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A survey of UK tram and light railway systems relating to the wheel/rail interface

FE/04/14

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EXECUTIVE SUMMARY

Unlike the British railway network, the modern UK tram and light rail systems have been designed and constructed without the benefit of any national standards or guidance. In an endeavour to promote the formulation of these HM Railway Inspectorate is supporting a programme of research focused on defining best practice in relation to the safety aspects of the wheel/rail interface.

This report contains the findings from the first phase of this project that set out to survey information relevant to the wheel/rail interface for all UK tram and light rail systems.

The collection of this information would not have been possible without the willing assistance of the many people associated with the operation and maintenance of Britain's varied Light Rail Transit systems.

Besides detail information relevant to each of the nine systems investigated, the report contains many tables summarising the data considered germane to the wheel/rail interface. Also included is a comprehensive set of drawings for the rail and wheel tread profiles currently in use as is a summary of general observations made throughout the work. The report highlights a number of areas of concern relating to UK practice in which wheels with square flange tips (which were developed for flange tip running through crossings) interact adversely with small radius turnouts constructed from flat bottom rail.

Systems such as the Tyne & Wear Metro have developed directly from heavy rail practice. However, the majority have not developed in such a way and have been found to have greater wheel spacings (back-to-back measurement) which significantly affects the design of switches and crossings.

1 INTRODUCTION

As the first generation of UK trams virtually disappeared in the 1960s much of the associated knowledge base went with them. So in the development of the new systems there has been limited past experience upon which to draw. Also, with the demise of the UK railway rolling stock industry the vehicles for most of the modern systems have been constructed on the continent to European practice. Unlike the national railway network that is constructed, maintained and operated according to UK Group Standards, the modern UK tram and light railway systems have developed piecemeal. Each system appears to have been built without the benefits of standardisation or interoperability, with all the attendant maintenance and financial implications.

To bring together all those with a direct interest in UK tram and light rail systems HM Railway Inspectorate (HMRI) hosted a seminar in early October 2003. This saw strong support from the industry. The purpose of the meeting was to outline an HMRI funded project intended to address some of the safety related aspects of the wheel/rail interface and to enlist the help of delegates in the collection of relevant information. The ultimate objective of this project is to encourage the setting of standards and developing guides to good practice relevant to UK systems. This survey of wheel and rail related information for each of the main UK undertakings was seen as the essential first step that would guide subsequent project phases and provide a suitable database.

The main features of the brief for this survey were:

- The collection of information concerning wheel profiles, rail section profiles and switch rails as used on the systems at Birmingham, Blackpool, Croydon, Docklands, Manchester, Nottingham, Sheffield, Tyne & Wear and The National Tramway Museum.
- To collect information concerning systems operation with particular reference to derailments, potential to wheel flange climb, wheel wear and the success of modifications.
- Information to be gathered through meetings, correspondence and by searching the literature.
- Provide some insight into European practice and standards.
- Analyse and present the information collected.

Upon starting out Andy Steel (then General Manager of Travel Midland Metro the operators of the Midland Metro system) and Joe Brown (Parsons Brinkerhoff/Permanent Way Institution) assisted in setting the scope of the survey. This was followed by contact and meeting those involved in the day-to-day operation of systems. Without their willing assistance this work would not have been possible.

A further seminar hosted by HMRI, was held in late October 2004 at which provisional findings from the survey were presented. This event again saw strong support from the industry.

The report has been arranged such that each system examined is the subject of a chapter. These can be found in Chapters 2 to 10. Information concerning European practice is collected together in Chapter 11. An attempt has then been made in constructing comparative tables in Chapter 12 which summarise the data collected. Observations made during the course of the study are presented in Chapter 13. The appendices of Chapter 14 contain drawings which show the rail and wheel tread profiles that are, or have been tried, on the systems. Finally the References and Bibliography of Chapters 15 and 16 give details of information sources, and an attempt has been made to construct a glossary of common tram and light railway terminology in Chapter 17.

2 BLACKPOOL AND FLEETWOOD TRAMWAY

2.1 INTRODUCTION

The tram system at Blackpool is the oldest in the UK, having started operation in 1885 along the Promenade. It is now a municipally owned company that is operated by Blackpool Transport Services Ltd. The system extends for a distance of 18km along the Lancashire coast, from Fleetwood in the north to Starr Gate in the south.

Blackpool Borough Council have responsibility for the track and Blackpool Transport Ltd maintain and run the tram service.

The system is now in need of upgrading and developing to reflect changes in legislation and inshore residential developments. To address these issues Blackpool Borough and Lancashire County Councils commissioned the consultants Steer Davies to examine options for upgrading and developing the tramway. Following initial work by the TAS Partnership a plan was submitted to the government in July 2001.

This plan set out a three-phase development. The first phase, requiring no legislation, proposes upgrading the existing line to facilitate reduced journey times, and the introduction of modern or modernised rolling stock with low floors. The ability to offer a heritage service would be retained. The second phase envisages a short loop to connect with Blackpool North railway station, and a link from the centre of Blackpool, initially on former railway trackbed, to Lytham via the airport and St Anne's. A new extensive loop line connecting Broadwater on the existing line with Thornton, Poulton and Blackpool North station comprises the phase three proposal. The second and third phases will require new legislation. Proposals for a £170m upgrade are currently on hold following their rejection by the Government in July 2004. The two authorities are now preparing a new submission to meet a request for reduced financial risk, reduced government funding and better value for money.

2.2 SYSTEM DETAILS

Schematic route map: See Figure 2.1.

Route distances:

In total there are just under 18km of mainly double track that runs from Starr Gate, on the Lytham St. Anne's boundary in the south, to Fleetwood in the north. For most of the route the tramway has its own reserved tracks, as shown in Figure 2.2 and 2.3. There is a small amount of street running in the vicinity of the North Pier tram stop (see Figure 2.4) and 1.6km in Fleetwood from Ash Street to the Ferry loop. There is a loop at each end of the line, so trams are driven from the same end throughout their period in service.

There is a double track loop at Pleasure Beach, and a single-track loop at Little Bispham, which can be used to turn vehicles. There are passing loops at Tower, North Pier, Cabin, Bispham, Thornton Gate and at the Ferry. There are also a number of cross-overs and turnbacks throughout the system.

Route details are given in Table 2.1 below.

Table 2.1 Blackpool and Fleetwood tramway route details

From	*To*	*Distance (km)*[1]	*Track*[2]
Starr Gate	Harrowside	0.80	Single (loop)/0.28km ballasted Double/0.52km grooved rail
Harrowside	Pleasure Beach	1.13	Double/grooved rail
Pleasure Beach	South Pier	0.32	Double/grooved rail
South Pier	Rigby Road	1.29	Double/grooved rail
Rigby Road	Foxhall	0.16	Double/grooved rail
Foxhall	Tower	0.80	Double/grooved rail
Tower	Talbot Square	0.32	Double/grooved rail
Talbot Square	Pleasant Street	0.64	Double/grooved rail
Pleasant Street	Gynn Square	0.97	Double/grooved rail
Gynn Square	Cabin	0.48	Double/grooved rail
Cabin	Bispham	1.29	Double/1.06km ballasted Double/0.23km grooved rail
Bispham	Norbreck	0.80	Double/1.58km ballasted Double/0.19km grooved rail
Norbreck	Little Bispham	0.97	
Little Bispham	Cleveleys	1.45	Double/1.37km ballasted Double/0.08km grooved rail
Cleveleys	Thornton Gate	0.64	Double/0.36km ballasted Double/0.28km grooved rail
Thornton Gate	Rossall Lane	1.45	Double/4.18km ballasted Double/1.14km grooved rail
Rossall Lane	Broadwater	0.97	
Broadwater	Stanley Road	1.45	
Stanley Road	Ash Street	0.48	
Ash Street	Kent Street	0.97	
Kent Street	Pharos Street		
Pharos Street	Fleetwood Ferry	0.48	Single (loop)/grooved rail
Rigby Road	Rigby Road Depot	0.32	Double & Single/grooved rail

Notes:

[1] Based on mileage table (to nearest 0.1 mile)
[2] Partial distances estimated from a rail length inventory

Power supply:

Overhead line equipment supplies trams with power at a nominal voltage of 550Vdc.

