$$\log m = \bar{5}{\cdot}648927$$

$$\text{Ordinate at } 10' = 0{\cdot}04'$$
$$20' = 0{\cdot}36'$$
$$30' = 1{\cdot}20'$$
$$40' = 2{\cdot}85' = y_c$$

$$\text{Secant, } H\,Q = (R + h - 10) \sec \frac{a}{2} - R_1.$$
$$= 11{\cdot}88'$$

$$\text{Secant, } P\,Q = R_1 + h_1) \sec \left(\frac{a - 2\gamma}{2}\right) - R_1$$
$$= 8{\cdot}54'$$
$$\therefore H\,P = 3{\cdot}34'$$
$$H\,V = \frac{3{\cdot}34 \sin 68^\circ}{\sin 2^\circ} = 88{\cdot}73'$$
$$\text{and } P\,V = \frac{3{\cdot}34 \sin 66^\circ}{\sin 2^\circ} = 87{\cdot}43'$$

$$P\,T = (R_1 + h_1) \tan \left(\frac{a - 2\gamma}{2}\right) + (x_c - x')$$
$$= 59{\cdot}75'$$

$$V\,S = 1{,}500 \tan \frac{\gamma}{2}\ 1{,}500 \tan 1^\circ = 26{\cdot}18' = U\,V$$
$$S\,T = P\,V - (P\,T + V\,S) = 1{\cdot}50'$$
$$\text{Total tangent } (H\,U) = 114{\cdot}91'$$
$$\tfrac{1}{2} \text{ Circular Arc} = R_1 \times \text{arc} \left\{ \left(\frac{a - 2\gamma}{2}\right) - \phi \right\}$$
$$= 17{\cdot}33' \ldots\ldots\ldots\ldots Q\,K$$

Example (4). Fig. 5 shows a curve of large radius with a small deflection angle. Suppose the deflection angle to be 10°. A suitable radius to adopt is 500 feet. Take this for the inner curve. The track centres should be 10·3 feet apart; an outer radius of 510 3 feet, therefore, will suit the case, and give concentric curves. The outer curve need not be transitioned; but a transition curve having a value of $h = 0{\cdot}30'$ will give the necessary clearance to the inner curve.

Since $h = 0{\cdot}30$,

$$\frac{h}{R} = \frac{0{\cdot}30}{500} = {\cdot}0006$$

The nearest value of h in the Table is

·000599

and the corresponding value of $\frac{x_c}{R}$ is 0·12

This will give a transition of 60 feet, the details of which together with the other dimensions of the curve may be readily calculated as in previous examples.

Some tables of dimensions usually adhered to in laying out tramway curves are appended; and the writer hopes the information contained in them may be useful to the reader.

With regard to the table of Compensations for Curvature, the rate of compensation is calculated from the formula—

$$S = \cdot 5 + \cdot 025\,(D^{\circ} - 10^{\circ})$$

where D° = degree of curve (*i.e.*, the central angle subtended by a chord of 100 feet).

The transition should be compensated for gradually, from zero to a maximum where it merges into the circular arc; but in practice an approximate average is computed in the following manner :—

In Fig. 1 the radius is 80 feet and the transition 40 feet.

The transition angle, ϕ, is 15° 38′ 24·5″.

The degree of curve of the transition is taken as equivalent to

$$\frac{15^{\circ}\ 38'\ 24{\cdot}5'' \times 100}{40} = 39^{\circ}\ 06'\ 00''.$$

On a ruling grade of 1 in 15, the compensated grade for this transition becomes 1 in 18½, and for the circular arc 1 in 22½, as may be seen by reference to the table.

Gauges, Grooves, Super-Elevation and Distance between Tracks on Tramway Curves.

