circular curve itself, it is obvious, therefore, that the length of the spiral used cannot be the same for curves of different radii. In other words, the spiral is chopped off at the point where its radius is a little greater than that of the circular curve. For instance, for a circular curve of 60' radius we would use a 15-0- plain spiral which has a length of ~~23.958~~ 35.739 (See Fig. 2) and for a circular curve of 100' radius we would use a 7° spiral having a length of 23.958.

An advantage of the spiral over other types of transitions is that a standard switch can be subsequently installed at very little cost. This point is shown clearly in Fig. 3.

<u>Switch Spiral</u>. When it becomes necessary to instal a switch and still maintain a spiral, at say a junction, then the plain spiral is modified slightly and it is then called a switch spiral. The difference between a switch spiral and a plain spiral is that part of the flat portion of the plain spiral is cut off; this is necessary as it would not be prac-

ticable to manufacture a servicable switch to conform to this curve - the switch would have to be of great length and the blade would have to be excessively long and thin. Fig. 3 shows the transformation of a 15-0- Lorains Standard No. 3 plain spiral into a 15-0- Lorains No. 3 switch spiral.

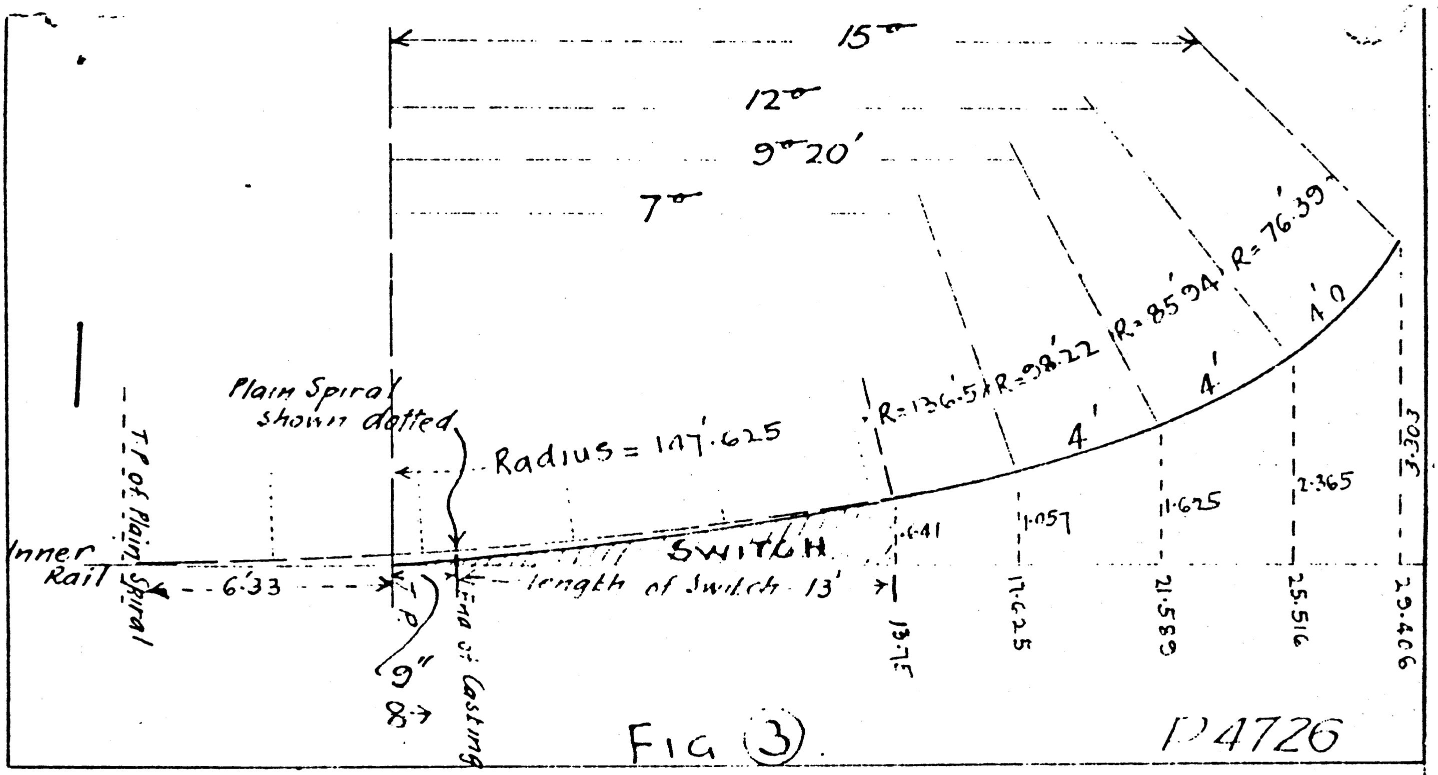
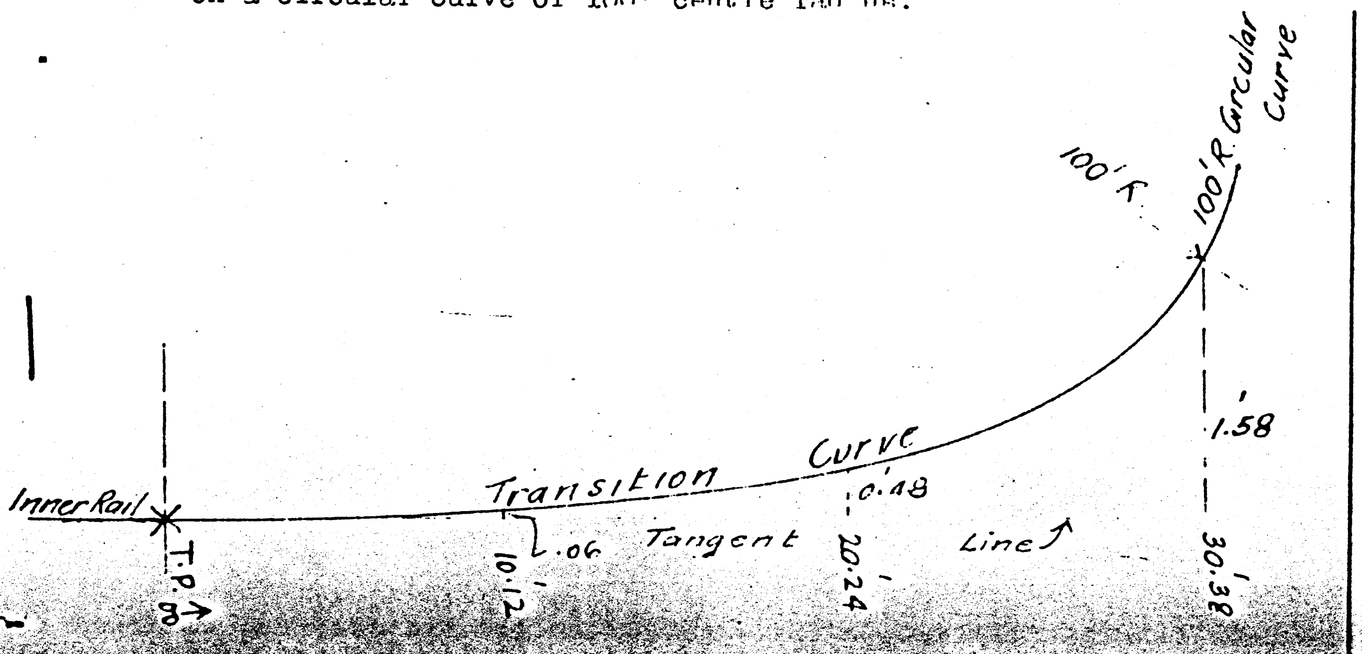


FIG (3).

Cubic Parabola. Provided that the speed of all trams is constant and no restrictions placed on super-elevation the cubic parabola is, theoretically, the best curve possible for a transition. Its use, however, is somewhat restricted on account of these conditions not being maintained. It is used on curves of large radii (300' radius to 500' radius) and on curves where clearance is a governing factor.

Switches cannot be used in conjunction with this transition as the curve of a standard switch will conform to no part of a cubic parabola.

An advantage of the cubic parabola over that of the spiral is that a longer transition can be obtained and hence a better approach. Fig. 4 shows a cubic parabola 30.38' long, on a circular curve of 100' centre radius.



BENDING DIAGRAMS.

Mr. Gray has already, in Lecture No. 2, described to you the bending diagrams given for bending rails to circular curves; the bending diagrams given for transition curves are somewhat different. At first sight they may appear more difficult, but if the diagrams are closely studied they become comparatively simple. Fig. 5 shows that Rail Bending Diagrams usually given for a 15-0- Lorains Standard No. 3 plain spiral.

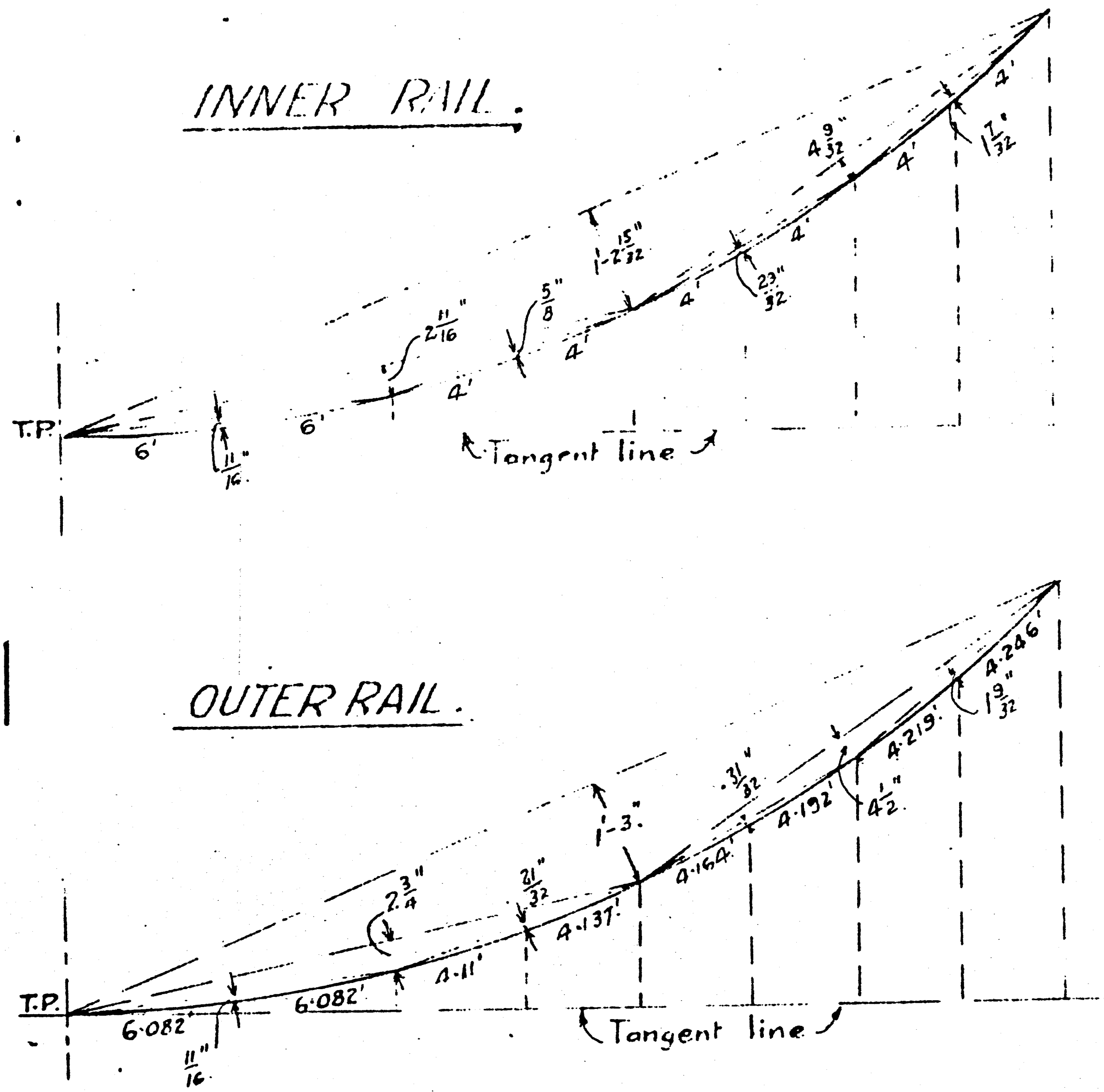


Fig. 5.

Fig. 6.- See 4a.

Fig. 6 shows the Rail bending diagrams usually given for a 15-0- Lorains Standard No. 3 Switch Spiral. If a switch is used then only that part of the diagram from the heel end of the switch onward is necessary.

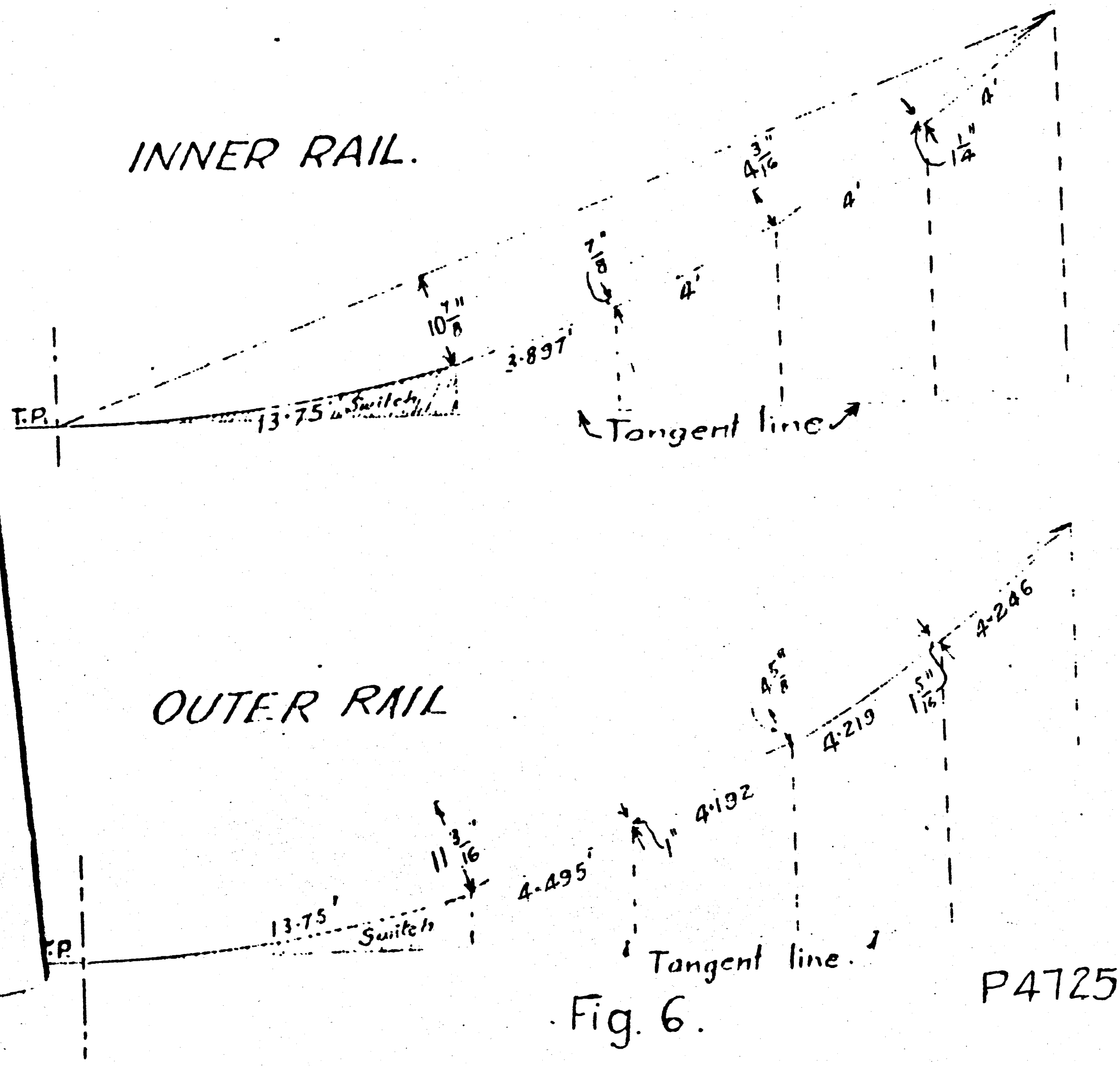

INNER RAIL.
T.P.
13·75
Switch
10 7/8"
3·897'
7/8"
4'
4 3/16"
4'
1 1/4"
4'
Tangent line
OUTER RAIL
T.P.
13·75'
Switch
11 3/16"
4·495'
1"
4·192
4 5/8"
4·219
1 5/16"
4·246
Tangent line
P4725

Fig. 6.