There are eight sub-stations, taking their supply at 6.6kV from Norweb, as listed in Table 2.2.

Table 2.2 Location of Blackpool and Fleetwood tramway electrical sub-stations

Distance (km)[1]	***Location***
1.9	Pleasure Beach
3.9	Rigby Road Depot
5.3	Metropole
6.4	Gynn Square
8.2	Bispham
10.0	Little Bispham
12.1	Thornton Gate
15.9	Copse Road

Notes:
[1] Approximate distances from Starr Gate

Tunnels:

There are no tunnels on the system.

Passenger Service Vehicles

There is a total vehicle fleet of 80, many of which are ‘heritage’ units. For the timetabled services the fleet of eight Centenary Class single decker one man operated vehicles together with two one man operated “Balloon” double deckers are used. For the summer timetable 12 vehicles are required, and 7 for winter. In summer up to 40 vehicles may be required to run extra services over the centre part of the route.

Journeys per route:

Winter Timetable (from November):

Monday to Friday there is a service frequency of 20 minutes both ways with daytime services starting from Fleetwood Ferry and Starr Gate at 06:32hrs and 07:22hrs respectively until 18:00hrs. The Evening service from 18:00hrs has a 30 minute frequency until the last full service run leaves Fleetwood Ferry and Starr Gate at 22:590hrs and 23:30hrs respectively.

The Saturday service between Pleasure Beach and Cleveleys is more intensive with a 10-minute daytime frequency.
The Sunday service starts from Fleetwood Ferry and Starr Gate at 07:02hrs and 8:12hrs respectively, and operates with the Monday to Friday frequency until 18:00hrs.

Summer Timetable (from July):

Monday to Saturday there is a service frequency of 10 minutes Starr Gate to Fleetwood and a 10 minute Starr Gate to Cleveleys which gives a 5 minute frequency from Pleasure Beach to Cleveleys. The first service from Fleetwood is at 06:27hrs, and from Starr Gate at 07:19hrs.The last service from Fleetwood Ferry is at 23:07hrs and Starr Gate at 23:19hrs.

The Sunday full service starts from Fleetwood Ferry and Starr Gate at 07:07hrs and 07:59hrs respectively, and then operates as the Monday to Friday frequency and times.

<u>Tram stops:</u>

The service vehicles call at stops by request, except for Starr Gate, Pleasure Beach, Manchester Square, North Pier, Bispham, Cleveleys, Thornton Gate, Broadwater and Fleetwood Ferry at which stops are made to meet service timings.

There are a total of sixty tram stops.

2.3 TRACKWORK

2.3.1 Plain track

<u>Grooved track (street running):</u>

The grooved rail used throughout the system is Ri 60 (see Appendix 4 for profile).

Corus manufactured the rail in France and Austria, which was supplied in 18m lengths.

The rail has been laid by continuously welding three 18m lengths and then fastening to the next similar length by fishplates. The rail is secured to maritime pine sleepers by rail spikes either side of the rail section (four spikes per sleeper). There are 22 sleepers per 18m rail length. The softwood sleepers are 130mm deep x 250mm wide x 2.5m long. The rail spikes measure 127mm long x 16mm square. Tie bars are installed every 2.245m.

The sleepers are laid on a 150 to 250mm deep base of 40mm single sized limestone, with 14mm single sized limestone packing ballast between sleepers. A sand and stone infill provides a base for a concrete flag topping level with the rail head. A cross-section through the trackbed typical of that used on the Promenade is shown in Figure 2.5. A section of such track, without infill, is shown in Figure 2.6.

For street running track, as shown in Figure 2.4, including all but one level crossing, the method of track construction is illustrated in Figure 2.7. This consists of a 0.2m thick concrete foundation slab upon which a 25mm thick layer of tar and chipping mix is laid beneath the position of the rails. The grooved rail welded and fishplated as described above, held to gauge by tie bars, sits on the tar and chipping layer. A cement compound infill of about 0.1m thickness is used to build up the surface between and around the rails, securing the tie bars. A layer of coarse asphalt topped by a finishing asphalt layer provides the road surface level with the railhead and keeper flange.[1]

There are no fixed lubrication systems associated with grooved rails.

Drain boxes, an example of which is shown in Figure 2.2(b), provide drainage. Pairs of boxes are connected prior to emptying into the street drains. Originally they drained directly into the sea.

Grooved track (design) dimensions are given in Table 2.3:

Table 2.3 Blackpool and Fleetwood tramway nominal grooved track dimensions

Gauge (straight track)	1435mm
Gauge (curved track)	Up to 1445mm
Rail inclination	Vertical
Minimum track radius	18.3m
Maximum track cant	Zero
Maximum track gradient	(Gynn Square) 2.5%
Rail running surface relative to road	Level
Wear tolerance of keeper flange	Visual inspection

<u>Ballasted track:</u>

Rail types - Bull head BS 95RBH is used for the majority of ballasted track (profile as shown in Appendix 8)
- BS 113A flat bottom rail (profile as Appendix 12) is now being introduced (4km since 2001)

Corus supplied the rail in 18.3m lengths.

For bull head track the method of construction is illustrated in Figure 2.8. The rail has been laid by continuously welding three 18.3m lengths and then fastening to the next similar length by fishplates. The rail is secured to maritime pine sleepers by cast steel chairs of type S1 (two chairs per sleeper). There are 23 sleepers per 18.3m rail length. The softwood sleepers are 130mm deep x 250mm wide x 2.5m long. The chairs are secured to the sleepers by galvanised chair screws 162mm long x 25mm diameter and plastic ferrules, three per chair[2]. Spring steel keys are used to secure the bull head rail in the chairs. Special chairs manufactured by Horwich Castings are used on curves where check rails are required, the flangeway being 35mm. There is one level crossing in which bull head rail is used with check rails to act as a keeper rails.

[1] The 'keeper flange' or 'keeper rail' is the part of a grooved rail that forms the groove adjacent to the running face. Its purpose is to hold back any surfacing within the four-foot so that a flangeway is maintained (see Figure 2.7).
[2] See BS 4521: Part 1: Section 1.1: 1971

The track construction with BS 113A flat bottom rail also uses three 18.3m continuously welded rails lengths fastened by fishplates to similar continuously welded rail sections. On straight track sections the rail is secured to concrete sleepers by Pandrol clips. On curves the timber sleepers are used with plates and Pandrol clips so that the gauge can be widened.

The sleepers are laid on a 150 to 250mm deep base of 40mm single sized limestone placed on a geotextile layer, with 14mm single sized limestone packing ballast between sleepers. There is a 1.37m spacing, between outer rail heads, of double track running lines.

Grease is manually applied to the rails of tight curves, such as those at Starr Gate.

The drainage of bull head tracks is taken to the sea or soakaways. The drains of the more recent flat bottom track are connected to the main sewers

The nominal plain ballasted track (design) dimensions are given in Table 2.4.

Table 2.4 Blackpool and Fleetwood tramway plain ballasted track dimensions

Gauge (straight track)	1435mm
Gauge (curved track)	Up to 1445mm
Rail inclination	1 in 20
Minimum track radius	Starr Gate loop 18.3m

2.3.2 Switches & Crossings

Grooved track (street running):

The system is equipped throughout (except for one bull head rail unit) with flange tip running turnouts as shown in Figure 2.9. Edgar Allen Engineering Ltd., Sheffield, supplied these to drawing No. C33040 (06.12.71) using Ri 60 grooved rail. The cast point units are 3.66m long and incorporate removable pivoted blades (tongues) of 2.46m length that are pivoted at the heel, as shown in Figure 2.10(a). The blades are connected 0.96m from the toe, the rod and spring return being housed in a connecting box. An example of a flange tip running crossing is shown in Figure 2.10(b).