Radius	Girder Rail		T Rail			Distance between Centres for Double Track.	Super-elevation 12 Miles per Hour	
	Weight	Gauge of Road.	Weight.	Gauge of Road.	Width of Groove		Old Table.	* New Table.
feet				ft. in.	in.	ft. in.	in.	in.
50	Girder Rails not to be used under 100 ft. Rad.		80 & 60 lb. / 80 & 80 lb. / or / 60 & 60 lb.	4 9⅜	1 11/16	12 10	4½	2
55				4 9 5/16	1⅝	12 8	”	1 13/16
60				4 9¼	1 9/16	12 4	”	1 11/16
66			”	4 9 3/16	1½	12 2	”	1½
70			”	4 9⅛	1 7/16	12 0	”	1 7/16
75			”	4 9⅛	1 7/16	11 11	”	1 5/16
80			”	4 9 1/16	1⅜	11 10	”	1¼
85			”	4 9 1/16	1⅜	11 9	”	1 3/16
90			”	4 9	1 5/16	11 8	”	1⅛
100	109 lb	4′ 8 15/16″	”	4 8 15/16	1¼	11 6	”	1
110	”	”	”	4 8⅞	1 3/16	11 6	”	⅞
120	”	”	”	4 8⅞	1 3/16	11 2	”	13/16
132	”	”	”	4 8 13/16	1⅛	11 1	4	¾
150	”	”	”	4 8 13/16	1⅛	11 0	”	11/16
165	”	”	”	4 8¾	1 1/16	11 0	”	⅝
180	”	”	”	4 8¾	1 1/16	11 0	”	9/16
198	”	”	”	4 8¾	1 1/16	10 10	2¾	½
chains								
3½	”	”	”	4 8 11/16	1	10 9	”	7/16
4	”	”	”	4 8 11/16	1	10 8	2⅛	⅜
4½	100 lb	4′ 8 9/16″	”	4 8⅝	15/16	10 7	”	5/16
5	”	”	”	4 8⅝	15/16	10 6	1⅝	5/16
5½	”	”	”	4 8⅝	15/16	10 5	”	¼
6	”	”	”	4 8⅝	15/16	10 4	1⅜	¼
6½	”	”	”	4 8⅝	15/16	10 4	”	¼
7	”	”	”	4 8 9/16	⅞	10 4	”	3/16
8	”	”	”	4 8 9/16	⅞	10 2	1⅛	3/16

* New Table to be used except where greater elevation would meet the contour, or through reserves, where old table will apply.

[The table on opposite page was adopted by the Dept. of Public Works, on March 18th, 1911, and is inserted here in place of that given by Mr. Try.]

COMPENSATION FOR CURVATURE ON RULING GRADE OF 1 IN 15.

Radius.	Degree of Curve.			Rate of Compensation. %.	Grade. %.	——
	°	′	″			
Straight	0	00	00	·00	6·66	1 in 15
5 chains	17	30	00	·69	5·97	1 in 16¾
4 ,,	22	00	00	·80	5·86	1 in 17
3½ ,,	25	00	00	·87	5·79	1 in 17¼
3 ,,	29	15	00	·98	5·68	1 in 17¾
2½ ,,	35	15	00	1·13	5·53	1 in 18
2 ,,	44	30	00	1·36	5·30	1 in 19
115 feet	51	30	00	1·54	5·12	1 in 19½
100 ,,	60	00	00	1·75	4·91	1 in 20½
90 ,,	67	30	00	1·94	4·72	1 in 21¼
80 ,,	77	30	00	2·19	4·47	1 in 22½
70 ,,	91	15	00	2·53	4·13	1 in 24¼
66 ,,	98	30	00	2·71	3·95	1 in 25¼

APPENDIX B.

TRAMWAY SURVEYS.

Paper read at a Meeting of the Institution oj Surveyors, N.S.W., on Tuesday, September 21st, 1909.

By Thomas Kennedy, Assoc. M. Inst. C.E.

The tramway system of Sydney and suburbs has become a huge concern, and is rapidly increasing. On the 30th of June, 1909, the street miles of tramway amounted to 118 miles 75 chains; this embraced 185 miles 11 chains of single track tramway. In the country there are 32 miles 29 chains of street miles of tramway totalling 35 miles 35 chains of single track tramway; the sidings, loops and cross-overs amount to 34 miles 32 chains.

It will be seen by the above figures that the surveying and setting out of these tramways involves a considerable amount of work for the surveyor requiring technical skill. It is proposed to describe the methods adopted in the location and surveying of the different lines. Mr. Try, of the Works Department, has in his paper contributed a collection of valuable information, which will prove useful to the surveyors who have to deal with tramway surveys. The subject is practically a new one, and the information obtainable is limited.

The first inception of a tramway is that a suburb or town finds that a tramway is necessary. It will either be a new tramway isolated like the Arncliffe to Bexley, and Manly to Curl Curl, or perhaps the extension of an existing line. A deputation is formed and the Minister for Works is approached, he is urged to grant the proposed request. If satisfactory, the matter is investigated by a responsible officer, and say a survey recommended so that an estimate can be prepared. This survey is a trial line or preliminary, and when there is no difficulty as to grades, a set of levels are taken down the centre of the streets, noting any sharp angles that would require resumption of property, a section is plotted and an estimate made. In cases where the grades are difficult the location is by no means easy, and the skill of the surveyor is at once taxed to find the best line; the steepest grade allowed is 1 in 15 and the sharpest curve 70 feet radius. So that with the steep grade and sharp curve a great many problems may be worked out before a final location is decided upon.