Fig. 7 shows the Rail Bending diagram for a 40' cubic parabola transition attached to a circular curve of 500' centre radius, the bending diagram in this case being the same for inner and outer rails.

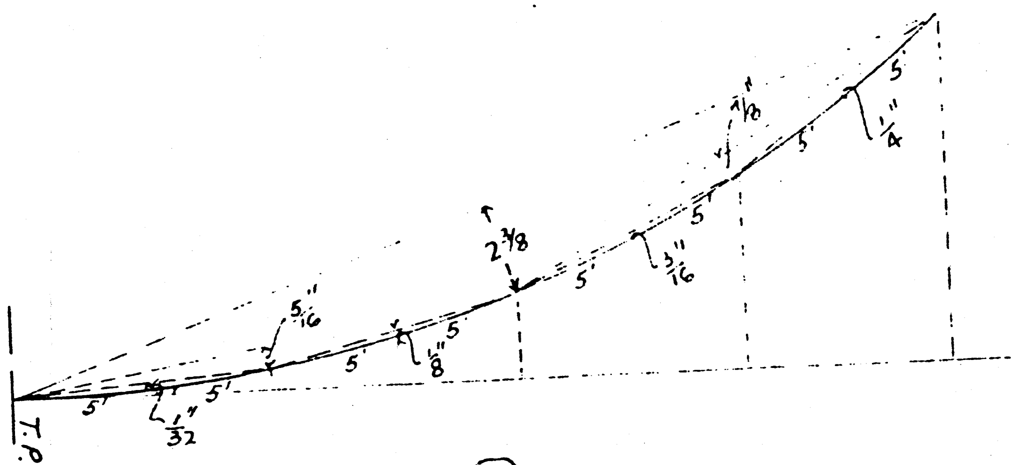


FIG. 7

SPECIAL WORK.

Where one track meets or crosses another track, special kinds of tram rails are required. Such special kinds of tram rails are called Special Trackwork, or Special Work.

Special work usually consists of Points and Crossings. They may be either cast or built up.

Cast Special Work is usually of Manganese Steel. If it is properly manufactured it has the peculiar property of being very ductile and yet very tough. All the cast special work now being purchased by the Board is of Manganese steel.

Built-up Special Work.consists essentially of -

- Base Plate
- Short lengths of Standard rails cut to the correct angle.
- Fishplates specially bent and fitted.
- Bolts.

The whole is assembled, bolted, and welded together. The ramping, if any, is done by means of electric arc.

Special Work Nomenclature. The correct naming of Special Work is, at times, of considerable importance; and it would often save time and money if the special work is correctly described. This applies particularly to Standard Special Work such as Switches, Mates, and Crossings. Quite frequently we see descriptions such as - "1 pr. of 90 lb. interconnected switches, 1 L.H. Switch & Mate, 2/1 in 5 Crossings", all of which are indefinite.

Special work should be described as follows:-

Switches

If Interconnected, then

Number of pairs
Whether 80 lb., 90 lb., or 102 lb.
Whether right-hand or left-hand throw.
Mark distinctly "Interconnected".

If not Interconnected, then

Number of Switches
Whether 80 lb., 90 lb., or 102 lb.
Whether L.H. to L., L.H. to R., R.H. to R., or R.H. to L.

Mates.

Number of Mates
Whether 80 lb., 90 lb. or 102 lb.
Whether R.H. to L., R.H. to R., L.H. to R., or L.H. to L.

Crossings.

Standard 1 in 5 Crossing.

Number
Whether 80 lb. 90 lb., or 102 lb.

If Crossings are not Standard.

Number
Whether 80 lb., 90 lb., or 102 lb.
Draw a sketch showing length of legs, whether legs are curved or straight, and spread at end of legs.

Switches are primarily used to turn trams from one line to another.

The main consideration with a switch is its correct operation. If a switch fails to work properly then it is endangering human life, and should be attended to immediately

Switches are either used in pairs or singly with an open Mate. It is godd practice to use interconnected switches for all facing points as it minimises the risk of derailments.

A switch complete consists essentially of :-

1 Switch stock
1 Movable tongue
1 3-way mechanism, box, and cover
1 Drain box and cover
1 Heel adjusting mechanism, box and cover.
3 Prs of Fishplates
18 Fishbolts

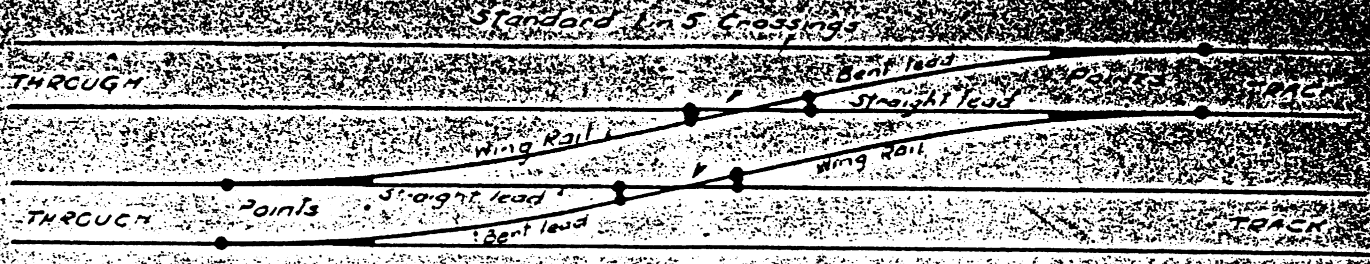
If the switch is one of a pair of interconnected switches then for the pair there would be in addition :-

1 Interconnecting rod, box and cover
1 Operating gear, bo x and cover.
1 Operating bar.

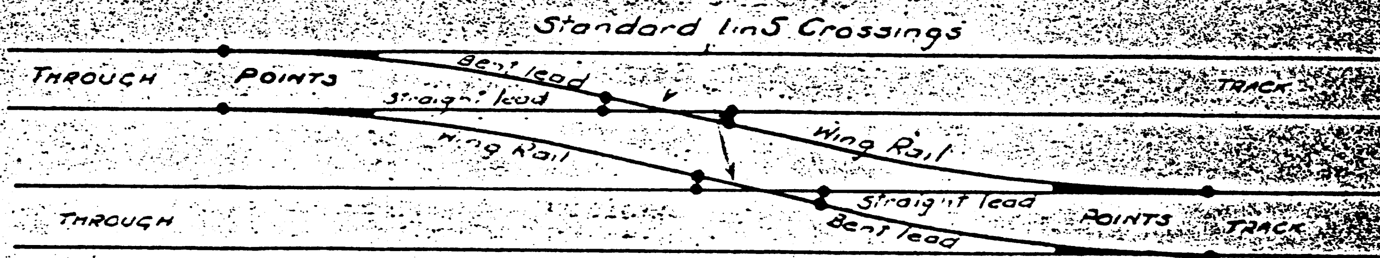
Attached is a blue print showing useful switch data.

Crossovers. There are 3 distinct types of crossover - Left hand, right hand, and Scissors (See Fig. 8).

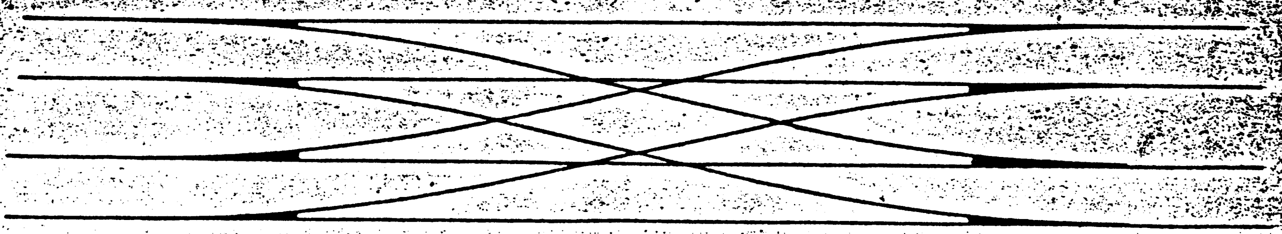
TYPES OF CROSSOVERS
FIG 8.



L. H. CROSSOVER.



R.H CROSSOVER.



SCISSORS CROSSOVER.

MELBOURNE & M...
TRAMWAYS BOARD

Date
Drawn JHD
Checked JHD 13/2/27

DRAWING NUMBER P 4724.

Scale Not To Scale.

The Scissors crossover is, however, rarely if ever used.

It is the best practice to use L.H. crossovers, as it is safer on account of :-

1. All the Switches are trailing, and hence do away with the dangers of derailment that occur with facing switches as in a R.H. crossover.

2. Trams passing over a L.H. crossover turn with the road traffic instead of against the road traffic as with a R.H. crossover.

A Left or Right-hand crossover is made up of :-

2 pairs of points.
2 Standard 1 in 5 Crossings.
Bent and Straight leads.
Wing Rails
Rail fittings.

(A pair of points may consist of either a switch and Mate or 1 pair of interconnected switches).

In laying a crossover if there are any irregularities in the crossing or switches it is the best policy to see that alignment on the through tracks is correct, and then adjust or "wangle" the bent leads to make the best possible job.

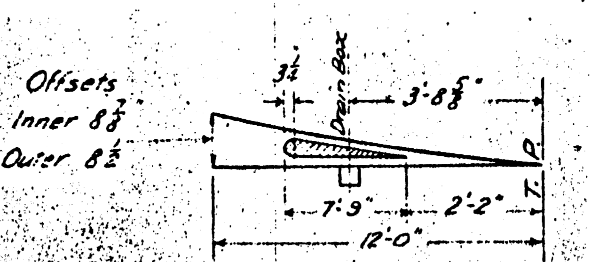
<u>Junctions</u>. Junctions may be small and simple or they may be large and complex. Attached is a list of all the different classes of junction usually met with in tramway work.

Junctions are, undoubtedly, the most difficult and complicated of all special trackwork to lay. In any junction there always crop up difficulties (and to which special attention must be paid) in drainage, in sleeper or timber spacing, in obtaining correct levels, and worst of all, in endeavouring to make the tracks "gauge" and at the same time have a reasonably good alignment.

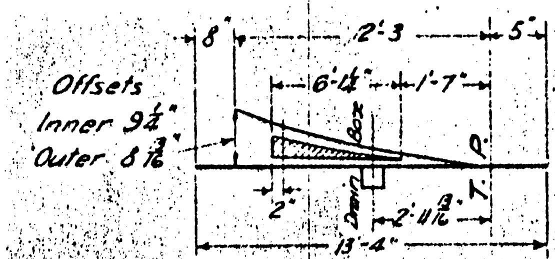
In the laying of a junction there are, generally, special opportunities offered for the Foreman to slum the work. It is far better, however, for him to do the work correctly than to receive the temporary praise of the Engineer for cheap and fast work. The patching up or reconstruction of a junction is an extremely costly operation.

MELBOURNE & METROPOLITAN TRAMWAYS BOARD

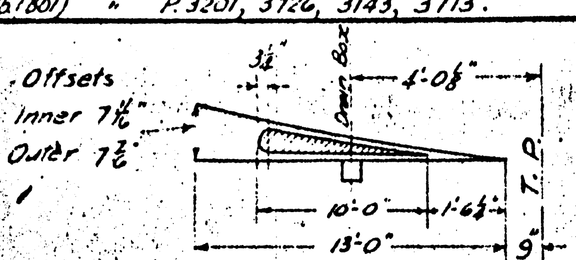
DIAGRAMS OF SWITCH DATA — M.&M.T.B. DRAWINGS



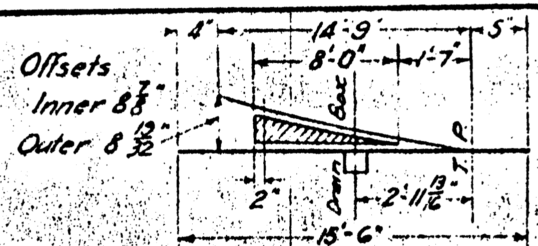
100'-0" Cen. Rad. Cast Switch
BS Nº1 & 1C & 80lb (801) Rails
B.S. Nº1 & 1C Drwgs P.2552, 2577, 2501, 2576.
80lb (801) " P.3201, 3726, 3143, 3713.



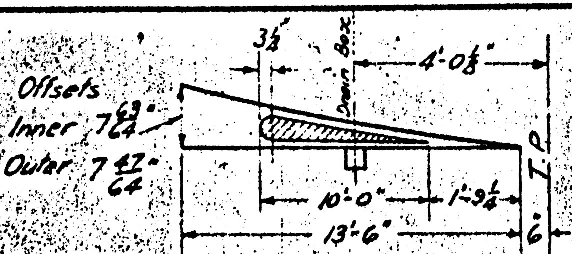
100'-0" Cen. Rad. Built Up Switch
80lb. (801) Rails
Drwgs: P.2840, 2853.



150'-0" Cen. Rad. Cast Switch
B.S. Nº1. & 1C Rails
Drwgs. P.2463, 2570, 2428, 2557



150'-0" Cen. Rad. Built Up Switch
80lb (801) Rails
Drwgs P.2791, 2792.



150'-0" Cen. Rad. Cast Switch
80lb. (801) Rails
Drwgs: P.2951, 3557, 2892, 3436

Switch ends conform to B.S.S. Nº1 (90lb) & Nº1C (96lb) Rails

100'	Centre Radius	Switch & Mate	Curved to Left	Drg. P.2501
100'	" "	" " "	" Right	" P.2576
100'	" "	Interconnected Switch	" Left	" P.2552
100'	" "	" "	" Right	" P.2577
150'	" "	Switch & Mate	Curved to Left	Drg. P.2428
150'	" "	" " "	" Right	" P.2557
150'	" "	Interconnected Switch	" Left	" P.2463
150'	" "	" "	" Right	" P.2570

Switch ends conform to 80lb (Nº800) Rails

100'	Centre Radius	Switch & Mate	Curved to Left	Drg. P.3143
100'	" "	" " "	" Right	" P.3713
100'	" "	Interconnected Switch	" Left	" P.3201
100'	" "	" "	" Right	" P.3726
150'	" "	Switch & Mate	Curved to Left	" P.2892
150'	" "	" " "	" Right	" P.3436
150'	" "	Interconnected Switch	" Left	" P.2951
150'	" "	" "	" Right	" P.3557

Built Up Switches 80lb (Nº801) Rails

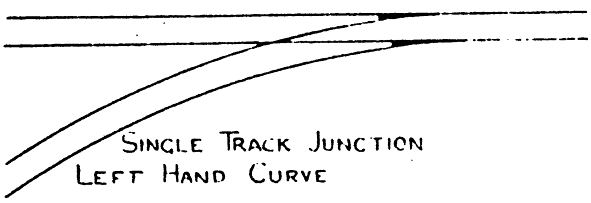
100'	Centre Radius	Interconnected Switch	Curved to Left	Drg. P.2853
100'	" "	" "	" Right	" P.2840
150'	" "	" "	" Left	" P.2792
150'	" "	" "	" Right	" P.2791

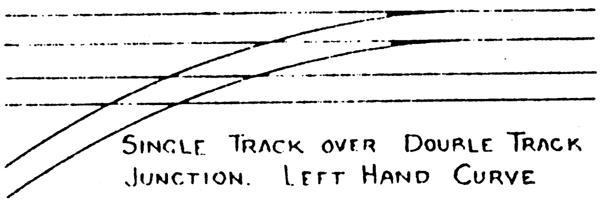
MELBOURNE & METROPOLITAN TRAMWAYS BOARD
[signature]
Date 30.10.26 Chief Engineer
Drawn A.T.G. | Traced 9.10.26 | Checked G.B. 28.10.26 | [illegible]
DRAWING NUMBER P.3733