The method of construction for all turnouts throughout the system is the same as that for street running plain grooved track shown in Figure 2.7 using timber sleepers, rail spikes and tie bars, except that the asphalt layers are replaced by concrete.

Wear to the top and bottom of the switch rails is countered by adding a liner to the seating. The crossing noses are repaired by welding each year.

There are 0.10m diameter drainage holes at the connecting box and heel positions each side, and a 0.08m diameter drain nozzle in the centre of the connecting box.

The nominal grooved turnout (design) dimensions are given in Table 2.5.

Table 2.5 Blackpool and Fleetwood tramway grooved turnout dimensions

Gauge	1435mm
Radius	(1 in 6) 45.7m
Switch rail type	Pivoted at heel
Flangeway	(For length of switch rail) 38.1mm
Switch opening	Matches rail groove
Flange tip running	All turnouts and diamond crossings

Ballasted track:

One set of turnouts constructed from BS 95RBH rail (see Appendix 8 for profile) is located at Thornton Gate tram stop, giving access to a permanent way yard. Service vehicles approach them in the trailing direction. They are constructed in a similar way to plain bull head track illustrated in Figure 2.8, with the special chairs for check rails, as used for check rails on plain track. They are of A4 design with the switch rails to BR Specification 1211.

Table 2.6 Blackpool and Fleetwood tramway plain ballasted turnout dimensions

Gauge	1435mm
Radius	A4
Switch rail type	Flexible
Check rail flangeway gap	35mm
Additional sleeper bracing to maintain alignment	Not used

2.3.3 Switch operation

All turnouts are operated manually. Drivers are required to visually confirm the setting of facing turnouts.

Switch mechanisms are inspected and cleaned weekly.

2.3.4 Track maintenance

There is no ultrasonic rail inspection.

Corrosion is found in the lower part of the web and flange of grooved rail used on the Promenade that is exposed to sea water.

2.4 VEHICLES

Centenary class tramcars:

Single decker Centenary class one man operated trams are used for the majority of timetabled service running. These were built in the period 1984 to 1987. The bodies were typical of the conventional bus construction methods then prevailing, and were supplied by East Lancashire Coachbuilders Ltd. The external appearance of these vehicles is shown in Figures 2.12. The bogie design is shown in Figure 2.11.

The vehicle passenger capacity is 55 seated and 20 standing.

Centenary class leading dimensions: See Table 2.7.

Table 2.7 Blackpool and Fleetwood tramway Centenary class dimensions

Overall length	15.700m
Length over body	15.240m
Body shell width	2.438m
Floor height above head of rail	926mm
Distance between bogie centres	8.125m
Bogie axle spacing	1.660m
Wheel diameter	686mm

Centenary class vehicle weights:

Tare weight = 17.5t

"Balloon" double decker tramcars:

English Electric built these tramcars from 1934 to 1935, and some of them were produced originally with open tops, though only one vehicle is now in this condition. The external appearance of these vehicles is shown in Figures 2.13 & 2.14.

The vehicle seated passenger capacity is 94.

"Balloon" double decker leading dimensions: See Table 2.8.

Table 2.8 Blackpool and Fleetwood tramway "Balloon" double decker dimensions

Overall length	12.878m
Width	2.286m
Floor height above head of rail	820mm
Distance between bogie centres	5.944m
Bogie axle spacing	1.450m
Wheel diameter	686mm

Centenary and double decker bogie details: See Table 2.9.

Table 2.9 Blackpool and Fleetwood tramway bogie details

Motor bogie	Two motor bogies (one each end) Motors are English Electric Type 305/1E (42.5kW) One powered axle per bogie (not coupled) Conventional wheelsets (two wheels per axle) Traction motors axle hung Rubber/metal primary suspension Rubber/metal secondary suspension See Figure 2.11

Wheel details: See Table 2.10.

Table 2.10 Blackpool and Fleetwood tramway vehicle – details of tyred wheels

Type	Tyre shrink fit on 558.8mm diameter wheel centre
Tyre Manufacturer	Cockerill Forges & Ringmill s.a., Serang, Belgium
Diameter	686mm (new) 623mm (worn)
Profile	See Appendix 14 for details
Re-profiling criteria	Based on visual assessment
Vehicle running distances between wheel re-profiling (approximate)	120000km (Major bogie overhauls)
Wheel discard criteria	Tyre thickness at 32mm (63.6mm thick when new)
Tyre material	BS 101/1929 Grade 'Y'
Wheelset back-to-back	1389.1mm
Lubrication	No on-vehicle system

All vehicles have sanding equipment associated with the driven wheels of each bogie.

2.5 OPERATIONS INFORMATION

Vehicle operations

The maximum speed through facing turnouts, level crossings and severe curves is 6.5km/h, and that through trailing switchs is 19.3km/h.
Other speed limits are:

26km/h - Starr Gate to Cabin
56km/h - Cabin to Fleetwood, except for the Orion curve between Little Bispham to Cleveleys for which the limit is 19km/h.

There are a number of 6.4km/h limits and compulsory stops at road crossings.

The braking of a Centenary tramcar has been demonstrated to achieve $0.2m/s^2$ deceleration during tests carried out in April 1997.

Operating environment

A road/rail cleaning vehicle with a rotary brush is used to remove the sand and debris from street and Promenade grooved track, including the rail groove. If the sand becomes compacted in the bottom of the groove it has to be manually removed with a bar or long bristled, narrow, wire brush.

2.6 OPERATING CHALLENGES

Maintenance

At low tide wind blown sand from a dry beach in summer at three locations can result in electrical return problems and sand blockage of drains. Sand and sea spray also present a hostile operating environment for the vehicles.

Sea debris can be deposited onto tracks during high tides at three locations when the sea overtops the sea wall, at which times services are suspended for about four hours.

In very hot weather some buckling of ballasted track can occur in the mid-afternoon, following steady heating by the sun through the day. Curved track is more prone to buckling than straight. As ballasted track is made up from 55m lengths of continuously welded rail with fishplates it is important to maintain the expansion gap and ensure that fishplates are not rusted and seized.

Rail wear

Excessive bull head rail wear is experienced at the Starr Gate loop, and with grooved rail on the four curves of the Fleetwood loop (see Figure 2.15).

There is a comprehensive programme of rail welding throughout the year. Rail replacement is made when there is 50% head wear after several repairs by building up with welding have been made.

Track quality

Tie bar failure can occur on grooved track on the Promenade, resulting in gauge changes, due to track movement initiated by high tides.

All concreted grooved rail track suffers from corrugations and gives rise to excessive noise. Rail grinding is carried out every two to three years. Rail corrugation is also found at tram stops.

Traction:

Problems with traction can occur on the inclined track between the tram stops at Gynn Square and Cliffs Hotel (about 500m) due to salt spray.