The system adopted by the writer is to take at first no notice of streets or property, but to look on the locality where a difficult tram is proposed as one devoid of houses and streets, and so to locate a line with the ruling grade and minimum curves in the most suitable place. It is usually found that this first location will not be far from the final line adopted; the question of avoiding resumption and making use of the existing roadway then become matters of detail. In the location of the tramway from the Lighthouse to Watson's Bay, and on the descent of the Spit to Manly tramway into Manly, it was found that the location favoured a route through the parks in each instance, and no objection was raised by the residents as it meant either a sacrifice of portion of the park or the tramway would not be built. In difficult places it is advisable to locate from contours and the tacheometer is found expeditious in getting the information, as the obstacles to chaining and levelling would greatly retard the ordinary method of taking cross sections. The compensation for curvature must be allowed for in the preliminary location, although it is finally adjusted in the permanent survey of the line. The formula in use is $\cdot 5 + \cdot 025 (D^{\circ} - 10^{\circ})$ when D° equals the degree of curve. A table has been supplied by Mr. Try shewing the compensation adopted for different curves. *The scales* of the preliminary plans and sections are usually 2 chains to 1 inch for the plan, and 2 chains to 1 inch horizontal and 20 feet to 1 inch vertical for the section.

When resumption of land is necessary and buildings to be avoided the detail survey is made use of. These detail sheets shewing an accurate survey of the building and streets have proved valuable in the location of tramways and other public works round the city: unless they are revised and kept up to date it will only be a matter of a few years when they will become obsolete. The azimuth of the tramway survey when possible is referred to the trigonometrical meridian.

After the preliminary surveys have been completed an estimate is made, and if the cost of the tramway is under £20,000 it is then only a matter for the Cabinet to decide on its construction, but if over that amount the line must be submitted to the Public Works Committee, and if approved, be finally passed by both Houses of Parliament.

After a tramway is authorised the permanent survey is commenced. The curves are all accurately set ont; the method of calculating the curves both of a single and double line has been described by Mr. Try. A single line presents very little difficulty, but with a double set of rails provision has to be made for clearance of tracks as describedin the former paper. Iron spikes are used in the metal road and wooden pegs through vacant land. All the pegs are preserved during construction, and no further setting out is required. An inspector takes precaution to reference all pegs so that they can be replaced, to finally set the rail centres in the proper position to give the required clearance when passing round corners. Levels and cross sections are taken at each chain, and where streets are crossed a longitudinal section is taken along the cross street for 3 chains on each side of the tramway. All pipes, gas, sewers, manholes, water supply, lamp posts, telephone poles, and any obstructions have to be shewn in detail on the finished plan; this is necessary, so that the poles to carry the overhead wiring may be fixed not to interfere with anything on the street. The permanent section is plotted to a scale of 10 feet to 1 inch horizontal and 10 feet to 1 inch vertical. Detail drawings are made of all curves on the double line to a scale of 10 feet to 1 inch shewing all dimensions. After the curves have been set out for a double line it is then necessary to mark a line midway between them for purposes of taking a longitudinal section and cross section, also to obtain the exact length of line. The chainage of the curve commences at the mean tangent on the centre of a line, joining the tangent points of the inner and outer curves, and ends at the centre of the mean tangent point at the ends of the curves; the distance adopted for the chainage being a mean of the total lengths of the inner and outer curves. The circular arcs of the curves are set out from the secant point, and the arc is usually divided into a number of short chords.

A simple method of setting out these curves is to divide the arc and half the central angle subtended by the same suitable number, then the distances and tangential angles are at once available for setting out the curves without any further calculation. The chord is taken at such a length so that the difference between chord and arc will not be appreciable in chaining round the curve. As an example, in a curve of 100 feet radius it is found that the circular area is, say, 78·48 feet and the central angle is 44° 58′. The length of chord used would be 78·48 divided by 9 = 8·72 feet, half the central angle = 22° 29′, this divided by 9 equals practically 2° 30′; this is the tangential angle for the length 8·72 feet.