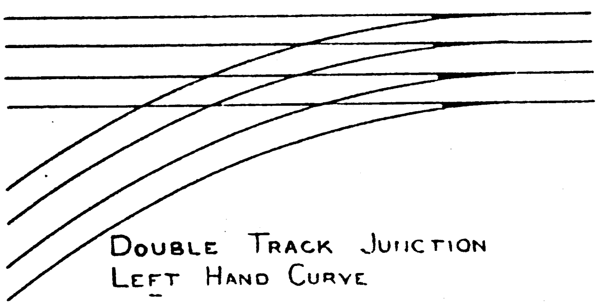
[initials] 28.10.26

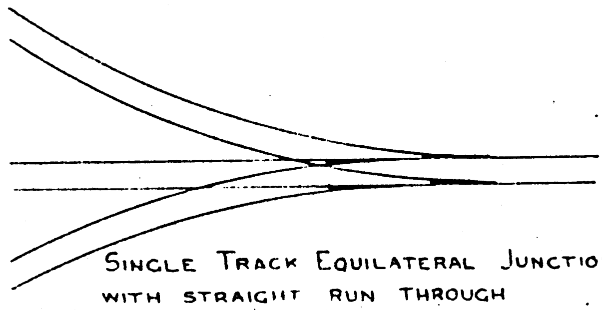
MELBOURNE & METROPOLITAN TRAMWAYS BOARD

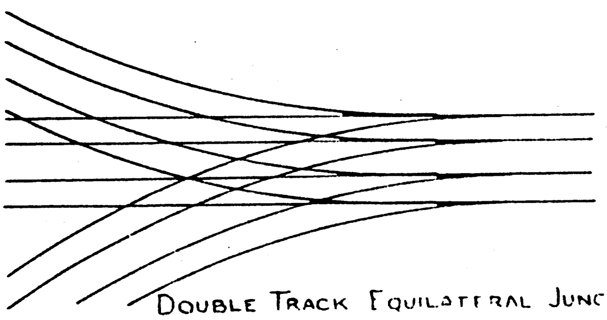
TYPES OF
JUNCTIONS & CROSSINGS

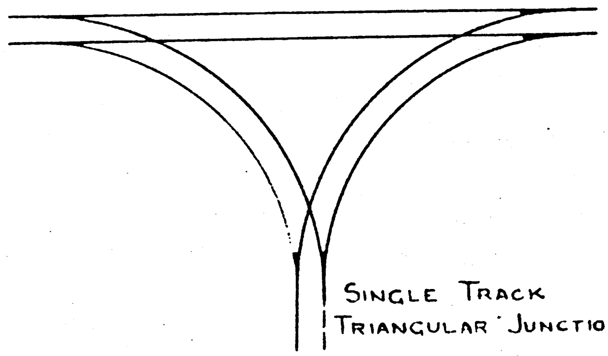

Single Track Junction
Left Hand Curve

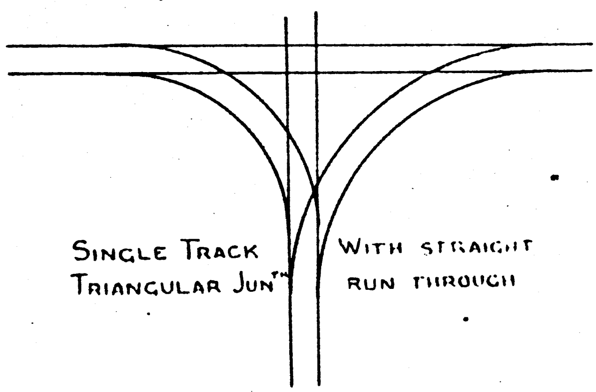

Single Track over Double Track
Junction. Left Hand Curve

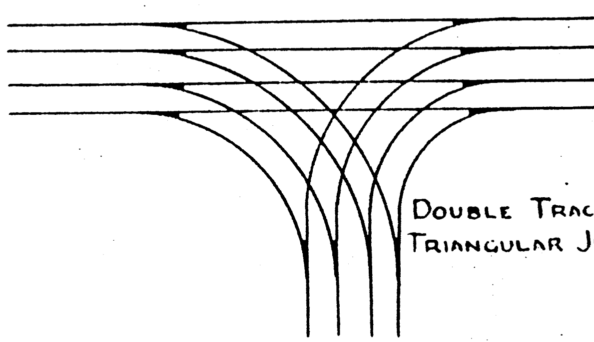

Double Track Junction
Left Hand Curve

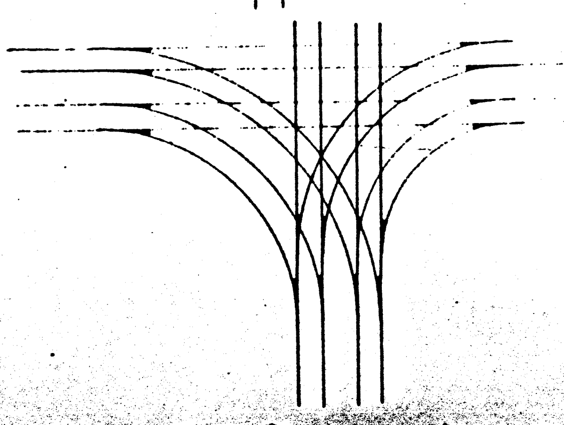

Single Track Equilateral Junction
with straight run through

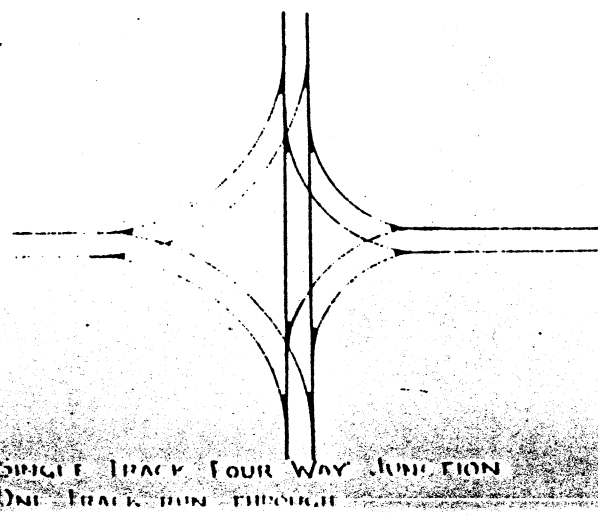

Double Track Equilateral Junction
with straight run through

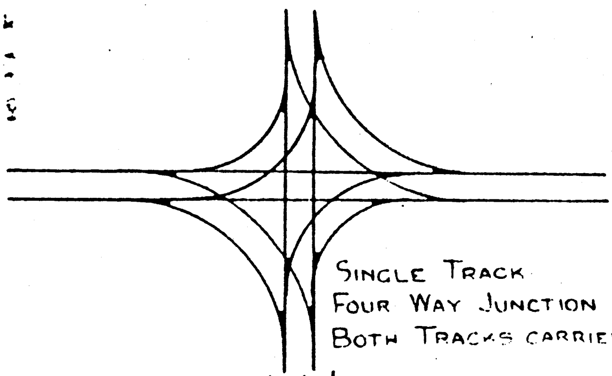

Single Track
Triangular Junction


Single Track
Triangular Jun^{TN}
With straight
run through

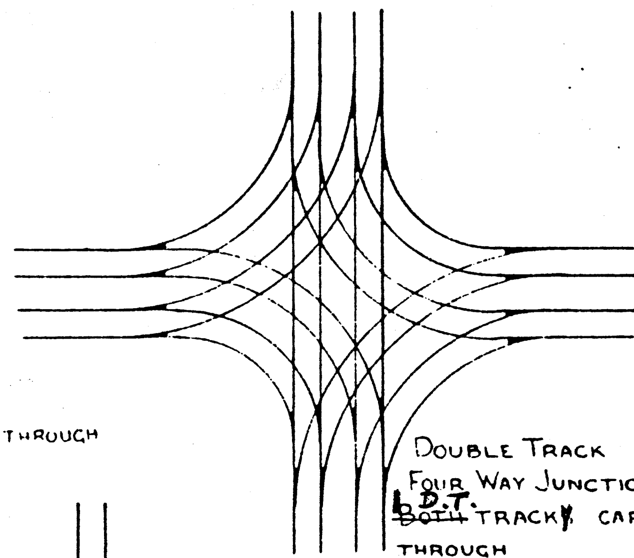

Double Track
Triangular Junc^{TN}


Double Track Triangular Junction
with straight run through

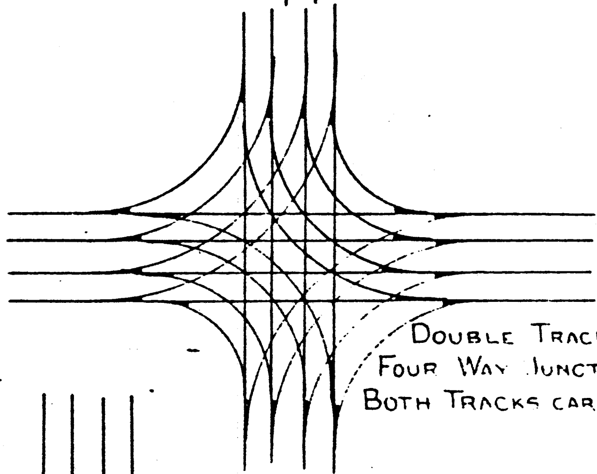

Single Track Four Way Junction
One Track run through



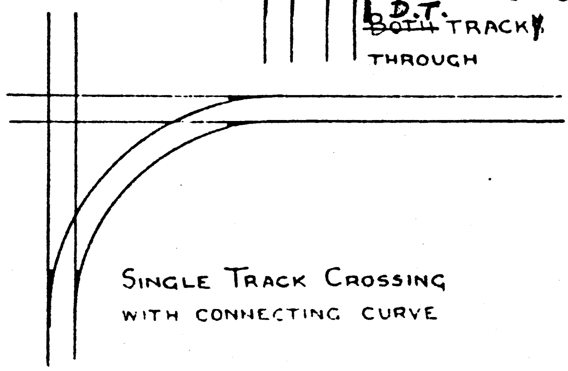
SINGLE TRACK
FOUR WAY JUNCTION
BOTH TRACKS CARRIED THROUGH



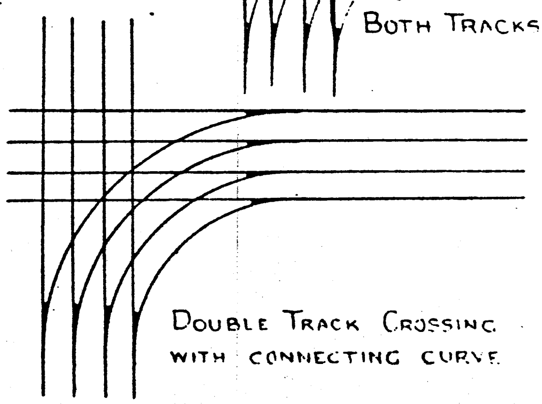
DOUBLE TRACK
FOUR WAY JUNCTION
~~BOTH~~ L.D.T. TRACKS CARRIED
THROUGH



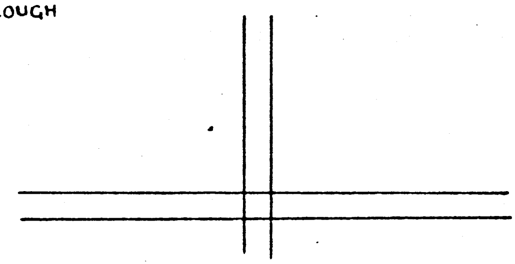
DOUBLE TRACK
FOUR WAY JUNCTION
BOTH TRACKS CARRIED THROUGH



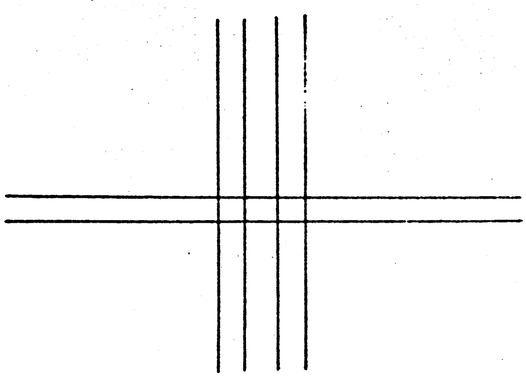
SINGLE TRACK CROSSING
WITH CONNECTING CURVE



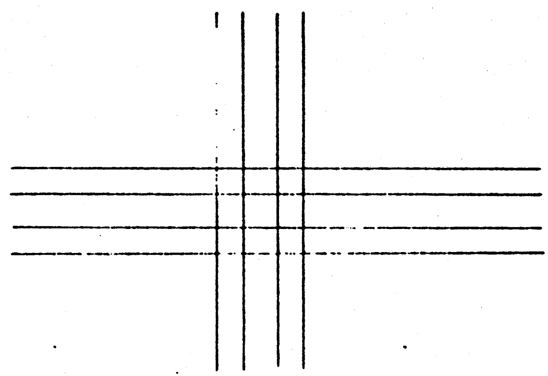
DOUBLE TRACK CROSSING
WITH CONNECTING CURVE



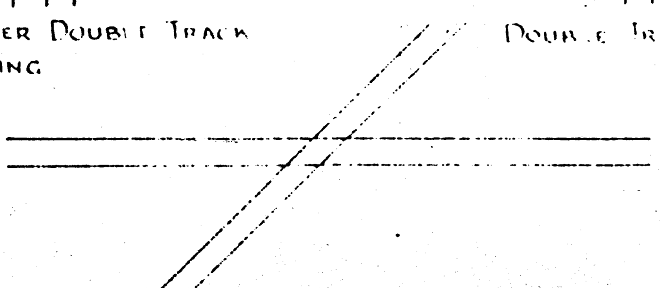
SINGLE TRACK CROSSING



SINGLE TRACK OVER DOUBLE TRACK
CROSSING



DOUBLE TRACK CROSSING



DIAMOND CROSSING

P4723

--- MELBOURNE AND METROPOLITAN TRAMWAYS BOARD. ---

LECTURE NO. 4 ... THE DRAINAGE SYSTEM.

A. Necessity for drainage of track.

B. Surface Water and methods employed in dealing with it.
(a) Waterproofing track surface.
C (b) Collection and disposal.

C. Principles involved in disposal of water.

D. Subsoil Water - Methods of dealing with it -
(a) Natural soil formation.
(b) Ashes.
(c) Subsoil drain.
(d) Protection drains.
(e) General.

E. Maintenance of the drainage system.

A. When a track is undrained the water enters it and remains there unless there is a natural or artificial outlet for it. When it remains the track foundation becomes waterlogged, and incapable of bearing the load put on it.

The track then settles unequally, the rails become wavy, the surface broken, rendering repairs necessary.

Sometimes the binder of the paving is attacked by the water, with consequent disintegration.

A well-drained track lasts longer than a badly drained one before needing extensive repairs or renewal, and requires less maintenance.

B. Surface Water.consists of rain, water from burst pipes, street or track flushing operations, etc., and may enter the track through the surface. It often carries considerable quantities of silt, horse manure, andother street refuse, choking up grooves, switches, and unless provided for, may cause derailments

(a) It is always essential to prevent water entering the track through the surface. Complete prevention has not yet been achieved, but various methods are used to-ward this end.

The surface should be waterproofed by topdressing or by laying an impermeable paving. Should the surface become broken immediate patching, from this point of view alone, is desirable. As water entering through the surface is difficult to remove, the work of patching is of greater importance than is usually realized, because it reduces the quantity entering.

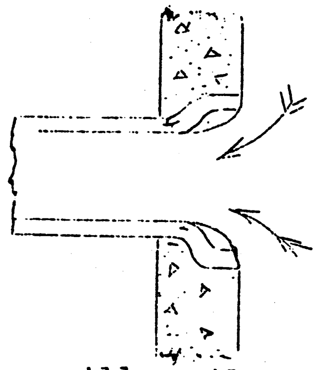
When laying the paving, special care is taken to make the entry of water between the rail and the paving as difficult as possible. This is attempted in woodblock or asphalt paving by filling the waist and painting the filler with bitumen to give a good bond. In bituminous penetration work the rail should be well cleaned, the space under the rail should be completely filled, the metal should be well consolidated along the rail, and extra bitumen poured beside the rail. It is expected that the extra bitumen will fill up the voids in the metal and adhere to the rail.