2.7 FIGURES

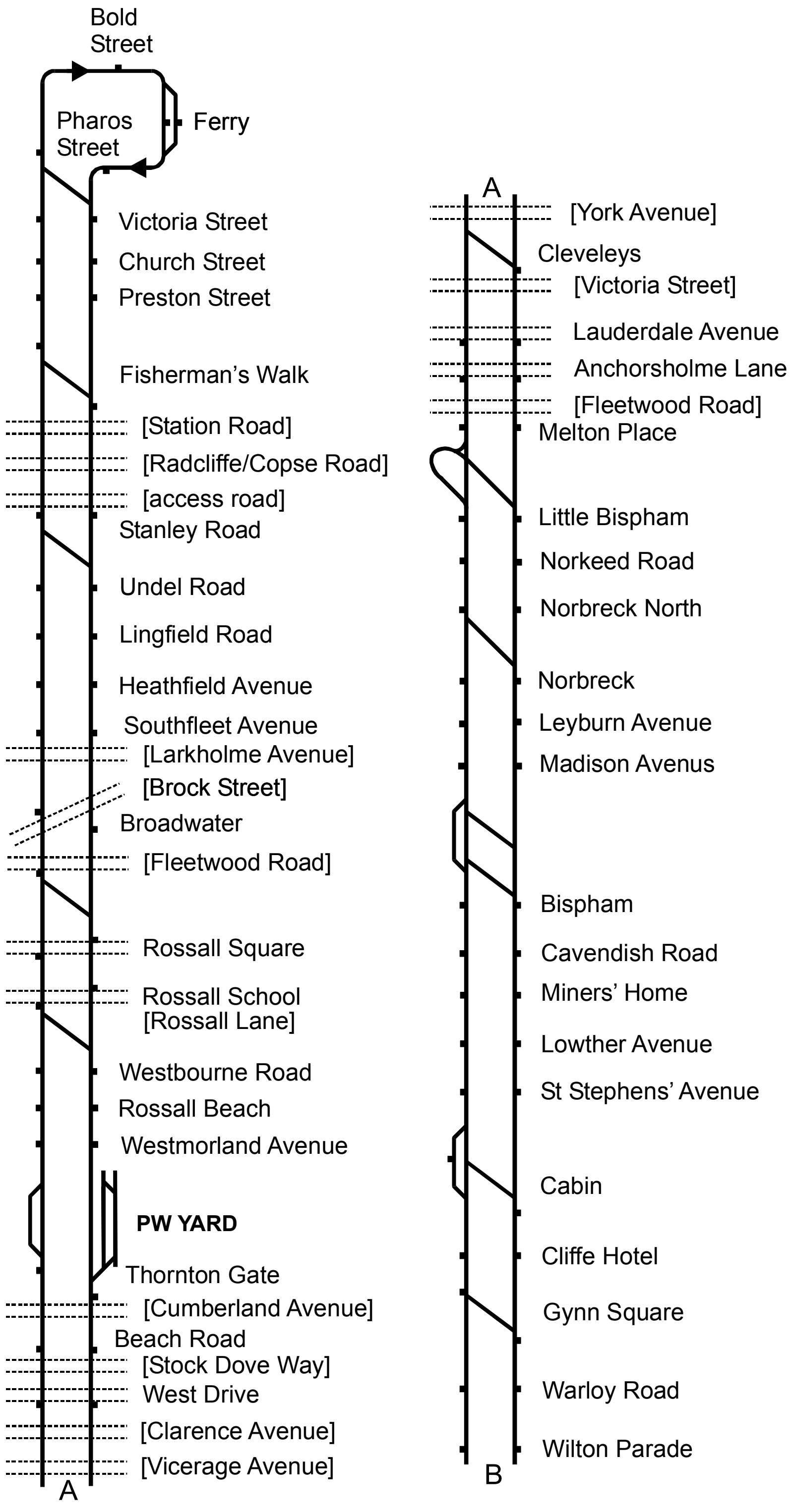


Figure 2.1(a) Schematic route map of the northern section of the Blackpool and Fleetwood tramway system

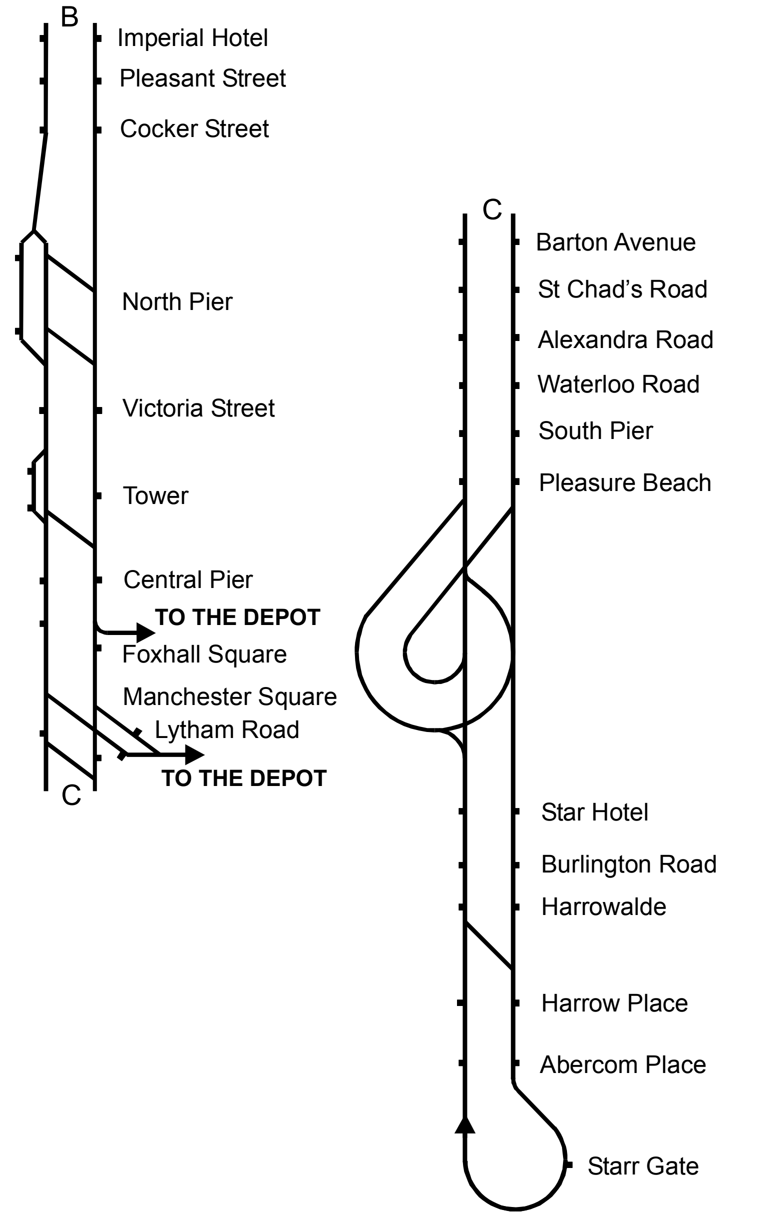


Figure 2.1(b) Schematic route map of the southern section of the Blackpool and Fleetwood tramway

EJH290304-04

(a) View of trackbed

EJH290304-05

(b) Detail view of drain

Figure 2.2 Blackpool and Fleetwood tramway reserved grooved rail track along the Promenade (29.03.04)