It will be seen that the chord of an angle of 5° for radius 100 equal 8·72, that is the chord and arc are practically equal; by adopting this method of setting out the curving a complete check on the whole of the calculation is made, for the circular curves must close on the transition points. To approximately indicate the position of the pegs in the roadway, lines are squared off by the eye and a painted mark made on each side of the roadway shewing tangent points and chain pegs; the chain pegs are numbered on the edge of the kerb or fence, the tangent points are marked by three pegs at right angles to the line, transition points by three pegs along the direction of the tramway; all other points are single pegs. Round-headed spikes are used weighing about 2½ to the lb., 4 inches long, ¾ inch thick; these are readily driven into the metalled road and the exact centre marked with a punch. Bench marks are left at least every half mile, and levels are referred to standard datum or mean sea level.

APPENDIX C.

TRANSITION CURVE TABLE.

(Compiled by Mr. C. J. Merfield.)

From "Journal of the Royal Society of N.S.W.," vol. xxxiv.

$\frac{x_c}{R}$	ϕ °	ϕ ′	ϕ ″	Log. (mR^2)	$\frac{x'}{R}$	$\frac{y_c}{R}$	$\frac{h}{R}$	$\frac{s}{R}$	$\frac{K}{R} = \frac{2\phi}{R}$
0·00	0	0	0·0	· ∞	0·000000	0·000000	0·000000	0·000000	0·000000
0·01	0	17	11·3	1·221855	0·005000	0·000017	0·000004	0·010000	0·010001
0·02	0	34	22·9	0·920878	0·010001	0·000067	0·000017	0·020000	0·020002
0·03	0	51	34·8	0·744872	0·015003	0·000150	0·000038	0·030001	0·030008
0·04	1	8	47·2	0·620049	0·020008	0·000267	0·000067	0·040002	0·040019
0·05	1	26	0·4	0·523287	0·025016	0·000417	0·000104	0·050004	0·050037
0·06	1	43	14·5	0·444376	0·030027	0·000601	0·000150	0·060006	0·060063
0·07	2	0	29·6	0·377552	0·035043	0·000818	0·000204	0·070009	0·070100
0·08	2	17	46·1	0·319806	0·040064	0·001069	0·000266	0·080013	0·080150
0·09	2	35	4·0	0·268932	0·045092	0·001354	0·000337	0·090018	0·090214
0·10	2	52	23·6	0·223487	0·050126	0·001673	0·000416	0·100025	0·100294
0·11	3	9	45·0	0·182442	0·055168	0·002026	0·000503	0·110034	0·110392
0·12	3	27	8·5	0·145034	0·060218	0·002413	0·000599	0·120044	0·120510
0·13	3	44	34·2	0·110687	0·065278	0·002835	0·000703	0·130056	0·130650
0·14	4	2	2·4	0·078953	0·070348	0·003291	0·000814	0·140070	0·140813
0·15	4	19	33·2	0·049474	0·075429	0·003782	0·000933	0·150086	0·151002
0·16	4	37	6·9	0·021966	0·080522	0·004308	0·001061	0·160104	0·161219
0·17	4	54	43·7	9·996194	0·085628	0·004870	0·001197	0·170125	0·171465
0·18	5	12	23·7	9·971962	0·090747	0·005467	0·001341	0·180149	0·181744
0·19	5	30	7·4	9·949111	0·095881	0·006100	0·001493	0·190176	0·192058
0·20	5	47	54·8	9·927502	0·101031	0·006770	0·001653	0·200206	0·202408
0·21	6	5	46·2	9·907018	0·106198	0·007476	0·001821	0·210239	0·212797
0·22	6	23	41·9	9·887559	0·111382	0·008219	0·001997	0·220276	0·223227
0·23	6	41	42·1	9·869036	0·116585	0·009000	0·002181	0·230317	0·233701
0·24	6	59	47·1	9·851375	0·121808	0·009818	0·002372	0·240361	0·244221
0·25	7	17	57·2	9·834510	0·127051	0·010674	0·002571	0·250409	0·254790
0·26	7	36	12·5	9·818382	0·132317	0·011569	0·002777	0·260462	0·265411
0·27	7	54	33·6	9·802939	0·137606	0·012503	0·002991	0·270520	0·276087
0·28	8	13	0·5	9·788135	0·142919	0·013477	0·003212	0·280582	0·286820
0·29	8	31	33·8	9·773930	0·148258	0·014491	0·003440	0·290650	0·297614
0·30	8	50	13·6	9·760287	0·153625	0·015547	0·003676	0·300723	0·308473
0·31	9	9	0·4	9·747173	0·159021	0·016644	0·003919	0·310802	0·319399
0·32	9	27	54·4	9·734558	0·164447	0·017783	0·004169	0·320886	0·330395
0·33	9	46	56·2	9·722417	0·169905	0·018965	0·004426	0·330977	0·341466
0·34	10	6	6·1	9·710725	0·175396	0·020191	0·004689	0·341074	0·352616
0·35	10	25	24·5	9·699461	0·180922	0·021462	0·004959	0·351179	0·363848
0·36	10	44	51·9	9·688605	0·186485	0·022778	0·005236	0·361291	0·375167
0·37	11	4	28·7	9·678139	0·192087	0·024140	0·005519	0·371410	0·386578
0·38	11	24	15·5	9·668046	0·197730	0·025550	0·005807	0·381538	0·398085
0·39	11	44	12·7	9·658313	0·203417	0·027009	0·006101	0·391674	0·409693