(b) The surface should be formed with just sufficient camber, and of a sufficient height to readily transfer the water falling on it to the rail grooves.

The water then travels along these grooves to places of collection at which are placed track drains, the water from the grooves entering by means of holes cut through the lip. Grids are provided to cope with sudden downpours or choked slots.

A track drain consists of frames and grids, a channel and outlet for the passage of water, and a trap for silt.

It should be so constructed that it is easily cleaned. Care is needed in seeing that the frames are well bedded on the walls of the channel and that the grids are seated properly on the frames. To get the easiest passage for water the sides and bottom of the pit and channel should be smooth, and the entrance to the invert bell-mouthed as shown in the sketch. The pit should be of such a depth that it will collect all the silt deposited between cleaning periods.



As switches will easily choke up in a sudden downpour, pits are provided at them for the purpose of catching the silt and in general protection is afforded by placing a track drain immediately uphill from the switches.

Outlets are generally laid with six inch pipes. These must have a fall from the inlet to the outlet. They should be laid to straight line and grade. Silt pits for the collection of silt should be placed every hundred feet. The outlet from these pits should be at least one inch below the inlet. The junction with stormwater channels should be made in keeping with the surroundings. The outlet should be so made as to direct the water down stream. In laying pipes it is a good plan to pull through a wooden plug to remove any pins left when rendering the joints. Pipes should be laid with the aid of a straight edge or a line. A level on the top of the pipe is not necessarily an indication of the grade of the invert.

As you all know, some surface water will enter the track. Provision must be made for its remoal or damage will result. In concrete track, weepholes are made through the slab for this purpose. Holes into track drains on uphill side are formed in tracks with concrete raft construction. In ballast track clean ballast under the sleepers will provide sufficient get away for this water.

The water from weepholes and through the ballast then travels through the ashes to the subsoil drain.

C. The first main principle underlying the disposal of water by means of drains is that water flows down hill. The other main principle can be illustrated by the following example. Let us suppose that a stream of water is flowing at a uniform rate of three feet per second, and that this stream is fully charged with silt, i.e. if any more be added to it the stream would deposit it.

Now if we, by means of an obstruction or a flattening of the grade reduced that rate of flow to half its former rate, a certain amount of silt would be deposited. The remarkable part is that this amount would be fifteen-sixteenths of the total amount carried when the rate was twice as great.

Ratio of stream speeds	1	4/5ths	$\frac{3}{4}$	2/3rds	$\frac{1}{2}$	1/3rd
Amount of silt dropped	Nil	3/5ths	2/3rds	4/5ths	15/16th	80/81ths

This means that the rate of flow should not be reduced below a certain amount or silt will be deposited. Where pipe lines have sags, those places get silted up. Should the drain be curled round an electric light post, it is liable to get blocked there. This is the reason for running drains in straight lines from pit to pit.

Now a pit will slow down the flow and although provision is made for collecting silt, it is desirable to let the water get away as quickly as possible: so the outlet is dropped an inch or two below the inlet.

Inlets to Council or other stormwater sewers from our drains should be located above the centre of the sewer as otherwise water may back up the outlet pipe to the disadvantage of the track. This trouble is generally present when track drains are connected to silt pits taking subsoil drainage unless the invert level of the outlet pipe is not less than six inches below the inlet invert level of the subsoil drain..

D. Subsoil Water consists of seepage from the surrounding soil, adjacent water pipes, streets and gutters. It comes from the sides and the bottom of the trench. Generally it is clear, but sometimes carries clay or silt. Quite often a continuous flow is met with.

(a) A sandy formation is often an efficient agent for disposing of subsoil water. In some cases a subsoil drain need not be laid though it is generally a safeguard. With certain classes of this formation ashes are not required.

(b) Ashes of the permeable variety have proved a great success in dealing with subsoil water in tracks, through other than sandy formations. Generally, a layer is put in the bottom of the trench and when the country is of a spewy clay nature, ashes along the sides prevent the clay from choking up the metal.

It is interesting here to note that the roller employed determines the quantity of ashes used to give a certain thickness. With a hand roller 10 cyds. per hundred feet are required for 3" depth in an 8 ft. trench; with a Fordson roller 12$\frac{1}{2}$ cyds. are required for the same dimensions. The earth formation should be given a fall to the subsoil drain to prevent the collection of water in pockets.

(c) Subsoil drains are of three general types, 4" agricultural pipe, 4" continuous invert, and 6" conversion type.

The ag. drain has given good service under ballast tracks. The following faults should be avoided in laying this drain :-

Humps or sags, sudden changes in direction, open joints, the laying of underburned pipes (usually pale in colour). It is easiest to lay the drain in ashes.

The four inch continuous invert drain is our first class drain. It is necessary to get a smooth even grade for this drain. Sags, humps, and turns have as bad effects in this type as in all others. Care is needed to see that the tiles are sound, and not under burned, as otherwise the tiles will rot in time. A common fault is the lack of bearing formed for the tile. This may be due to a large or thick tile, to early stripping of the mould boards, or faulty mould boards.

The conversion type consists of a 6" half-round tile laid on the old tunnel invert.

Thorough cleaning and building up where necessary to improve the invert or to increase the grade, is always carried out prior to laying the tiles.

(d) Protection drains are necessary where seepage is expected from the side of the trench on account of leaky pipes, or where the channel is higher than the track, or where there is a hill on the side of the track. Strangely enough, these drains are often necessary on the highest point of section as it is here that the track is in a cutting.

They may be 4" ag. pipe, with pits and outlets, or a spall or ash drain at the edge of the trench, with frequent outlets across to the subsoil drain. In the spall or ash drain, care must be taken to give it the efficient fall to the subsoil drain to enable water to get away from it, and to prevent a full pipe in the subsoil drain filling the ash or spall drain. To attain this end the cross drains are usually made at an angle of 45^{o} to the centre line in the direction of the fall.

(e) As the subsoil water is generally clean and of small flow, and as the surface water often carries silt and debris, it is always wise to separate these two classes of drainage. Unless it is certain that no silt can choke up the subsoil drain or the water waterlog the foundation, then it is essential to get rid of the surface water in such a manner as to prevent these evils. No general method can be given for this. It is always necessary to try the subsoil drain immediately each length has been rolled, and to rectify any damage before any further work is done.

Faults met with are :-

1. Rattling grids and covers.
2. No floor to the pit.
3. Rough surface of the walls.
4. Joint between floor and walls imperfectly made.
5. Arranging pit so that it cannot be easily cleaned.
6. Outlet from pit higher than inlet.
7. Faucets down hill.

8. Faucets clay filled or improperly filled.

9. Faucet instead of the barrel laid on the bottom of trench.

10. Filling around pipes done in a slovenly fashion with unselected material.

11. Pipes notlaid to surveyors' grade because board or string not used.

12. Diversions around poles or other obstructions.

13. Changes in direction without pits.

14. Siphons put in to pass under mains and no pit made.

15. Laying pipes without a concrete casing adjacent to trees or shrubs.

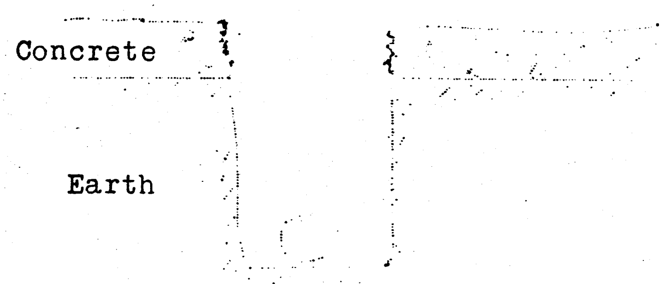
16. Laying unreinforced or earthenware pipes across roadways or entrances.

17. No outlet.

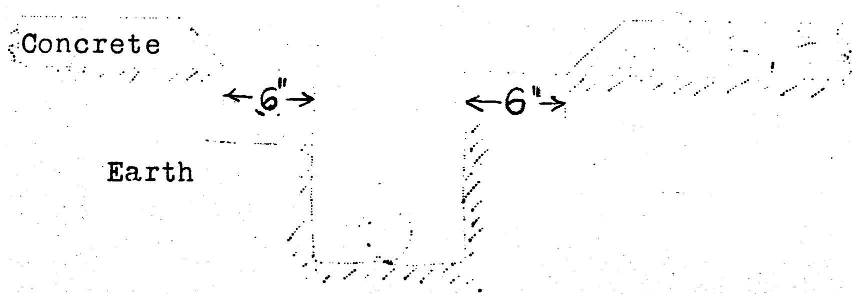
18. End of drain running up hill.

19 Ugly and dangerous finish at the outlet to the street channel.

20. This shape of trench for outlet;-



instead of this :-



E. <u>Maintenance of the drainage system</u>. Firstly, inspect it thoroughly before taking over. Then any faults are made known and can be remedied. This, of course, entails the proper provision for flushing and inspecting all the separate portions of the drainage system.

Secondly, make proper provision for cleaning out the track drains, point drains, and silt pits. These should be cleaned out in regular order so that none will be missed. It required considerable judgment to so arrange this work that the drains are cleaned out frequently enough, and yet not too frequently.

Thirdly, make proper provision for systematic flushing of the drainage system and the attendance to any defects found.

Fourthly, remember the importance of cleaning the rail grooves, of patching and topdressing, and of the general care of the tracks.

Lastly, keep on inspecting the drainage system.

LECTURES TO PER. WAY INSPECTORS, SUB-OVERSEERS & GANGERS

LECTURE NO. 5 - CEMENT CONCRETE

By MR. H. H. GRAY.

INTRODUCTION.

Concrete is a mixture of cement, water, and aggregate, put in place in a plastic condition, but hardening soon after, due to a process known as the hydration of cement. The basic requirements of all concrete used in tramway tracks are strength, durability, and economy, and the main factors determining these qualities are - quality of materials, water content, proportioning of the mixture, time of mixing, curing conditions, age, and temperature.

MATERIALS.

Given good cement, good concrete can be made from almost any aggregates provided that they are of a clean, strong, durable, nature, free from deleterious matter and graded into suitable sizes, but their selection depends on the work which the concrete is to perform. For concrete used in tramway permanent way construction metal, screenings, and sand are used exclusively as the aggregates, and the desirable qualities are as follows :-

Cement. Three classes are used, depending on the time available before opening the track to traffic:-

Aluminous Cement.

Rapid Hardening Portland Cement.

Portland Cement.

As all cements are thoroughly tested before being allowed to leave the manufacturers Works or bulk store, they can generally be relied on provided they have been stored in a dry place on the job for a period not exceeding about 3 months. Various types of cement should on no account be mixed owing to their chemical action on one another.

Coarse (Stone) and Fine (Sand) Aggregates used should consist of clean, hard, sound, durable, uncoated pieces, free from injurious amounts of soft, thin, elongated, or laminated pieces, loam, alkali, organic, or other deleterious matter, and must be graded within the limits specified:-

Clean because an excess of dust or clay in the fairly rich mixture used renders the mix fatty and liable to crack; hard and sound because soft metal or sand, and vesicular metal are less durable and have a much lower crushing strength than sound material; free from thin, elongated or laminated pieces, because they do not work or pack together well, and they break easily; uncoated, because a film of dirt sticking to the stone or sand prevents a good bond with the cement; free from alkali, organic material, and loam, because these materials interfere with the proper setting of the cement. The materials are required to grade between certain specified limits, because materials of these grades have been found to give the densest and most workable concrete for our type of work. If the sand and stone were allowed to vary, we would have to be continually altering the measuring boxes to get the right mix.

Clean water, fit for drinking, is specified because brackish or dirty water may contain alkali or organic matter and these interfere with the proper setting of the cement, and may also rust the reinforcement.

PORPORTIONING.

In working out the proportions to be used, we first fix on the strength which is required. For a certain strength we know that certain proportions of cement and water are necessary. Thus, if we want our concrete to stand a pressure of 2200 lbs. per sq. in. when it is 7 days old, we use 14 lbs. of cement for every 86 lbs. of stone and sand.

After receiving samples of the stone and sand properly selected by the method of quartering, they are graded into nine sizes. A calculation is then made to find the best proportions of sand and stone to give a dense mixture. Several trial samples are mixed up with the proper weight of cement and water, so as to see if the mixture is workable. The proportions are varied a little if necessary to get a good workable mix, and if time permits the samples are tested before the job starts, so as to see if the selected mix gives the required strength.

The proportions must, of course, be finally fixed on the job, as that is the only place where the workability can be tested properly. The use of too much metal will give a rough, harsh working mix, which will be difficult and costly to place properly, and also causes the metal to separate out in the barrows or trucks. A mix having an excess of sand (although it will work more easily) will be porous, and when tested at a long period after pouring, will give a poor strength; it also requires more water to produce the same workability, which reduces the strength.

WATER CONTENT AND WORKABILITY.

From the point of view of economy and early strength the water content is of supreme importance, and from the necessity to get the concrete in place around the reinforcement and against the stringers or sleepers, and to produce a dense, rock-like mass, the workability is almost of equal importance. The amount of water used with each bag of cement is the greatest factor controlling the early strength, the resistance to wear, and the bond between concrete and reinforcement. The effect of water on the strength is so definite that if we know the mixture used we can foretell what strength the concrete will have for any particular quantity of water used. The effect of using too much water is shown below. Using the same mixture, the following strength will be obtained at 28 days by varying the water content.

3 gallons per paper bag of cement - 6000 lbs. per sq. in.
6 " " " " " " - 2500 lbs. " " "
9 " " " " " " - 1000 lbs. " " "

In general without mixtures, 5 1/3rd gallons of water/ with each paper bag of cement should be aimed at. With 5 gallons, the workability will be bad (too stiff); with 5 2/3rds gallons it will be equally bad, but in this case the mix will be too wet. If the aggregates are wet, particularly the sand, less water than 5 1/3rd gallons should be used. Mixes that are too dry will give a good laboratory strength test, but will give harsh-working, honeycomb concrete, while in those which are too wet the metal will separate out and the concrete will give poor strength and slump away from the stringers and sleepers, and also show excessive laitance on the surface. A golden rule in the mixing of concrete is "Too little water is better than too much".

MEASURING, MIXING, TRANSPORTATION, AND PLACING. In order to secure the correct proportions, and maintain a uniform mixture, all aggregates should at least be measured in properly made boxes. In other countries elaborate weighing plants are coming into common use for this purpose. The <u>water content</u> (for the reasons given above) must be accurately measured and carefully controlled, otherwise the advantages of a properly designed mix will be lost. One experienced man only should be allowed to adjust the quantity of added water to compensate for wet aggregates. The time of mixing and the type of mixer blades have a considerable effect on the uniformity and workability of the concrete, and on its strength at 1 year and longer. Approximately 20% extra strength at this age is obtained by mixing for 2 minutes instead of for half a minute, and 10% by mixing for 2 minutes instead of 1 minute. It is the time of mixing and not the number of turns given that has the greatest effect; increasing the rate of rotation above about 18 turns per minute has little effect on the concrete being mixed. The <u>method of transportation</u> to be used is primarily a question of economy, as long as the method found cheapest does not cause segregation. Since the best possible laboratory tests are of no walue if the material is not placed correctly in the structure, it is at the point of placing that the greatest care must be exercised and the material placed nd packed instead of being run or pushed into position. The concrete should always be placed in position within 15 minutes after being fed into the mixer; after that it will lose strength owing to the setting which goes on.