(a) Ballasted track and level crossing

FES0410-01/24

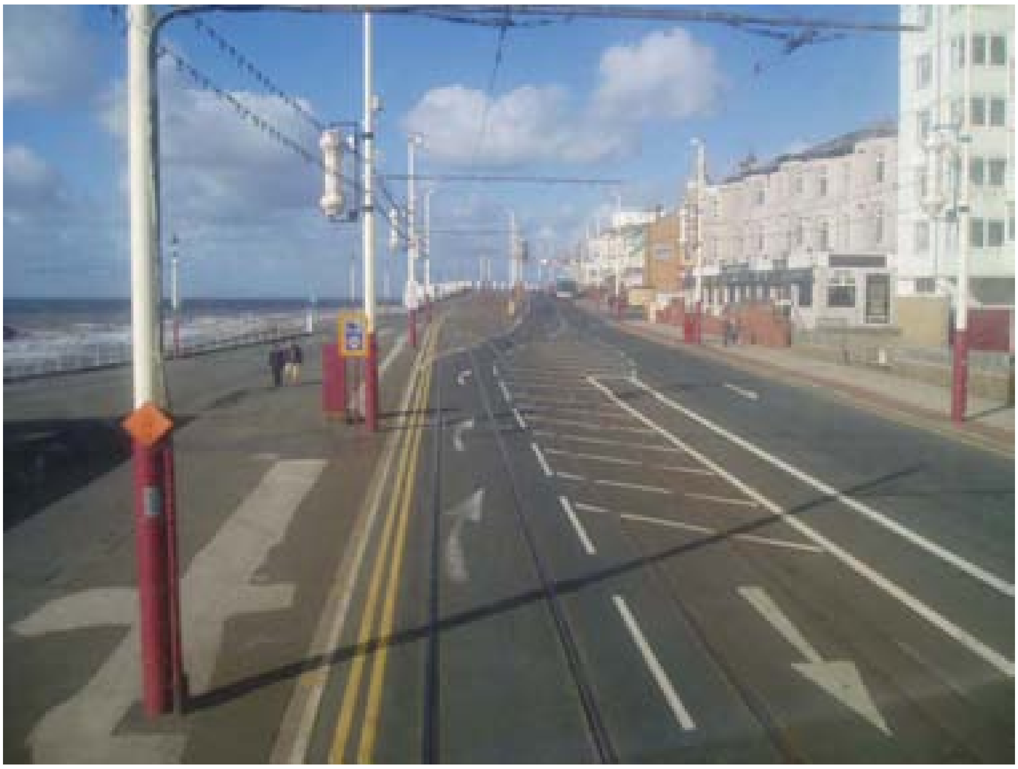
FES0410-01/25

(b) Ballasted track with check rails

Figure 2.3 Examples of Blackpool and Fleetwood tramway reserved ballasted track (04.10.04)

FES0410-01/14

(a) In the vicinity of North Pier



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(b) Between North Pier and Cocker Street

Figure 2.4 Examples of Blackpool and Fleetwood tramway street running tracks (04.10.04)

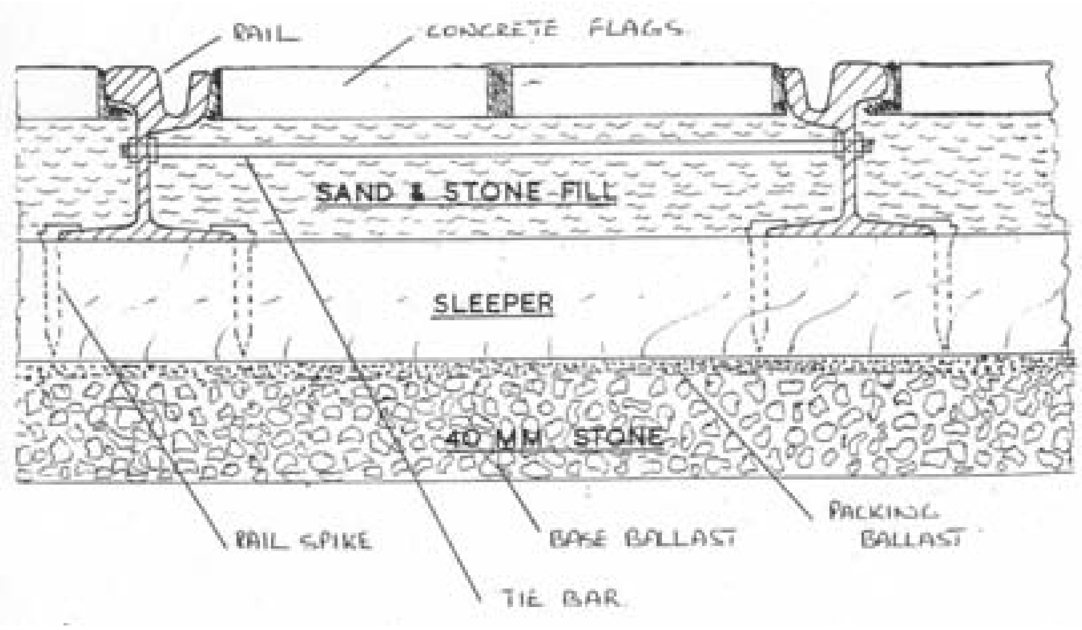

Figure 2.5 Schematic diagram of Blackpool and Fleetwood tramway grooved rail track construction as used on the Promenade

FES0410-01/28

Figure 2.6 Example of Blackpool and Fleetwood tramway grooved rail track construction without infill at transition to bull head rail

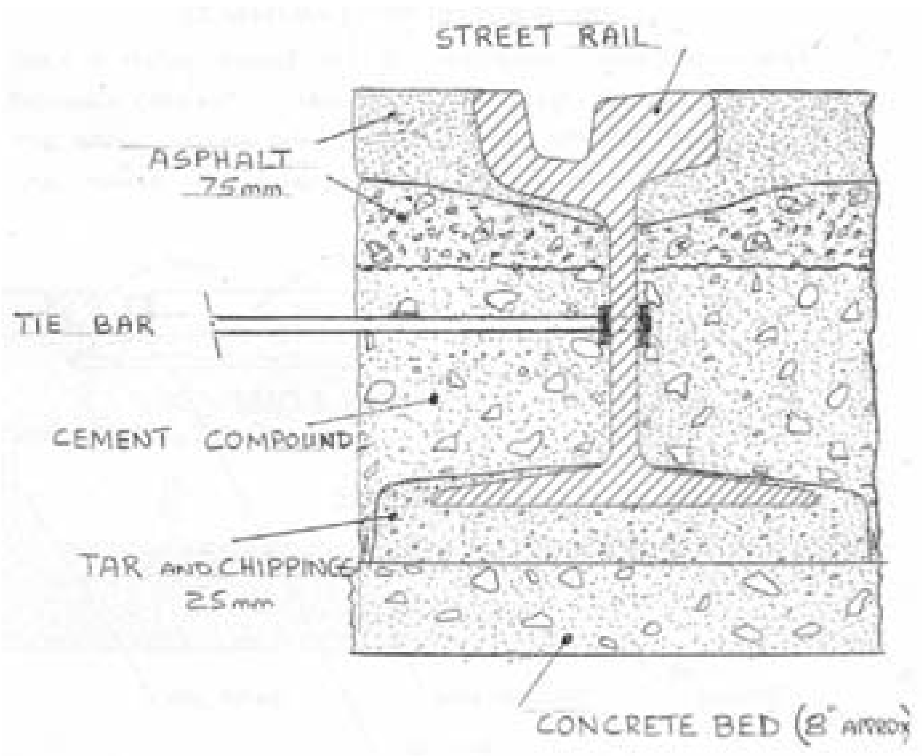

Figure 2.7 Schematic diagram of Blackpool and Fleetwood tramway grooved rail track construction as used for street running tracks and level crossings