Transition Curve Table—*Continued.*

$\frac{x_c}{R}$	ϕ °	′	″	Log (mR^2)	$\frac{x'}{R}$	$\frac{y_c}{R}$	$\frac{h}{R}$	$\frac{s}{R}$	$\frac{K}{R}=\frac{2\phi}{R}$
0·40	12	4	20·9	9·648927	0·209149	0·028517	0·006401	0·401818	0·421408
0·41	12	24	40·8	9·639875	0·214928	0·030077	0·006706	0·411972	0·433237
0·42	12	45	13·0	9·631147	0·220758	0·031688	0·007016	0·422137	0·445185
0·43	13	5	58·0	9·622733	0·226642	0·033353	0·007331	0·432312	0·457257
0·44	13	26	56·8	9·614624	0·232581	0·035074	0·007651	0·442497	0·469462
0·45	13	48	9·9	9·606814	0·238580	0·036851	0·007974	0·452694	0·481807
0·46	14	9	38·4	9·599295	0·244642	0·038687	0·008301	0·462903	0·494301
0·47	14	31	23·1	9·592062	0·250770	0·040583	0·008631	0·473125	0·506951
0·48	14	53	24·9	9·585110	0·256968	0·042543	0·008963	0·483361	0·519768
0·49	15	15	45·0	9·578435	0·263242	0·044568	0·009298	0·493612	0·532762
0·50	15	38	24·5	9·572035	0·269595	0·046660	0·009634	0·503878	0·545944
0·51	16	1	24·7	9·565907	0·276032	0·048822	0·009970	0·514160	0·559326
0·52	16	24	46·9	9·560051	0·282560	0·051058	0·010307	0·524460	0·572923
0·53	16	48	32·8	9·554465	0·289184	0·053370	0·010643	0·534778	0·586748
0·54	17	12	43·8	9·549151	0·295911	0·055761	0·010976	0·545116	0·600818
0·55	17	37	22·1	9·544112	0·302749	0·058236	0·011306	0·555475	0·615152
0·56	18	2	29·6	9·539349	0·309706	0·060801	0·011633	0·565857	0·629769
0·57	18	28	8·6	9·534869	0·316792	0·063459	0·011954	0·576264	0·644692
0·58	18	54	21·9	9·530677	0·324018	0·066216	0·012267	0·586698	0·659947
0·59	19	21	12·4	9·526782	0·331395	0·069078	0·012570	0·597160	0·675563
0·60	19	48	43·5	9·523193	0·338937	0·072052	0·012861	0·607654	0·691572
0·61	20	16	59·2	9·519923	0·346659	0·075147	0·013138	0·618182	0·708014
0·62	20	46	4·0	9·516917	0·354581	0·078372	0·013397	0·628748	0·724932
0·63	21	16	3·1	9·514405	0·362723	0·081738	0·013635	0·639355	0·742376
0·64	21	47	2·9	9·512199	0·371111	0·085259	0·013847	0·650009	0·760409
0·65	22	19	11·0	9·510399	0·379774	0·088949	0·014028	0·660715	0·779105
0·66	22	52	36·5	9·509041	0·388751	0·092827	0·014170	0·671479	0·798551
0·67	23	27	30·8	9·508171	0·398085	0·096916	0·014265	0·682310	0·818858
0·68	24	4	8·0	9·507848	0·407835	0·101245	0·014301	0·693219	0·840163