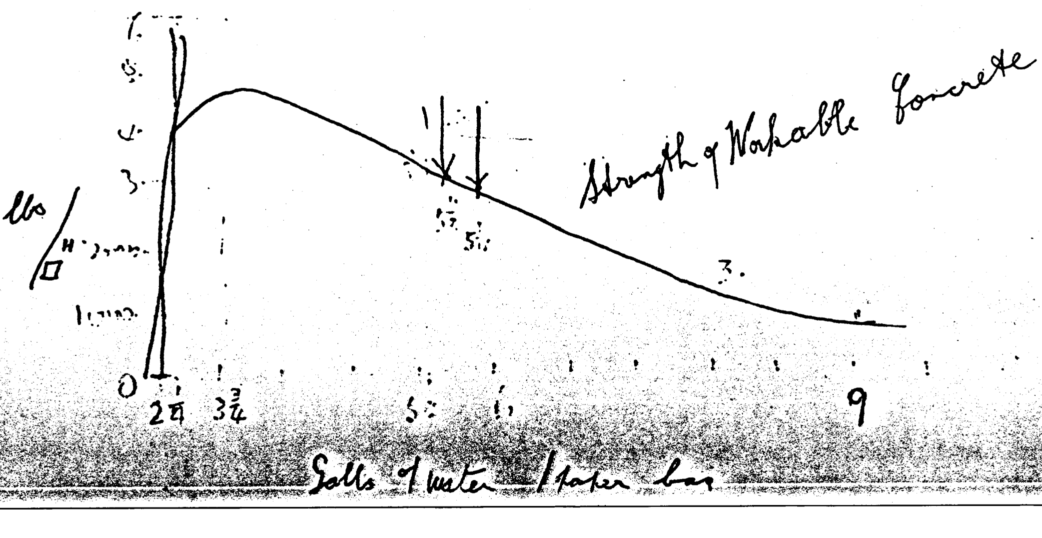
CURING.

Concrete hardens because of the chemical action between the cement and the water. The process is slow and will continue almost indefinitely provided favourable conditions are maintained. The concrete should be kept thoroughly wet from 8 hours to at least 7 days after placing in order to develop good strength and prevent cracking. Keeping it wet also increases its resistance to wear. By keeping the concrete wet for the periods shown below, the strength can be increased over that which would be obtained with the same mix if allowed to dry out quickly.

Concrete	kept	wet	for	7 days	gives	an	increase	in	strength	of	50%
"	"	"	"	10 "	"	"	"	"	"	"	75%
"	"	"	"	3 weeks	"	"	"	"	"	"	115%
"	"	"	"	4 months	"	"	"	"	"	"	145%

TESTING.

Continuous collection of samples and testing are carried out by the Board to determine the strength of the concrete placed in the track structure, and to see if all the specified conditions for mixing, etc., are being observed. As these tests do not tell us anything about the concrete after it goes into the job, it is important that proper methods of placing and curing should be adopted and strictly enforced.



SIXTH LECTURE

RAILS AND FASTENINGS.

By MR. A. T. O'MEARA.

RAILS.

USE: Rails are used

1. To give a smooth surface for car wheels to run on.
2. To keep the cars in their proper place in the street.
3. To withstand the wearing action of the car wheels.
4. To spread the load of the cars over the foundation of the track.

HISTORY.

As far as we can find out, the first people to use rails for moving wheeled vehicles on were the miners of Germany, in about the 14th or 15th Century. The rails were wooden, and several hundreds of years passed before someone thought of laying a strip of iron on the top of the wood so as to prevent it wearing out so quickly. This served its purpose until the steam engine was invented; this was too heavy for wooden rails, and cast iron was used for a time, giving place later in the 19th century to iron rails, and later steel.

Tramways, however, continued to use the combined wood and iron rail until about 1880. Some were even laid in Sydney in 1879, when the first steam tramway was operated there. (Similar rails may be seen in the old market-gardeners' tracks). About 1880 several inventors introduced the grooved rail, with a web and flange, and it has remained standard practice until to-day.

MANUFACTURE.

First of all iron ore is roasted in a blast furnace and the metallic iron is melted out of it. This is run into big ladles and put into a big basin known as an Open Hearth. This raw metal contains a lot of impurities which are taken out by throwing in fluxes, causing the impurities to rise to the top in the form of slag. At the same time the carbon, manganese, and other substances needed in the steel are added to it. When the molten steel is of the right composition it is run into big moulds known as ingots, each ingot containing enough to make one rail. The ingots, when cold, are taken out of the moulds, and heated up in an oven to a bright red heat ready for the rolls. Then each ingot is put thro' a series of rolls, each one making it a little more like a rail, until finally the finished rail is run out. The ends are then sawn off to correct length, and the rail straightened and bored cold

The Inspectors have to look for these defects :-

Bad shape
Bad fishplate fit.
Flaws, especially in the head
Cracks,
Folds
Pipes
Crookedness.

TYPES OF RAILS USED.

Here we use three main types, the No. 801 Section, the 90 lb., and the 102 lb. Besides these we have the Australian Standard 80 lb. Railway Rail (in Royal Park, for instance) and also the 96 lb. rail for use on curves.

The No. 801 Section is a railway rail, and is quite suitable for open track, but has the following disadvantages for street use :-

1. It needs a 34 lb. guard, so that the total weight is 114 lbs. per yd. and costs more than (say) a 90 lb. rail.

2. It is not stiff enough for ballasted tracks carrying heavy traffic.

3. It is not strong in a crosswise direction, and therefore knocks out of line easily. A look at St. Georges Road will confirm this.

4. The flange is too narrow; on concrete foundation the rail wears into the sleepers too quickly.

5. It is not deep enough to make a strong fishplate joint which can be welded.

6. Water can get through between guardplate and rail, and so down into the foundation.

The 90 lb. Section. This has none of the above objections, but is not quite stiff enough in the web nor wide enough in the head - tyres over-ride the head when they become worn a bit.

The 102 lb. Rail has been adopted by the authorities as the Standard grooved rail for tramways in Australia.

It has none of the defects of the other two, and in addition has a deeper head and groove, so allowing for more wear before it has to be scrapped. It is heavier and therefore stronger than either the 80 lb. or the 90 lb., and the fishplates are much stronger also. The weight from the wheels is taken more directly over the web than in the 90 lb. rail.

The 80 lb. Australian Standard Railway Rail is suitable only for open track, because the head is so shallow that a guard plate bolted on to it would cause the wheels to "bottom" before the head had half worn down,

CARE IN LAYING.

It is not enough to lay rails correctly to gauge, level, and with a good top. The rail must also be upright, otherwise the wheels will only tread on a small portion of the head, and this will cause heavy wear on the wheels as well as displacement of the metal in the head of the rail. Probably corrugations start more easily under these circumstances. Where hewn sleepers are used, they should be adzed carefully, using a good stiff adzing gauge, so that the two flats are properly in line. Even sawn sleepers should always be tested with an adzing gauge before the rails are laid on them, in case they are twisted or warped. A full bearing on the wood is needed, otherwise the rail will "work" under the weight of the cars, thus wearing into the sleeper and breaking the paving alongside.

SPECIALLY HARD RAILS.

A special steel can be got in England known as Sandberg Silicon Steel, and rails made of this steel do not wear out as rapidly as those made of ordinary steel. These rails can be picked out by the letters SSS rolled or stamped on them. Another process known as Sorbitizing is also used. This consists of blowing cold air from jets onto the rails as they come away from the rolls (while red hot). The effect is to harden or temper the outside of the steel for a depth of ⅝" or so. This process can be used either with ordinary steel or with high silicon steel. For curves, the best rails (except for manganese steel) are those made of high silicon steel treated sorbitically. Sorbitic rails are painted blue on the ends.

Wear. Except on curves, rails take many years to wear out. The cable trams are still running on many rails that were laid over 40 years ago. This is principally because the foundation under the rails was made amply strong enough to hold the rails up. If the foundation is weak, the rails will cripple unless they are continually being lifted, and so their real wearing life is not got out of them. Measurements have shown that on ballast with medium traffic the wear is only about 1/32" per year, or less. On concrete base the wear takes place more rapidly.

On curves, the wear on the running rails can be kept in check a lot by frequent attention to the guard rails. The guard rail should take all the side thrust of the cars going round a curve; it is cheaper to replace the guard rail than the running rail.

CORRUGATIONS.

The cause of corrugations has not yet been proved. It would appear, however, that they show up quickly where the rail has a slight springing action, as on a concrete base where the clips are not quite tight. This causes the rail to rattle or vibrate under the car wheels, so producing waves in the surface. Where the rails can move freely under the load such as on a ballasted track, corrugation takes many years to appear.

It is important, therefore, to see that all clips are very tight and that they remain tight. As soon as movement in the rail is noticed, the rail should be tightened down on the stringers by inserting shims under the clips and tightening the nuts.

The remedy for corrugations is to grind them out: A large machine with four grinding wheels is now being built for the Board to do this work.

FASTENINGS.

FISHBOLTS, ANCHOR BOLTS, GUARDBOLTS.

These are all made locally, the first operation being the drop forging of the bolt in properly shaped dies, out of pieces of steel bar. After being shaped in the die, the fins are removed and the bolts are put in a screwing machine and the thread cut automatically. The bolts are then dipped in oil and bagged. Except for dimensions, the main things to watch in the inspection of bolts are the way the threads are cut and the tightness of the nuts. The nuts on all track bolts should be too tight to turn by hand when full on, but easily turned with an 18" spanner. Anchor bolts are made with a wide head so as to give a good hold in the concrete.

COACHSCREWS.

These are made in the same way as bolts. The shape and finish of the threads are the main things to watch in manufacture. When screws are being put in, the hole should be at least $\frac{1}{8}$" smaller than the screw, so as to prevent the screw lifting out easily. Hammering should not be used.

DOGSPIKES are also die forged, the fins being removed and the point formed all in the one operation. The hole for a dogspike should be no bigger than the thickness of the spike (that is, for a $\frac{3}{4}$" dog the hole should be not more than $\frac{3}{4}$" in diameter.

CLIPS. are now made of rolled steel, but were originally of cast iron. The steel clip is dearer, but can stand more pressure without breaking, and gives a better fit. The bars are rolled in a mill much the same as rails are. Then each bar is put through a combined punching and cropping machine, which cuts off each clip in turn, and at the same time punches a hole in it. If necessary the clips are then flattened before being bagged. In placing clips in the track the hole should be bored so that the shoulder of the clip is tight against the rail flange and against the bolt.

TIEBARS are now made in our own shops. They are cut from mild steel bar and the ends forged to a round shape under the steam hammer. The bars are then put in a screwing machine and the round ends screwed. Nuts should be nearly as tight as on a fishbolt. Round washers are provided to give a smooth bearing for the nuts. The main thing to watch in a tiebar is that the two screwed ends are in a line. If they are not, one rail or the other will be tilted when the nuts are tightened up. Tiebars are made stiffer than they were some years ago, because in stringer track they have not the assistance of sleepers in holding the rails to gauge during construction and after. In macadam track the tiebars are blocked up so that the roller will not bend them. A bent tiebar is no good and may as well be out.

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD

LECTURE NO. 7 - WELDING.

BY MR. A. R. SMITH

A. Welding Defined.

B. Types of Welds.

C. Applications of Welding.

D. Welding as applied to Tramways.

E. Electric Arc Welding of Tramway Permanent Way
   1. Welding Set in use.
   2. Types of Welding done.
   3. Electrodes used.

F. Welding Costs.

A. WELDING may be defined generally as "the art of joining metals", but strictly speaking it is the "uniting of two pieces of metal by pressing them together by hammering or otherwise while they are hot and plastic", such as a blacksmith's weld.

Nowadays, however, metals are joined by many different methods, most of which are termed "welding" as the term is now applied.

Any process by which cohesion or combining of the molecules or particles of the pieces to be joined is brought about is called welding, in a general sense. Modern methods of obtaining high temperatures by the use of gases and electricity have made possible the carrying out of welding that could not be done by the earlier process of heating and hammering.

B. TYPES OF WELDS. There are four general classes of welding, each of which is subject to much variation. These classes are :-

1. Smith or forge welding.
2. Cas or hot flame welding.
3. Chemical welding.
4. Electric welding.

In addition to the above classes, we have -

5. Soldering, and

6. Brazing;

both of which are allied to welding.

Rivetting is an entirely different process from welding, and is fast being superseded by the latter in many forms of construction.

C. APPLICATIONS OF WELDING.

1. Smith Welding - or forging - is probably the oldest form of welding, and dates back almost to prehistoric times. Evidence is available to show that good welding of this type was carried out at least 2000 years ago (Delhi, India).

Forging is generally done using hot metals, heated by means of a suitable fire to the proper welding temperature. Though a very common and important method of joining metals it depends very largely on the skill of the operator for success, and is in general rather expensive, slow, and not so suitable for large or heavy work as some of the other processes which are gradually replacing it.

Smith welding is, of course, of very wide application, but is now used mainly in blacksmiths Shops. Large forgings such as making crankshafts and other heavy pieces, are carried out in large workshops. Unlike other welding processes, the plant required for smith welding is not very portable, and this somewhat restricts the scope of this type of work.

The main work of this nature carried out on our Per. Way Dept. jobs consists of renewing the points of picks, beater, packing tools, chisels, etc.

2. GAS WELDING. There are three main commercial processes of this class, viz -

1. Oxy-acetylene welding.
2. Oxy-hydrogen welding
3. Oxy-Blau-gas welding.

In all these processes oxygen is used with another gas to form a flame of very high temperature, When correctly mixed in a suitable burner. The flame is directed on the work in such a way as to cause the metals to melt and flow together.

In most cases extra material in the form of welding wire or metallic filling rods is added to form the weld.

Of these classes of welding the oxy-acetylene process is best known, and it may be applied to practically all classes of repair and construction work in which metals are used. It is a relatively cheap process, but the cost rapidly increases with the size of the job.

3. Chemical Welding. "Thermit" welding is the best known of this class of weld. A mixture of oxide of iron and aluminium is placed in a suitable mould and ignited. A chemical reaction is thereby set up causing intense heat, and "thermit" steel is formed. This molten steel is allowed to run out of the mould into and around the part to be welded, forming a cast-weld of considerable strength.

As a mould has to be formed about the parts to be welded to hold the "thermit" steel until it has cooled, the process is rather slow and expensive, but it forms a very good joint.

"Thermit" welding is most suitable for large repair jobs and also produces a satisfactory, though expensive, tram rail joint.

The main drawbacks to the Thermit welding of tramway rail joints are as follows -

(a) Highly skilled operators are required.

(b) The work cannot be done under traffic.

(c) Repairs to broken joints are difficult to do, and generally require the cutting in of a "closure".

(d) The cost is about twice as high as that of an electrically welded joint.

4. Electric Arc Welding. This is probably now the most widely used form of welding, and is yet only in its early stages. The necessary heat for welding is produced at the site of the weld by causing it to be a point of high resistance in an electric circuit.

The main systems of electric welding are as follow, viz:-

1. The Thompson Process - using alternating current and bringing both pieces to be welded in contact.

2. The Zerener Process - using two carbon electrodes and a filling piece.

3. The Bernardos Process - using a carbon electrode, and a metal filler.

4. The Slavianoff Process (Metallic Arc) - using a metal electrode which also acts as a filler.

5. The LaGrange-Hoho Process - a combination of electric and smith welding - the pieces being heated by electricity and joined by hammering.

The Slavionoff Process, which is a modification of the Bernardos Process, is in most common use, and is used on our work for rail joint welding, etc. An electric arc is formed between the work and the electrode, and the intense heat so formed melts the end of the electrode, thus providing filling material which falls directly into the molten patch of metal on the work, and thus provides a seam of metal joining the two parts.

Electric arc welding is applicable to all classes of work and can be used with most metals. It is the simplest type of welding process, is economical, and a commonsense operator can soon become sufficiently skilled to produce good work.

Advantages of Electric Welding. The main advantages over the other systems of welding for tramway work are -

a. Economy.

b. Portable apparatus.

c. Can be carried out under traffic on the works.

d. Repairs and maintenance work easily carried out on joints and special work.

e. Operators for other than very special work need not be exceptionally highly skilled.

5. Brazing, is very closely allied to welding, and consists of joining metals by fusing a filling material called spelter into the joints by heating, the joint surfaces having been previously treated with a suitable flux. Theheat is produced at a high temperature.

6. Soldering - (metallic gluing) is done by melting a soft alloy into the space between the parts to be joined - It can be done at fairly low temperature, but does not give much strength, and is unsuitable for joints in iron, steel, etc.

A flux is always required for this work, to clean the surfaces to be joined.

Expansion and Contraction in Welding.

The effects of expansion and contraction should be carefully considered for all welding operations, and allowances mad for such alterations in shape of the materials during welding.

Castings to be welded should be very carefully treated, and are generally preheated by means of gas furnaces, etc., before welding, and reheated afterwards to relieve them of any stresses set up in them during welding.