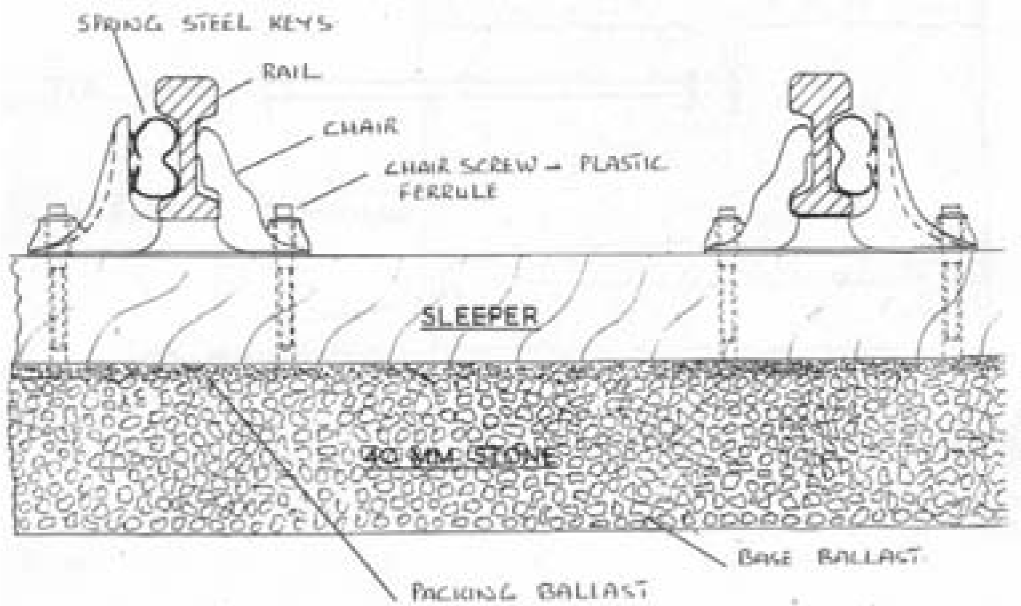

Figure 2.8 Schematic diagram illustrating Blackpool and Fleetwood tramway bull head rail track construction

FES0410-01/01

Figure 2.9 Blackpool and Fleetwood tramway grooved rail turnout (04.10.04)

FES0410-01/11

(a) Pivoted blade and cast rail housing

FES0410-01/04

(b) Flange tip running crossing

Figure 2.10 Turnout detail from segregated Promenade tracks on the Blackpool and Fleetwood tramway (04.10.04)

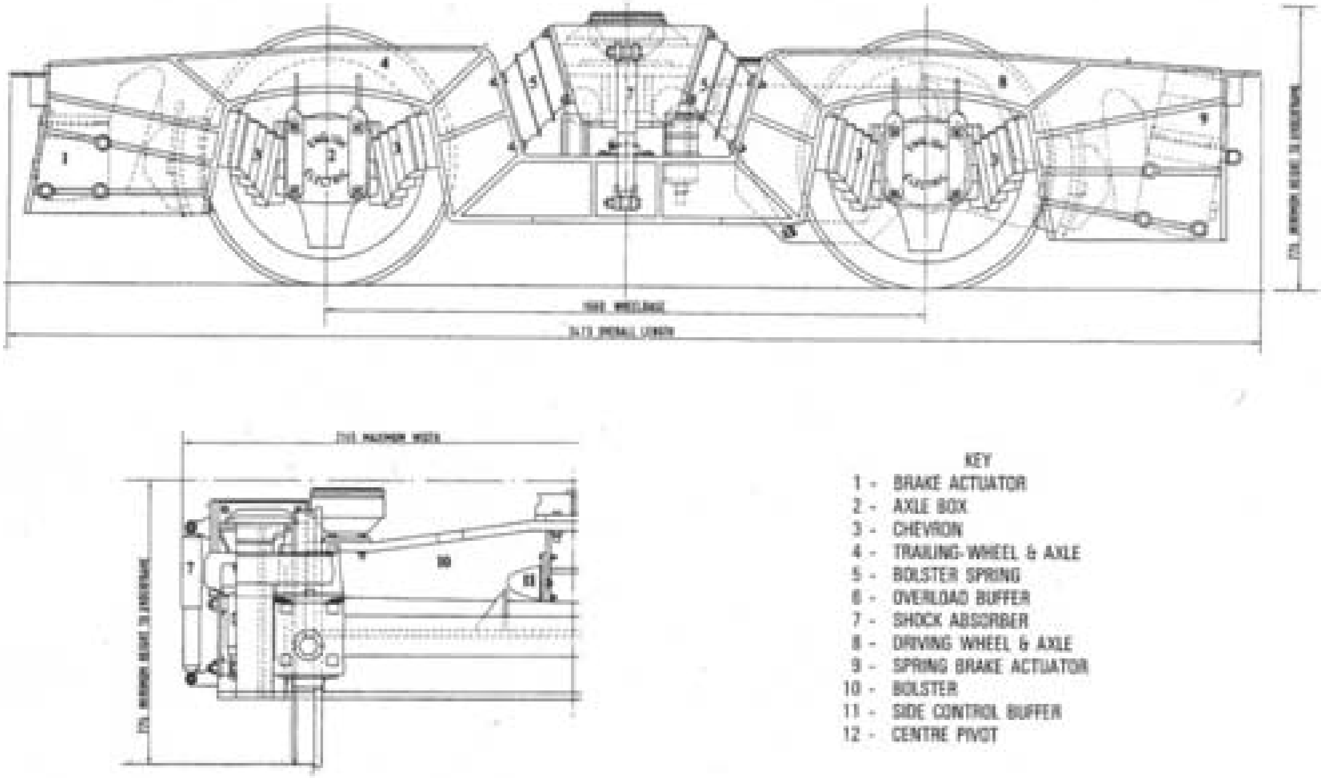

Figure 2.11 Bogie unit of the Blackpool and Fleetwood tramway single decker Centenary class tram

EJH290304-02

Figure 2.12 Blackpool and Fleetwood tramway Centenary class tram No. 646 (29.03.04)

HSE0305-019/4

Figure 2.13 Blackpool and Fleetwood tramway “Balloon” double decker tram No. 723 (17.09.01)