D. WELDING AS APPLIED TO TRAMWAYS.

Welding plays a very important part in tramway construction and maintenance, and also in the Workshops.

In the Workshops considerable smith welding, forging, etc., is done, and also some oxy-acetylene welding and a considerable amount of electric arc welding.

On the Permanent way, or tram tracks, practically all of the welding done is carried out with the electric arc, though a little oxy-acetylene and smith welding is done.

We are therefore mainly concerned in our work with electric arc welding.

E. ELECTRIC WELDING OF TRAMWAY PERMANENT WAY.

1. Welding sets in use. In the M. & M. T. B. the welding sets used are of the motor-generator type. The electric motor takes direct current from the trolley wires at a voltage of 600, and drives a generator which produces a suitable current for welding. The voltage before striking the arc is about 60, and is about 30 when the arc is struck. The amperage can be varied by the operator by means of a rheostat or resistance in the circuit according to the needs of work. The amperage used generally varies from 100 to 200 according to the conditions met with.

The welding sets of the Board use direct current, but alternating current is quite satisfactory for welding and is used to a very large extent by firms specialising in welding work.

In tramway work the welding of the tracks has to be done in place on the job, and thus the sets used must be portable so that they can be easily shifted from place to place. For this reason most of our sets are mounted on Ford Trucks.

Welding sets are available which can be operated independently of a source of electric supply such as the overhead trolley wire. They are provided with petrol or other independent types of motors for turning the generator, and thus producing the welding current. With such sets a constant voltage can always be maintained in the circuit, which helps to give a good uniform weld.

Our sets taking current from the overhead wires are subject to large variations of current at times of peak loading on the tram lines, and this seriously affects the quality and quantity of the welding done at these times, especially in outlying parts of the system.

In practice, the electrode is inserted in an insulated handle or holder in the electric circuit, and thus attached to one side or pole of the generator, while the work is connected to the other pole. The operator, after starting the machine, touches the electrode against the work, thus completing or closing the circuit, and immediately withdraws it about $\frac{1}{8}$", thus producing an electric arc of intense heat, which melts the end of the electrode and also that portion of the work where the arc strikes. Molten metal from the electrode falls on to the work, combines with the molten metal of the pieces to be joined, and on cooling out a good joint is made if the operation has been properly done.

2. Types of Welding Done in Per. Way work. The main types of electric welding now carried out by the Per. Way Dept. welders are as follow:-

(a) Seam welding - Joining fishplates, soleplates, guard plates, etc., to various types of rails

(b) Bonding - attaching bonds to special work where seam welding cannot or should not be done, and also across rail joints in open par construction.

(c) Building up worn track work -

1. Cupped rail heads, etc.
2. Worn edges of railheads and checks round curves.
3. Special work - switches, mates, crossings, etc., which are usually made of special cast manganese or high carbon steels.

(d) Ramping up crossings at special work intersections to carry the whel treads over the crossings without bumping. The whole of the weight of the from the wheel is transmitted through the narrow wheel flange to the ramp and thence to the rail, thus the ramps have to withstand very severe treatment.

3. Electrodes used In our work, the electrodes used consist of steel wire rods varying from 6 to 10 gauge according to the class of work to be done, and the current available, and are cut into convenient lengths of about 18 inches.

Various types of electrodes too numerous to mention here can be obtained from various makers, each type being designed for some particular class of job and for a certain set of conditions.

The main classes of electrodes used are -

(a) Bare mild steel wire, specially prepared, with bright finish and hard drawn from high grade mild steel rods.

(b) Special classes of electrodes - of the Quasi Arc type - These are covered with a layer of some type of flux or slag which is melted by the heat of the arc during welding, thus forming a film or covering over the molten metal, protecting it from the oxidising action of the air, and also allowing it to cool down more slowly, thus improving its mechanical strength.

These electrodes are used for welding special classes of steel for which bare wire is unsuitable, and can be made to give deposits of steel of varying composition, either by using steel wire of suitable composition, or by incorporatin in the flux covering certain ingredients which are absorbed into the weld during welding.

Thus, for welding special steels electrodes which give a deposit similar in composition to the steel itself, can be obtained.

Electrodes used in our work are as follow:-

1. For seam welding. (Joints, soleplates, etc.) bare mild steel welding wire usually dipped in lime paste, which acts as a light flux and tends to keep the arc steady. Flux covered mild steel wire would probably be slightly better, but is much more expensive.

2. For Bonding, bare mild steel electrodes are used. The bonds are of copper, with steel ends which are welded direct onto the flanges of the rails. If no steel ends are used, special copper electrodes are required.

3. For Building up trackwork.

   (a) For cupped rail heads, bare mild steel wire electrode is used generally, though a covered medium carbon steel electrode would be satisfactory.

   (b) For building up round curves we at present use bare mild steel electrodes. Here again a covered medium carbon electrode would be satisfactory.

   (c) For building up special work - switches, mates, crossings, etc., - special flux-covered electrodes are used, their composition being such as to give a welded deposit of steel similar in composition to that of the parts to be welded. For cast manganese special work, manganese steel electrodes giving a deposit containing 14% manganese are used. For high carbon steel, electrodes giving a deposit with a high percentage of carbon are used.

   Where a very hard and wear-resistant surface is required, chromium self-hardening electrodes may be used.

   Ordinary bare mild steel wire does not give a good deposit on special steels, and vice versa, special electrodes do not generally give a satisfactory job on mild steel.

4. For Ramping up Crossings, etc. For this work, special electrode which give a deposit that can stand up to excessive wear should be used.

   Mild steel electrodes give too soft a deposit and are soon worn down, whereas a manganese or high carbon electrode will give a deposit capable of standing up to the work for a considerable time. To save building up the whole ramp with expensive special electrodes, filling pieces of mild or cast steel shaped to fit into the groove may be used, and flooded over with a layer of hard steel deposited from say a manganese or high carbon steel electrode.

   Great care must be taken to embed such filling pieces firmly in the rail groove so that they are not liable to be shaken loose by the bumping of tram wheels over them.

   Ramps should be brought no higher than ½" below the rail tread, the wheel flanges being 9/16" deep - thus a new ramp would raise the wheel tread 1/16" above the rail head at the actual point of crossing, but it would soon wear down a little.

   If ramps are made too high there is a danger of throwing trams off the rails, and in any case causing too much of a bump, which sometimes chips pieces off the wheel flanges.

Care in Welding. Owing to the responsible nature of their work, and the fact that they are often working along the tracks without supervision, welders should be very honest and careful men, and should exercise commonsense in their work.

In building up special work already in position on the tracks, e.g. switch stocks, mates, crossings, etc., the welder must be careful to make a smooth even job without sudden bumps, and to see that the track is in all cases safe for traffic. He must take notice of any distortion occurring in the work through the heating due to welding, and must endeavor to counteract this if possible.

Switch tongues must on no account be built up in the track but should be replaced by temporary tongues and taken to the special work depot to be repaired and afterwards straightened.

Welding steel deposited on running surfaces should be hammered while hot to give as smooth and even a surface as possible, and preferably ground smooth with a suitable grinding machine.

Unless good penetration of the welding deposit into the main body of steel is obtained, the job will not be successful.

For seam welding the operator does not require such a high degree of skill as for building up special work, but he must nevertheless exercise great care in order to obtain a good job.

He must get good penetration into both the metals to be joined, but at the same time must take care not to burn the deposit by using too much current.

He should produce a good full, even seam free from blowholes, cracks, etc., provided he has suitable electrodes and current. He should notice any tendency of the work to distort owing to heating, and should take steps to counteract these effects by taking down the work here and there, and perhaps by commencing running a seam in another part of the job. A careless welder can throw the rails of a track considerably out of line by carelessly welding of the fishplates without thought of expansion effects.

Fishplates are shaped at the top and bottom so as to make a suitable angle with the rail head and flange for seam welding, to enable the welder to play the arc well into the joint and thus obtain good penetration on both sides.

It is preferable to run a light seam first with say a No.10 gauge electrode to penetrate well into the joint, following this up with a heavier seam using say a No. 7 gauge electrode to give a strong weld.

Welding of joints should be carried out as soon as possible after the track has been lined up and properly fastened so as to catch the joints before they open up through expansion and contraction of the rails owing to temperature variations in the atmosphere.

Any open joints should be packed as tightly as possible with mild steel shims shaped like the rail section before the welding is done, and the parts to be welded should be scraped clean and brushed with a wire brush to give the best results, but this is not so important if covered electrodes are used, as the impurities in the joint are dissolved by the slag and come to the surface of the molten metal. For this reason it is undoubtedly better to use say covered mild steel electrodes in preference to bare wire in repairing seam welded joints already in the track, and also for welding joints in old reconditioned rails which are generally dirty and rusty.

Fishplated joints are welded in order to -

1. Maintain good electrical donductivity across the joints.

2. Add strength to the joint.

Inspection of Welding. A careful inspection will generally suffice to determine whether welding work is reasonably good or otherwise, the main points to look for being as follow, viz.

1. The welded surfaces must be well and evenly tacked together. This can be judged fairly well by eye.

2. The color of a weld indicates its quality. If the bead turns red and rusty looking within 20 minutes after the weld is completed, it means that the heat was too great and the metal was burned. If it stays steel-colour it has not been overheated.

3. Penetration, or depth of weld, which is very necessary for proper uniting of the parts, is indicated by absence of "spattering" of metal. The presence of "spattered" metal shows lack of depth of weld, and probable weakness. If the bead stands out on the surfaces, and shows an undercut edge, like a drop of solder, the fusion is insufficient, but if the bead surface at the edge is curved the other way, and looks saucer-shaped, good fusion and penetration is indicated.

Precautions in Welding.

1. Protection of the eyes. The electric arc provides a very intense light that is injurious to the naked eye and consequently should not be looked at except through suitable dark glasses, even for a second or so only. All our welders are provided with shields fitted with dark glasses

2. Connection of machines to overhead wires. Great care must be taken to see that the machine is earthed to the rails, etc., before making the overhead connection, and to see that the latter is disconnected before the connection to the rails (which should be welded) is broken off, otherwise there is danger of severe electric shock.

(F). WELDING COSTS (ELECTRIC ARC WELDING).

The M. & M. T.B. spends a large amount of money annually on welding.

The Per. Way Department has seven portable welding sets in action at present, with a personnel of 9 welders, 9 assistants, and 1 Foreman welder, the total annual wages alone for these men amounting to approximately £5,500-

(a) Costs of electrodes:- (March 1928)

No. 7 gauge Bare Mild Steel wire	- £22- per ton or abt. 1/5d per 100	
" 8 " Flux Covered " "	about 20/- per 100'	
" 8 " " " Manganese Steel wire	" 35/- " "	
" 8 " " " Medium Carbon steel wire	" 25/- " "	
" 8 " " " High Carbon Steel wire	" 30/- " "	
" 8 " " " Chromium Self Hardening Steel wire	" 30/- " "	

(b) Electric Power costs about 3d per machine hr of welding

(c) Costs of Welding Joints, etc. with bare wire - No. 7 gauge

Details	90 & 102lb. rail jt.	80 lb. (80l) rail jt.	10 inch soleplate	Steel ended bond (both ends)
Weld. Materials				
Electrode	25' - 4½d	30' - 5d	6' - 1d	say 1d
Flux	say 1d	say 1d		
Current	" 3d	" 4d	" 1d	" 1d
Labor	1hr. @ 2/4 } 1hr @ 2/- } 4/4	1¼hr @ 2/4 = 2/11 " @ 2/- = 2/6	¼hr. @ 2/4 = 7d " @ 2/- = 6d	¼hr @ 2/4 = 7d " @ 2/- = 6d
Total cost per unit (actual labour & Materials	5/0½	6/3d	1/3d	1/3d
Add 40% of labor for O'head	1/8½d	2/2d	5d	5d
Total cost per unit (Incl. O'head)	6/9d	8/5d	1/8d	1/8d

(d) Cost of special welding. This varies considerably according to :-
(1) The type of work to be done
(2) The class of electrode used
(3) The skill of the operator
(4) The traffic conditions, etc.

and thus no definite figures can be given.

--- MELBOURNE AND METROPOLITAN TRAMWAYS BOARD ---

LECTURES TO PERMANENT WAY INSPECTORS & GANGERS. 19.3.28

LECTURE NO. 8

TIMBER

By MR. J. J. FISCHER.

INTRODUCTION.	DECAY OF TIMBER
PROPERTIES & STRUCTURE	SPACING & LAYING OF SLEEPERS TIMBERS STRINGERS
SUITABLE & AVAILABLE VARIETIES PRODUCTION. SEASONING AND PRESERVATION.	WOODBLOCKS.

INTRODUCTION.

In practically all of the Permanent Way at present being laid by the Board some timber is used; it may be considerable or it may be small. The quantities and costs of the timber used per mile of double track, 90 lb. rail, 11' centres are roughly:-

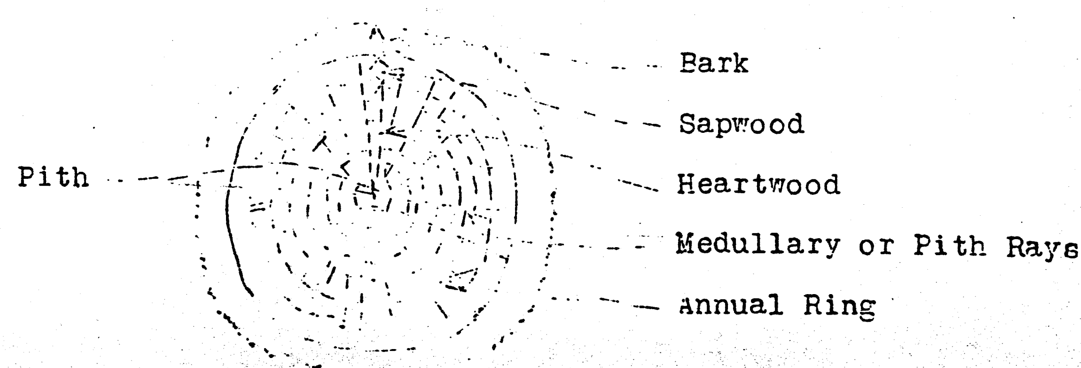
Sleepers -	4500 ...	£2,200
Stringers	1408 ...	£1060
Woodblocks	285,000...	£5000

These costs do not include that for cartage, laying, etc. It can be seen, therefore, that some knowledge of timber is of importance in tramway work.

PROPERTIES AND STRUCTURE OF TIMBER.

All timber is cut from a tree; therefore, to understand the properties and structure of timber, it is necessary to study the tree from which it is cut. A tree consists essentially of 3 distinct parts - roots, trunk and limbs and leaves. As all timber for Tramway work is cut from the trunk, the other parts will not be considered here.

If we cut through any tree, especially a young one, we will see certain markings as shown below:-



On the outside we have a corky layer, or bark, then a light coloured wood or sapwood, then a darker coloured wood or heartwood. If we look more closely we will see in the wood a series of circles; these are called annual or wood rings. On looking still more closely we will see fine straight lines running from the bark towards the centre - these are called medullary or pith rays. Right in the centre of the tree, inside the first ring is called the pith.

These can all be seen with the naked eye, but if we now make an examination with a microscope we will see that the woody fibres consist of a large number of small cells or tubes, rectangular in shape, which are packed closely as in a honeycomb, but on a much smaller scale. These tubes extend from the roots to the ends of the branches, and they provide a channel through which sap flows to all parts of the tree.

All timber trees grow from the centre outwards. That is, the woody fibres are added on the outside and not on the inside as in cases of numerous smaller plants.

The bulk of the timber is made up of annual rings, each of which represents one year's growth. The lighter rings are formed in the spring time and the darker ones in the autumn. The wood cells are packed much closer and the cell walls are much stronger and darker in the autumn wood than in the spring wood.

SUITABLE AND AVAILABLE VARIETIES.

It is generally conceded that the strongest and most durable timber is that of greatest density - this is not always correct, but it is generally so - and the most dense timber is usually that of very slow growth or which show otherwise the annual rings very close together.

It is often asked - "which is the best timber?" For Tramway work this practically means which is the most durable. Of course there are other essential properties such as strength, ability to withstand wear, gripping power on spikes, etc., but in Australian timbers it can be fairly truthfully said that if the durability of a timber is satisfactory then it is also satisfactory as far as the other requirements are concerned. Although there are undoubtedly numerous varieties of timbers very suitable for Tramway work we are practically confined to a few because of the limited supply of some of them. Then again, there are ample supplies of some varieties, which are of inferior quality. Below is a list of the classes of timber which are available and have proved satisfactory for Tramway work:-

Red Ironbark
Grey Ironbark
Red Box
Grey Box
Yellow Box
Gippsland Box
Forest Red Gum
Murray River Red Gum
Jarrah

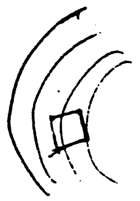
Of course, if timber has a bad defect before it is placed in position we cannot condemn that variety of timber for early decay. The ideal position would be to have every piece of timber perfect; this is impracticable, especially in Victorian timbers, as the cost would be not only prohibitive, but the supply would be very much limited. We have to be contented, therefore, with timber reasonably sound, but of course free from any vital defects.

The main defects usually met with when inspecting timber are rot, white ants, grub holes, gum pockets, shakes, cracks, knots, waney edges, warps and twists, sapwood, pith, pipes, undersize, and not the least important, variety.

PRODUCTION.

Very little need be said about how the different kinds of finished timber articles are produced. You are all familiar with that. It is as well, perhaps, to point out, however, a few of the main features.

The best time for felling timber is in the winter months, as there is practically no flow of sap, which means that there is less inducement to decay.



In the production of timber it must be remembered that the shrinkage of a log is not uniform throughout. It is twice as great around the annual rings as across them; the shrinkage lengthwise is so small that it is practically negligible.

Stringers, timbers and sleepers are cut "on the back" for the obvious reason - to minimise splitting.

Woodblocks are cut with the longitudinal fibres running the same way as the depth of the block.

SEASONING AND PRESERVATION.

The whole problem involved in timber preservation is the replacement of the sap by some suitable preservative. This means that the sap must first of all be removed, as it is impossible to satisfactorily force any preservative into the small cells or cavities if there is something already in them. This removal of sap is accomplished by seasoning.

(a) Seasoning; It has already been mentioned that all timber is really a honeycomb mass, and when the tree or timber is green the cells and cell walls are, to a great extent, saturated with sap. Seasoning means the drying out of a large percentage of this sap. Timber is said to be seasoned when it has lost one fifth of its weight. Seasoning may be natural or artificial.

Natural Seasoning , as the name implies, is getting rid of the sap by natural means. The most common method is air seasoning, and is the method adopted by the Board at present. This is usually done by stacking the timber so that air can pass freely through the stacks. The length of time to season timber by this method - in fact any method - depends largely on the sizes of the pieces. For sleepers it is from 9 to 12 months.

Another satisfactory method is to soak the logs in water for several days. They are then pulled out and allowed to dry in the air. By this means the sap is replaced to a large extent by water, and when the log is allowed to dry the water drys out. Water drys out much more quickly than sap.

Artificial Seasoning is used to expedite or hurry on the removal of the sap. What takes several months by natural seasoning can be accomplished just as satisfactorily in a few hours by artificial means. There are numerous methods, but perhaps the most satisfactory method is to place the timber in a warm, moist atmosphere and then the moisture gradually reduced until dry air only is used.

(b) <u>Preservation</u>. If water or sap can be dried out of timber, so can water re-enter it, and the water that re-enters the timber is not always - in fact, very seldom - pure. It usually contains, amongst other things, very small spores of rot fungi. These spores are so small that they can be carried wherever water will go, and once they are lodged in suitable surroundings, decay will commence. It is obvious, therefore, that once we have got rid of the sap water must be prevented from entering the timber. This is done by means of a suitable preservative. If a permanent pre servative is satisfactorily applied, timber will last a very long time indeed. The main cause of many failures in the preservation of timber is that the preservative itself is not permanent. It would appear then that the ideal would be to remove all the sap and refill every cell with a permanent preservative, such as bitumen. This can be done, but is extremely costly. We have to be content, therefore, with the most economical proposition. Generally in other countries the treatment of sleepets, etc., with Creosote (either by pressure or steeping methods) is the most economical. (Creosote is distilled from tar and can be briefly said to be all that part of the tar heavier than water and lighter than the residue, pitch). No definite information can be obtained, however, whether it would be an economical proposition for our best hardwoods, such as Iron-bark, etc.

The Board at present use the steeping process for wood-blocks, and painting process for stringers, using crude tar as the preservative; the sleepers and timbers in most cases receive no treatment whatever. It is our intention, however, to look into the question of treatment, and if a more economical proposition can be found, new methods may result.

<u>DECAY OF TIMBER</u>.

There are many different kinds of diseases, not only in dead timber, but also green timber. But as all timber dealt with by the Board is dead, we will deal with that alone.

Although "wet rot" is undoubtedly the most general form of decay, the most common disease occurring in Tramway work is "dry rot" (The name "dry rot" is misleading, as the disease cannot exist where moisture does not occur). We can, I think, safely say that 90 per cent of our failures are due to this particular disease. For the successful growth of this rot, the conditions must be suitable for it, and unfortunately, the timbers in our tracks are in such a position as to oonform to that suitability.

The essentials for the growth of this disease are moisture, warmth, still air, and darkness. If we do away with any of these factors we do away with the disease. This is another reason why special attention should be paid to track drainage.

<u>SPACING AND LAYING OF SLEEPERS, TIMBERS, AND STRINGERS</u>.

<u>Sleepers and Timbers</u> are usually spaced at about 2'6" centres, with a maximum of 3' and a minimum of about 1'6". The maximum distance is governed to a large extent by the strength of the rail. The factor governing minimum spacing is the difficulty of packing materials satisfactorily under them.

Sleepers and Timbers are cut "on the back" and are placed with the sap side uppermost. *heart side down*

Stringers are, as you all know, placed under the rail continuously. They are, like timbers and sleepers, also cut "on the back" and placed with sap side up. The sap side is dressed to ensure a good continuous seat for the rail.

It may as well be mentioned that on account of the difficulty of ascertaining on the job which side should be placed uppermost due to the stringers being tarred, a small chip is taken off one corner, on the sap side, before tarring.

WOOD BLOCKS.

Woodblocks are cut, as stated previously, with the grain of the timber running with the depth of the block, for the reason that end grain offers the greatest resistance to wear and that shrinkage is the least in this direction.

Upon their arrival in the Store, woodblocks are inspected, gauged, and stacked. They remain stacked until required on the job so as to allow as much as possible of the sap to dry out, and they are then tarred before being sent out.

In laying woodblocks adjacent courses should have the joints staggered. On account of the blocks swelling when they get wet, expansion joints are provided.

LECTURE NO. 9 - PAVING TRAMWAY TRACKS.

MESSRS. EAKINS AND GRAY.

A. PAVING MATERIALS

1. Wearing Materials.
2. Binders.

B. PAVEMENTS

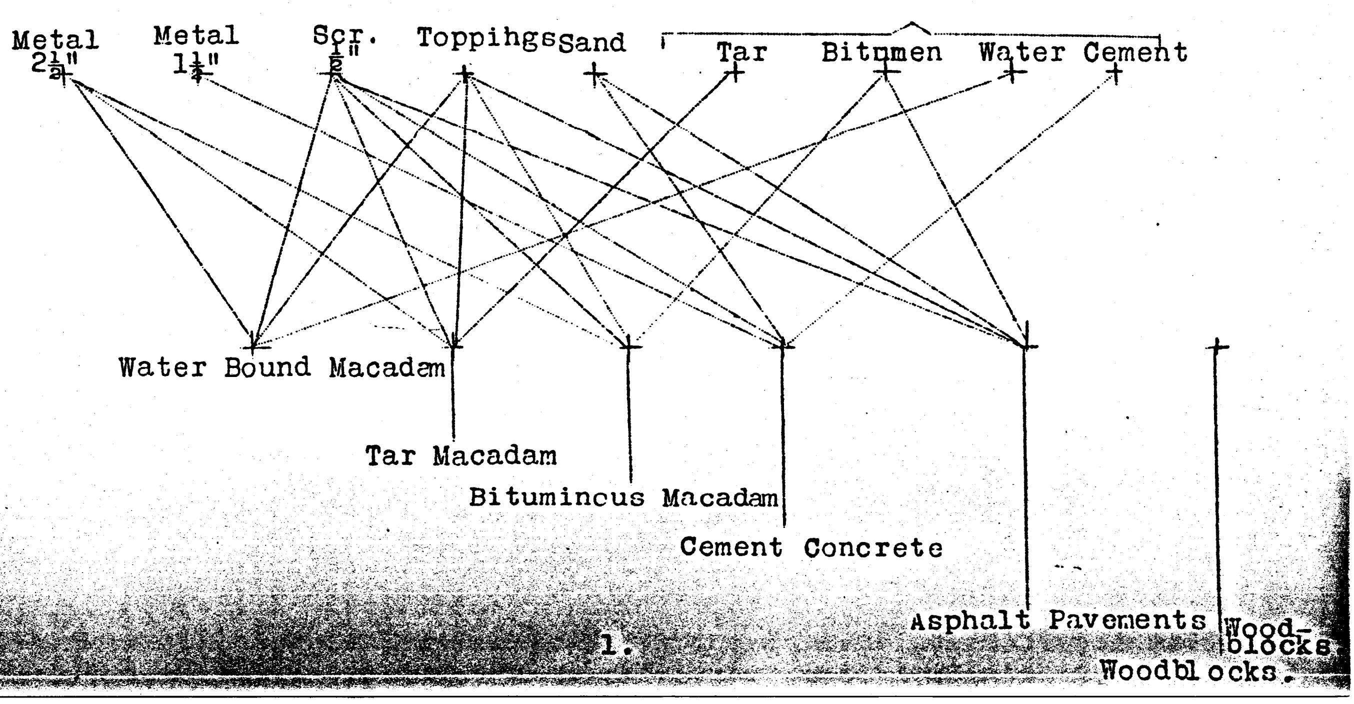
1. Waterbound Macadam.
2. Tar Macadam.
3. Bituminous Macadam.
4. Cement Concrete.
5. Asphaltic Concrete.
6. Topeka Asphalt
7. Warrenite.
8. Sheet Asphalt.
9. Refined Rock Asphalt.
10. Woodblocks.

C. SPECIAL WEARING COATS.

1. Topdressing.

A. PAVING MATERIALS.

WEARING MATERIAL. BINDER



A. PAVING MATERIALS:

(1). Wearing Materials.

The metal used should be of good quality to resist the forces operating to destroy the pavement and should possess the following qualities:-

1. Hardness, or the property to resist the abrasive action of wheels and horse shoes on it. For City work under heavy traffic where a good binder is usually used very hard stone is desirable.

2. Toughness, or the quality to resist sharp blows from steel or solid rubber tyres without fracturing and thus becoming loose in the pavement.

3. Fracture, or the stone's ability to break into well-shaped pieces under the action of a jaw or gyratory crusher.

Many different types of rock can be crushed into good metal but since most of our metal is obtained from quarries around Melbourne, we get practically nothing other than basalt.

Basalt is the rock formed when molten material called magma flows on to the surface of the earth through a volcano or fissure and cools on the surface; all the basalt around Melbourne flowed out from Mt. Macedon and Sunbury when this area was active. As Mt. Macedon was active intermittently there are numerous flows, each showing different characteristics, and as many as three different flows can be seen in one quarry, each layer producing a metal of totally different quality, one being compact and close grained, and another coarse grained and honeycombed, and generally unsuitable for heavy traffic. Vesicular or honeycombed basalt is caused by water in the magma turning into steam on the release of pressure, when the material flows on to the surface, the steam blowing the holes in the slowly cooling rock. Even in one large flow it is found that the bottom stone is dense and hard while the top stone is soft and full of holes.

(2). Binders.

1. Tar. Tar is the by-product of a number of commercial provessos, such as the manufacture of gas in a water-gas plant, the manufacture of coke in coke ovens when using blast furnaces, and in the manufacture of coal gas in retorts.

As tar from the manufacture of coal gas is the only type produced in Melbourne in large quantities, I will deal with it in some detail. The coal is heated in a retort either horizontal or vertical, the latter generally, as it produces more gas per ton of coal than the older horizontal type of retort. From our point of view the latter produces a less quantity and poorer quality of tar. When the gases pass to the condensors and scrubbers ammoniacal liquors, water, and tar are drawn off and run together into a separator tank, where more or less of the ammoniacal liquors are drawn off; the tarry product called crude tar being run to the storate tanks. The crude tar is then carted to a distillery for the removal of the water and lighter oils and the production of various grades of distilled tar according to the temperature to which it is raised. Removing all the water by heating to approximately 170° C. will leave dehydrated tar in the still, up to 230° C. will leave medium refined tar up to 270° C. heavy refined tar, and above 270°C: pitch. The light oils taken off are separated generally into ammonia, benzine, carbolic, cresote oil and green grease, from which numerous valuable chemical products can be obtained.

The quality of the distilled product obtained from a coal gas crude tar depends from a road making point of view on the quality of coal used. the type of retort in which the gas is extracted, and the temperature to which the crude tar is raised and the time it is kept at that temperature in the tar distillation plant.

2. Bitumen, Bitumen free from organic or mineral matter is obtained from two sources. the first being in certain natural deposits in Utah and Colorada in the U.S.A., the second being a by-product from the distillation of crude oils for kerosene and petrol. The crude oils are obtained largely in Mexico, America. Persia and Russia. As little or no bitumen from the first source is used by us, I will deal more particularly with the second class. The crude oil is first put through an elaborate process for the removal of as little kerosene and as much petrol as possible. leaving as little residue as the manufacturer can. The residue is then passed to stills and its temperature raised by certain steps, using fires or steam according to the patent under which the particular manufacturer works, the distillation proceeding somewhat similarly to that used for tar except that steam or hot air is blown into the still to agitate the crude oil and that lubricating oils and commercial greases are removed and by careful manipulation of the temperature and time in the still the various grades of commercial bitumen are produced. The grades produced vary in consistency, which is called the penetration and indicates the suitability of the product for various classes of work, traffic, and temperature conditions. The grades or ranges of penetration are usually stated for the harder types in 10 point intervals. e,g, 30 - 40, 40 - 50, 50 - 60, 60 - 70, 70 - 80, 80 - 100, and 150 - 250; the lower the penetration number the harder the bitumen is. The quality of the bitumen from our point of view depends on many complex factors, the most important of which are the type of crude oil from which the material is distilled, and the process of distillation and agitation used during manufacture.

B. PAVEMENTS.

(1) Waterbound Macadam. This pavement is unsuitable for tramway work as it disintegrates rapidly alongside the rail owing to the weakness of the binder. It consists of a layer of broken stone $2\frac{1}{2}$" gauge spread evenly and compacted by a roller. $\frac{3}{4}$" screenings are spread and the road is then watered and rolled. The coating with screenings, the watering, and the rolling are continued till the pavement does not move under the roller. The $2\frac{1}{2}$" stone is really held together by the weak cement of stonedust and water formed in the process of laying the pavement.

(2). Tar Macadam is a pavement which consists of broken stone, $2\frac{1}{2}$" gauge held together by means of tar. A good surface is generally obtained by laying a $1\frac{1}{2}$" (consolidated) coat of tarred $\frac{1}{2}$" screenings. This class of pavement has been superseded by the bituminous pavement on account of the longer life of the latter.

3. Bituminous Macadam. The penetration type of this class of pavement has proved entirely suitable for ballast tramways and for surfacing suburban tracks carrying medium road traffic. As it comprises a large area of the present tramway pavements the method of obtaining a good pavement is dealt with in detail.

(a) The rails, particularly under the head and lip are thoroughly cleaned. This is necessary to give the bitumen a chance to stick to the rail. It will prevent early patching along the rail.

(b) The secondhand metal, if available, is then evenly spread to the level of the rails. No lumps of asphalt or stone which will not pass through a 3" ring should be left in the track. Small stone and dirt or clay should be kept out of the track. The space under the rails should be well packed with metal. If new metal is used for this layer it should be bound with forkings or screenings.

(c) This layer is well consolidated by means of a power roller. Lack of rolling at this stage will lead to wavy and low pavements. It is impossible to consolidate a layer of greater thickness than six inches in one rolling.