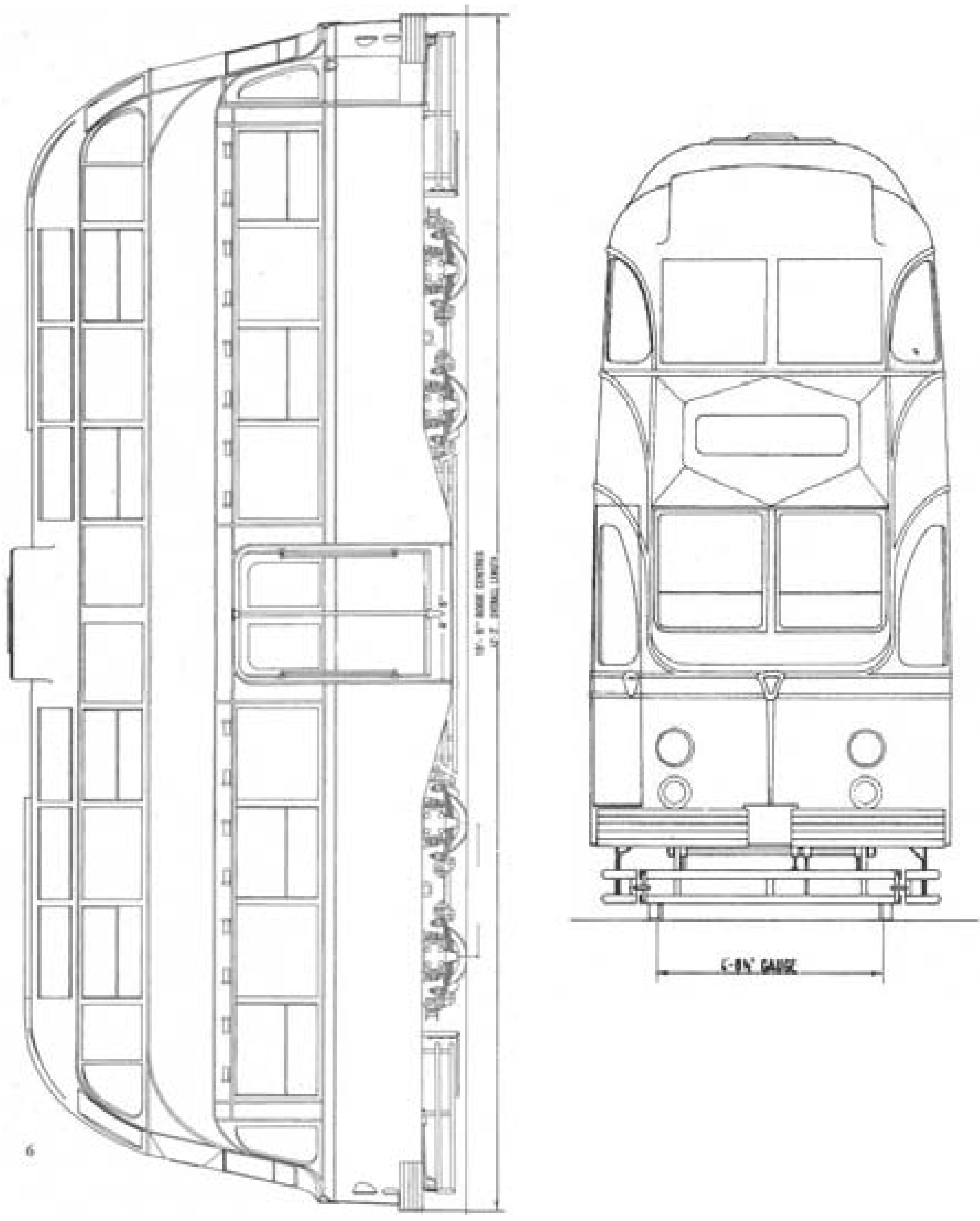

Figure 2.14 Blackpool and Fleetwood tramway “Balloon” double decker tram

FES0410-01/05
(a) The Promenade

FES0410-01/29
(b) Fleetwood Euston Hotel

FES0410-01/38
(c) Repair to keeper flange, Fleetwood Ferry

FES0410-01/42
(d) Wheel wear mark on rail head at Fleetwood Ferry

Figure 2.15 Examples of grooved rail wear on the Blackpool and Fleetwood tramway

3 CROYDON TRAMLINK

3.1 INTRODUCTION

Following completion of the township of New Addington, which was developed as overspill housing for inner Croydon, residents were reliant on a bus service following a hilly route and taking up to 45 minutes to reach Croydon. Various studies were carried out following completion of the last major house building in the 1970s. As Croydon is Britain's tenth most populous town outside central London, with the largest concentration of office space and largest urban shopping centre in the south-east, the provision of a light rail was considered to be the best transport system at helping Croydon sustain its development, as an alternative to costly road schemes.

In 1990 a final detail study was conducted to define a light rail system. This became the basis for the deposition of a Parliamentary Bill by London Transport and London Borough of Croydon in 1991. The Croydon Tramlink Act was passed in July 1994. A competition was launched under the Private Finance Initiative in late 1994, such that a formal construction start date of 25th November 1996 was agreed with Tramtrack Croydon Ltd (TCL) under a 99 year concession to design, build and maintain the system.

The Tramtrack Croydon Ltd consortium originally consisted of:
First Group Tram Operations - operators
Bombardier Transportation - design, build, maintenance and repair of trams
Royal Bank of Scotland and 3i - finance
Sir Robert McAlpine/Amey Construction Ltd - construction

Of these, First Group and Bombardier have since withdrawn as shareholders and remain simply as contractors to TCL.

Tramlink utilises former railway for almost half its length, which, as a condition of the Act, had to be fully separated from Railtrack infrastructure. Eight kilometres of the 16 inherited from Railtrack was refurbished and reused, with a further 1km reused in the Depot.

The main infrastructure was completed in July 1999 and all the 24 trams had been delivered to the Therapia Lane depot by June 1999. Trams were running on the system from September 1999.

3.2 SYSTEM DETAILS

Schematic route map:

See Figure 3.1.

Route distances:

See Table 3.1 below. A fully annotated detailed route map showing distances can be found at [http://tramlink.trap-door.co.uk/info/infra/maps.shtml].

In total there are just less than 52 track kilometres making up the 28km system. The Wimbledon and Beckenham branches are a mixture of twin and single track. Croydon town centre consists of a single track 'loop' with twin track extending to Sandilands in the east. The New Addington branch is all twin track with the exception of a short length, just before the terminus at New Addington.

Table 3.1 Croydon Tramlink route details

Line	*From*	*To*	*Distance (km)*	*Main Track Type*
1	Wimbledon	Reeves Corner	9.54	Double/ballasted single/ballasted
1,2,3	Reeves Corner	Sandilands Junction	2.22	Single/grooved rail Double/grooved rail
1,3	Sandilands Junction	Arena Junction	2.51	Double/ballasted
1	Arena Junction	Elmers End	0.91	Single/ballasted
2	Sandilands Junction	New Addington	7.24	Double/ballasted
3	Arena Junction	Beckenham Junction	4.18	Single/ballasted Double/ballasted

There is only 3.5km on-street route distance out of a total of 28km, with the majority segregated from other traffic. The Depot at Therapia Lane has 3.4km of track. The total length of grooved rail track is 6.9km.

Track distances according to track type are shown in Table 3.2 below:

Table 3.2 Croydon Tramlink track distances by type

Distance (km)	*Track Type*
1.3	Double grooved rail (street) track
2.4	Single grooved rail (street) track
0.5	Double grooved rail segregated track
16.0	Double ballasted track
8.5	Single ballasted track

For convenience the distances between tram stops are summarised in the tables below:
Table 3.3 – Wimbledon to East Croydon
Table 3.4 – West Croydon to New Addington
Table 3.5 – Sandilands to Beckenham Junction

Table 3.3 Croydon Tramlink tram stop distances between Wimbledon and East Croydon

From	*To*	*Distance (km)*	*Track*[1]
Wimbledon	Dundonald Road	0.473	Double/ballasted
Dundonald Road	Merton Park	0.623	Double/ballasted
Merton Park	Morden Road	0.805	Double/ballasted
Morden Road	Phipps Bridge	0.954	Single/ballasted
Phipps Bridge	Belgrave Walk	0.383	Double/ballasted
Belgrave Walk	Mitcham	0.656	Double with some interlacing/ballasted
Mitcham	Mitcham Junction	1.117	Single/ballasted
Mitcham Junction	Beddington Lane	1.073	Single/ballasted
Beddington Lane	Therapia Lane	1.058	Double/ballasted
Therapia Lane	Ampere Way	0.529	Double/ballasted
Ampere Way	Waddon Marsh	0.721	Double/ballasted
Waddon Marsh	Wandle Park	0.499	Double/ballasted
Wandle Park	Reeves Corner	0.650	Single/ballasted (0.399km) & plinth Single/grooved rail (0.049km) Double/grooved rail
Reeves Corner	West Croydon **[East bound]**	0.690	Single/grooved rail
West Croydon **[East bound]**	Wellesley Road **[East bound]**	0.653	Single/grooved rail
Wellesley Road **[East bound]**	East Croydon	0.437	Single & double/grooved rail
East Croydon	George Street **[West bound]**	0.457	Single & double/grooved rail
George Street **[West bound]**	Church Street **[West bound]**	0.392	Single/grooved rail
Church Street **[West bound]**	Wandle Park	0.846	Single & double/grooved rail
Church Street	West Croydon	0.703	Single/grooved rail

Notes:
[1] Distances taken from Parascandolo (2004)

Table 3.4 Croydon Tramlink tram stop distances between East Croydon and New Addington

From	*To*	*Distance (km)*	*Track*[1]
East Croydon	Lebanon Road	0.545	Double/grooved rail
Lebanon Road	Sandilands	0.512	Double/grooved rail
Sandilands	Lloyd Park	1.599	Double/ballasted
Lloyd Park	Coombe Lane	1.586	Double/ballasted
Coombe Lane	Gravel Hill	1.398	Double/ballasted
Gravel Hill	Addington Village	0.831	Double/ballasted
Addington Village	Fieldway	0.873	Double/ballasted
Fieldway	King Henry's Drive	0.678	Double/ballasted
King Henry's Drive	New Addington	0.385	Double & single/ballasted & slab track