(d) A layer of new stone 2½" gauge is then spread over the secondhand metal and well rolled. It is essential to spread this metal evenly and to get a good surface parallel to the final one. Tipping up dray loads in one lot should not be allowed.

(e) A final layer of new 2½" metal is then spread so as to finish to approximately 1" above rail level after finishing the pavement. The metal is packed tightly under the head and lip of the rail.

It may be necessary to add this layer in two or three portions when the work is done under traffic. Care should be taken to get the surface of this layer without bumps or hollows, low at the track drains, flat across important street crossings, or where one track is much above the other.

The new metal should be from 3" to 4" thick when finally consolidated. Rolling should cease before the stone crushes and fills the voids.

(f) Hot bitumen of a suitable grade is then poured along each rail for a width of six to eight inches. The quantity should be from two to two and a half gallons per sq. yd., i.e. 4 gallons for 40 feet of strip. Immediately after pouring, ½" screenings only sufficient to prevent the roller picking up the bitumen, are spread on the strips. Without delay the remainder of the metal is covered with a coat of bitumen which is poured from side to side in diagonal strips, the splash at the ends giving the rail strips a light second coat. For this portion approximately 1½ to 1¾ gallons of bitumen is used per sq. yard. ½" screenings are then spread as for the rail strips, the roller being used immediately to tighten the pavement.

The bitumen should be as near to 350° F. as possible for pouring. In cold weather this is more necessary than in hot. The temperature in the tank should not be allowed above 350° F. as it will be damaged. Even pouring is essential to save hungry or fatty patches.

The stones should be well coated and the bitumen should go down the three or four inches of new metal.

The reason for putting the screenings on and rolling immediately after pouring is that the bitumen cools off quickly and hardens. After this occurs extra rolling fractures the bond between the stone and the bitumen.

The extra bitumen is put along the rail to get a good bond between the rail and the stone.

The quantity of bitumen required is more in the winter than the summer. For winter work 80/100 penetration is suitable, while for summer work 60/70 is best.

The diagonal pouring tends to prevent any cross ridges. With inexperienced pourers it is desirable to pour in a direction parallel to the rails in long strips finishing these on the skew.

(g) Rolling is continued till no movement is noticed under the passage of the roller and till the surface is smooth to the correct shape.

Should fracturing occur rolling should be postponed till the temperature is higher. If too little bitumen has been used, the pavement will not tighten under the roller but will keep on the move.

(h) Hot bitumen is then poured over the surface by the "tin-hare" method, and toppings dusted on it, after which a final rolling is given. This method is the one used to give a thin coat of bitumen approximately 1/10th gallon per square yard.

(i) During the whole operation care should be taken to avoid dirt grooves and delays or derailments to traffic. Some cars give only two inch clearance on a level road, and this adds to the difficulty of the work. On vertical curves the clearance is decreased.

4. Cement Concrete. This pavement is seldom used in tramway work. It is placed in the usual way, but special attention is given to getting a stiff mix and to the finishing operations. The surface is first screeded, then mechanically tamped or rolled, with a light roller, and smoothed with a belt. The concrete is cured by covering with damp earth or sand for periods up to six weeks.

5. Asphaltic Concrete Pavement consists of stone passing a 1" screen, ¼" Screenings, Sand, a bitumen heated and mixed in a special plant, and laid while hot in a 2 or 3 inch layer. A seal coat of sheet asphalt is spread in a thin layer over the first layer and the whole rolled as one. This type has been used in Camberwell and Whitehorse Roads and High Street Malvern by the Councils.

6. Topeka Asphalt is a hot mix pavement consisting of carefully graded stone, sand, and filler, and bitumin spread and laid while hot. The maximum size of the stone is ¼". Not more than 30% of the aggregate is retained on a No. 4 sieve, and containing not less than 10% of Portland Cement of limestone dust as a filler.

7. Warrenite is a hot mix pavement consisting of carefully graded stone, sand and filler, and Warren's bitulithic cement spread and laid while hot. There are two layers, the bottom layer of coarser material being covered with a thin layer of finer material, both layers being rolled together to form a single carpet. The aggregate of the bottom layer has 60% - 70% retained on No. 4 sieve.

8. Sheet Asphalt is a hot mix pavement consisting of a carefully graded mixture of sand passing a No. 10 sieve, Portland cement filler, and bitumen. The mixture usually contains from 70% - 80% of sand, 10% to 14% of filler, and 9% to 11% of bitumen mixed in a special plant and laid while hot, forming the highest class of asphaltic wearing coat.

9. Refined Rock Asphalts consist of sandstones and limestones naturally mixed with native bitumen found at Val de Travers, Seyssel, Lunmer, Bermuda, and Trinidad. The rock asphalt is dried and blended to produce the correct mixture and quantity of bitumen and exported in blocks. The blocks when required for use are heated until the whole mixture becomes plastic, and then laid and consolidated while hot.

10. Woodblocks.

(a) Rendering. In laying a woodblocked pavement the first essential is to have the rendering well done. Without this a good job is impossible. The rendering in all cases should be parallel to the finished surface. Care is required at silt pits, track drains, important cross streets, etc.

(b) Waistfiller. The next process is the filling of the waist of the rail. Cement mortar, 1:4 is commonly used and has proved successful when well put down before the line is open to traffic. Bitumen, sand and stonedust if properly formed make a good rail filler. The "waist filler" must be full so that the blocks can press into them.

(c) Foot of rails. The opening at the foot of the rails is filled with bituminous concrete or sheet asphalt, well-rammed in, to give a true and solid surface for the blocks to sit on.

(d) Blocking. The rendering should be thoroughly clean; the waist filler should be painted with bitumen before blocks are laid. Blocks should be laid to give a break of joint of not less than 2". A string course is necessary at the edge of each margin, and two are required in the six foot. Cutting of blocks should be reduced to a minimum. All cut blocks should be dipped in tar and all spaces under them filled with the bituminous mixture.

(d) cont'd.
If any blocks rock they should be replaced. Blocks should not be cut over tiebars, but butted close to them. The whole over the tiebars should be filled with waist filler mixture.

Expansion joints should be left in the margins and the six foot, the number depending on the class of block. Red gum shrinks more than jarrah.

These should be ½" wide, filled to 1" depth, with well-rammed sawdust and the remainder with bitumen. As soon as possible after laying the blocks the surface should be top-dressed to keep the water out.

Woodblock pavement is our first class pavement and is adapted for the heaviest traffic.

C. WEARING COATS.

Topdressing is applied to all pavements other than those of the asphaltic type, and is laid to waterproof the surface, provide a wearing carpet which can be easily and cheaply renewed, and to protect the underlying pavement from excessive wear and disintegration. In the case of woodblocks it also protects them from the results of the exposure to the direct ray of the sun.

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD.

LECTURE NO. 10.

Monday, April 16th, 1928.

TYPES OF TRACK.

By A. T. O'MEARA.

In deciding on the type of track to be laid in any particular street, we have to take into consideration the following points :-

1. The cost.
2. The foundation must be properly drained.
3. The load of the tramcars coming onto the rails must be spread well over the foundations, a weak foundation requiring a stronger base under the track.
4. The rails must be supported and anchored so as to have very little movement.
5. The rails must be held securely to gauge.
6. If possible, some sort of cushion should be provided under the rails to give smooth riding.
7. The paving must be of a kind that will stand up to the vehicular traffic without unduly expensive maintenance.
8. The rail joints must be designed to withstand the impact from car wheels and to give good electrical conductivity.
9. The part which is the most expensive to renew should be the most permanent.
10. Probable future alterations.

Tramway Engineers are still searching for the ideal type of track that will fulfil all of the conditions mentioned above, but we can study some of the types used in Melbourne to see how near they come to the ideal.

BALLASTED TRACKS.

(a) Open Ballast.

1. Cost. This is the cheapest type to build, costing from £18,000 to £26,000 per mile of double track according to the fencing, kerbing, crossings, etc., required.
2. Foundation is easily drained, either by using a cambered formation with open side drains, or 6" subsoil drain.
3. The load is spread over the foundation by means of sleeper and metal ballast.
4. Rail movement does not matter much, as there is no paving to be destroyed.

5. The sleepers hold the track to gauge securely.

6. Cushion under the rail is provided by the ballast, which permits the rail to move up and down a little. The metal also deadens the noise.

7. No paving is needed.

8. Rail joints can be made strong by using flanged fish-plates. Bonds provide the return circuit.

9. Renewal of the ballast is necessary only after many years, and can then be done cheaply.

10. Future alterations are easy.

The life of rails and sleepers in an open ballast track should be about 20 years, except on curves. The maintenance should be light, consisting only of occasional lifting at low joints, etc., weeding, and attention to drains.

(b) Closed Ballast Track.

1. Cost of this type is £23,000 to £26,000 per mile D.T.

2. Foundation drainage is provided fairly easily by means of a layer of ashes and a suitable subsoil drain.

3. The load is spread over the foundation by means of sleepers and ballast. The depth of ballast should be greater on weak subsoils.

4. Rail movement becomes pronounced after a year or two and is the main cause of maintenance. It is due to the rail moving a little on the sleepers, and the sleepers moving on the ballast. Water gradually gets in alongside the rail, and by "pumping" action sooh destroys the pavement and brings mud up into the ballast. Frost plays a part in breaking up the pavement along the rails, and the vibration of the rail also contributes.

5. Gauge is held fairly definitely by the sleepers.

6. Cushion is provided just the same as in an open ballast track, except that the movement of the rail and sleeper is less owing to the weight of the pavement. The riding qualities are good until the "top" gets pretty bad.

7. Pavement is never laid of a better type than bituminous macadam, because the lifting that is necessary every 4 to 6 years would be made very costly if the pavement were of sheet asphalt, say. In America it is common to pack a track on ballast, and then lay a concrete pavement over the sleepers. This concrete has to be renewed every time the track is lifted, but cement is cheap in America and machinery is used to a larger extent than in this country, so the cost is not as great as it would be here. The track rides a good deal better than one having concrete under the sleepers as well.

8. Joints are welded to give strength and conductifity. Soleplates are now used on all ballast track.

9. Renewals are extremely expensive in this type of track, owing to the fact that the weakness lies in the ballast, which is the most expensive part to get at. Except on very good subsoils or under very light traffic, it is more economical to put down a concrete foundation in the first place.

10. Future alterations can be made easily.

The life of a boxed-in ballast track, with effective sub-drainage, is about 12 to 15 years, but lifting is needed after the first 4 to 6 years, and again at 8 to 10 years, depending on the traffic and the foundation. After 12 or 15 years, the bottom ballast needs renewing, and generally the ashes and drain, but the rails and sleepers should last another 6 years or so. Patching has to be done continually owing to the rail movement, and topdressing is needed generally every 2 years.

CONCRETE FOUNDATIONS.

(a) With Sleepers.

1. Cost about £32,000 per mile D.T. using bituminous macadam paving, or £45,000 using woodblocks.

2. Drainage by means of ashes and "A" type drain.

3. Load is spread over the subsoil by the feinforced concrete base. This is less severe on the subsoil than sleepers and ballast.

4. Rail movement is small, unless the sleepers are packed with a compressible mixture such as bitumen and screenings; even then the movement does not grow to such an extent as in a ballasted track, although in time the rails cut into the sleepers. Coachscrews are used instead of dogspikes, as they do not loosen so easily due to rail vibration.

5. Gauge is looked after by the sleepers, and by tiebars in woodblocked tracks.

6. Cushion is not provided to any extent, although with bituminous packing under the sleepers the track is better riding than one of stringer construction.

7. Pavement of any type can be used, but if anything better than macadam is adopted, the sleepers should be fitted with steel plates under each rail, and concrete should be used as packing. These two precautions will keep down rail movement and so prevent expensive maintenance on the pavement.

8. Rail joints are welded and fitted with soleplates.

9. Renewals are not very costly unless the concrete foundation goes. If the sleepers are not expected to last for the life of the concrete (say 25 to 30 years) the

concrete should be laid in two courses, the bottom course being finished a couple of inches under the sleepers to allow for packing. Then the sleepers can be renewed (or the track lifted to a new top) without taking out the bottom concrete. This scheme also prevents the concrete base from being cracked by expansion of the rails while the concrete is green.

10. Future alterations are fairly easily managed as follows:-

(a) In alignment, by moving rails on sleepers.

(b) Raising, by cutting out top concrete and repacking on the concrete base to the new level.

(c) Lowering for about 4 inches can be done by replacing the sleepers with shallow steel ties requiring only about 3" of packing under the rails.

The life of such a track before renewal of the rails is necessary would be 12 to 15 years, and the sleepers should last even longer if rail movement can be kept down. The foundation should last 25 to 30 years.

Maintenance will consist principally of attention to fastenings so as to keep the rail tight on the sleeper, grinding to remove corrugations, top-dressing every two years or so, and in case of macadam paving there will be patching at frequent intervals as well. If bituminous packing is used, a lift after 4 or 5 years will probably be needed to renew the packing and so keep down patching expense.

Steel and Composite Sleepers. We are now experimenting with sleepers made out of old rails, both with and without a timber cushion.

The all-steel sleeper should give a completely rigid track, and may therefore keep down corrugations to some extent. On the other hand there will be no "give" in such a track, and it will probably be noisier and more severe on the rolling stock when first laid then tracks utilizing timber under the rails. The cost of this type is less than that with stringers or ordinary sleepers.

The composite sleeper aims at greater resiliency than is provided by stringer construction, without the disadvantages of ordinary wooden sleepers. It is the most expensive of all, however.

(b) Stringer Construction.

1. Cost is less than for sleepers in concrete, being £29,000 to £32,000 per mile D.T. if macadam paving is used, and £40,000 to £43,000 per mile D.T. if woodblocks are laid.

2. Subdrainage is by means of a layer of ashes and "A" type drain..

3. The load is spread over the formation by the reinforced concrete base.

4. Rail movement is more than we expected to be the case when this type was first laid. The timber compresses under the rail, and the slight movement thus caused soon loosens the clips and allows more movement. Shrinkage of the timber is also liable to occur, and this loosens the clips also. If water is present, pumping under the rail will take place and the wood will be worn away (a wear of $\frac{3}{8}$" has been measured). The movement, however slight, allows vibration in the rail, and this destroys the bond with the pavement.

5. The anchor bolts and tiebars hold the rails to gauge securely.

6. Cushion is provided to some extent by the stringers, but not as much as expected.

7. Paving may be of any kind, as the rail movement is not so great as to cause heavy maintenance even on a wood-blocked pavement. Probably sheet asphalt would be better laid on a more rigid track.

8. Joints are not as easy to make as in sleeper track, as there is difficulty in fitting a soleplate. Up to the present we have depended on welded fishplates.

9. Renewals of rails are easily done, but renewal of stringers will be fairly difficult. The stringers are dressed on one side so as to be of even thickness; thus when renewals are necessary the new stringers should give a good top without any adzing.

10. Future alterations are practically impossible, either in line or level. In either case the stringers would have to be re-packed after breaking out some of the concrete, and new anchor bolts would have to be put in by drilling holes out of the solid concrete. The old anchor bolts would be cut off with oxy-acetylene.

The life of a stringer track foundation should be 25 to 30 years; rails and stringers would require renewing after 15 or 18 years.

Maintenance: The most important item of maintenance is keeping the rail tight down on the stringer; if allowed to get loose, patching and grinding will be heavy. Unfortunately, the paving has to be removed alongside the rails for the whole length to attend to the fastenings, and this is the principal weakness of the stringer track.

Removal of corrugations by grinding will be necessary every 2 or 3 years on heavy traffic lines, and every 4 or 5 years on others.

G E N E R A L..

Woodblock paving is now laid 3/16" below rail surface for two reasons:

(a) The blocks will not stick up so high when the rail wears down.

(b) The wheels do not ride on the blocks or tip them up, when first laid.

Weepholes are included in all concreted tracks so as to offer a get-away for water that finds its way through the surface. They are spaced not more than 20 ft. apart in each line (eight lines of holes being used in double track) and should be carefully tested before covering them over.

Fastenings. Dogspikes, coachscrews, and anchor bolts should be tightened very carefully so as to prevent rail movement, which is the cause of two thirds of our maintenance cost.