Notes:
[1] Distances taken from Parascandolo (2004)

Table 3.5 Croydon Tramlink tram stop distances between Sandilands and Beckenham Junction

From	*To*	*Distance (km)*	*Track*[1]
Sandilands	Addiscombe	0.828	Double/ballasted
Addiscombe	Blackhorse Lane	0.612	Double/ballasted
Blackhorse Lane	Woodside	0.406	Double/ballasted
Woodside	Arena	0.723	Double/ballasted
Arena	Harrington Road	1.121	Double/ballasted
Harrington Road	Birkbeck	0.756	Single/ballasted
Birkbeck	Avenue Road	0.569	Single/ballasted
Avenue Road	Beckenham Road	0.553	Single/ballasted
Beckenham Road	Beckenham Junction	1.233	Single/ballasted
Arena	Elmers End	0.958	Single/ballasted

Notes:
[1] Distances taken from Parascandolo (2004)

Services from the New Addington and Beckenham Junction termini include loop running around the centre of Croydon. The Wimbledon to Elmers End service is between termini.

Power supply:

Overhead line equipment supplies trams with power at a nominal 750 Vdc from 13 substations rated at either 600MVA or 1000MVA (town centre section).

The 13 sub-stations are detailed in Table 3.6 below:

Table 3.6 Location of Croydon Tramlink electrical sub-stations

Distance (km)[1]	*Location*
10.1	Dundonald Road
7.3	Belgrave Walk
5.6	Mitcham Lane
3.4	Therapia Lane (divided into Main Line & Depot)
1.0	Jubilee Bridge
0.0	East Croydon
1.2	Sandilands
3.6	Oaks Road
6.5	Addington Village
8.4	New Addington
2.9	Woodside
4.8	Harrington Road
7.8	Blakeney Road

Notes:
[1] Approximate distances from East Croydon station

Tunnels:

There are three tunnels located between Sandilands Junction and Lloyd Park Tram Stop, as indicated on the map in Figure 3.1. These tunnels accommodate double ballasted tracks, details as Table 3.7 below:

Table 3.7 Croydon Tramlink tunnel details

Length (metres)	*Name*
243	Woodside Tunnel
112	Park Hill Tunnel
144	Coombe Road Tunnel

Passenger Service Vehicles:

Twenty-one vehicles out a fleet of twenty-four are required to operate a full service.

Tram stops:

The service vehicles call at all stops in each direction (Line 1: 24 stops, Line 2: 14 stops and Line 3: 12 stops).

Start of services:

Line 3, Croydon to New Addington, was the first to be opened for service on 11 May 2000. Line 2, Croydon to Beckenham Junction, opened on 23 May and Line 1, Wimbledon to Elmers End, followed this on the 27 May 2000.

3.3 TRACKWORK

3.3.1 Plain track

Grooved track (street running):

Rail types
- Ri 60 is used for the majority of track (see Appendix 4 for profile)
- Ri 59 (with wider flangeway) is used on curves with radii less than 75m (see Appendix 3 for profile)

The type of rail wear gauge used is shown in Figure 3.2

British Steel manufactured the rail.

The continuously welded grooved rails are embedded in slots cut into a reinforced concrete track slab. A cold-curing polymer holds the rails to gauge and provides electrical and vibration insulation. For those sections shared with road traffic a more durable finish was used than for the segregated track sections. Examples of grooved rail track are shown in Figure 3.3 and 3.4 that also show how drainage of the rail groove to the street drainage system is provided. The consequence of poor track and street drainage is illustrated in Figure 3.5.

Road surface faults adjacent to the rail keeper flange are shown in Figure 3.6

There are no fixed lubrication systems associated with grooved rails.

Grooved track (design) dimensions are given in Table 3.8:

Table 3.8 Croydon Tramlink nominal grooved track dimensions

Gauge (straight & curved track)	1435mm
Rail inclination	Vertical
Minimum track radius	25m
Maximum track cant	15mm (To allow track to conform to the highway camber
Maximum track gradient	9%
Rail running surface relative to road	-3mm +/-3 (As designed)

The plain grooved rail track maintenance tolerances are given in Table 3.9:

Table 3.9 Croydon Tramlink plain grooved rail track maintenance tolerances

Gauge - absolute value	-3/+6mm
- relative per metre	2mm
Horizontal alignment (straight line)	
- absolute	+/-10mm
- relative (20m base)	4mm
- relative (10m base)	3mm
Horizontal alignment (curve)	
- absolute	+/-10mm
- relative (versine[3] on 20m chord)	4mm
- relative (versine on 10m chord)	3mm
Vertical alignment	
- absolute value	-20/+10mm
- relative value on 30m base	5mm
Cant (maximum divergence from theoretical)	+/-4mm
Twist - on 3m base (additional to cant)	1 in 200

<u>Ballasted track:</u>

Rail type: - Flat Bottom BR 109lb, BS 110A and BS 113A profiles, reused from the previous Railtrack lines (see Appendices 9, 11 & 12)
- S 49 (see Appendix 13)

An example of a wear gauge for S 49 rail is shown in Figure 3.7.

[3] Versine ~ The offset to the circumference at the centre of a chord of a circle measured at right angles to the chord.

British Steel supplied the BS 110A and BS 113A rail and Voest-Alpine Stahl GmbH (VAE) the S 49.

Pandrol rail fastenings secure the BS 110A and BS 113A rail to either concrete or timber sleepers. Vossloh Type W14 fastenings secure the S 49 rail to pre-stressed monobloc sleepers, as shown in Figure 3.8. All rails are continuously welded, with expansion joints bracketing sharp curves.

Examples of curved track, together with bracing, are shown in Figures 3.9 and 3.10. Straight track with vertical irregularities is shown in Figure 3.11, and an expansion switch example is illustrated in Figure 3.12.

There are 12 track mounted lubrication units positioned on the tightest curves.

There are 22 highway level crossings. At such locations the plain track, with S 49 rail, is fitted with checkrails to retain the bitumen embedment.

The nominal plain ballasted track (design) dimensions are given in Table 3.10.

Table 3.10 Croydon Tramlink plain ballasted track dimensions

Gauge (straight & curved track)	1435mm
Rail inclination	1 in 20
Minimum track radius	25m
Maximum track cant	150mm
Maximum track gradient	8%

The plain-ballasted track maintenance tolerances are given in Table 3.11.

Table 3.11 Croydon Tramlink plain ballasted track maintenance tolerances

Gauge - absolute value	-3/+10mm
- relative per metre	2mm
Horizontal alignment (straight line)	
- absolute	+/-20mm
- relative (20m base)	6mm
- relative (10m base)	4mm
Horizontal alignment (curve)	
- absolute	+/-25mm
- relative (versine on 20m chord)	6mm
- relative (versine on 10m chord)	4mm
Vertical alignment	
- absolute value	+/-25mm
- relative value on 30m base	7mm
Cant (maximum divergence from theoretical)	+/-6mm
Twist - on 3m base (additional to cant)	1 in 200

3.3.2 Switches & Crossings

Grooved track (street running):

The system is equipped with plain turnouts supplied by Voest-Alpine Division Bahnsysteme (VAE), as the example shown Figure 3.13. Crossing and switch rail detail is shown in Figure 3.14

Drainage slots in the rail groove are connected to the street drain system.

The nominal grooved turnout (design) dimensions are given in Table 3.12.

Table 3.12 Croydon Tramlink grooved turnout dimensions

Gauge	1435mm
Radius	50m and 100m
Switch rail type	Flexible
Flangeway	22.5mm
Switch opening	(Set by switch mechanism) 40mm
Flange tip running	None

Turnouts are maintained to the same limits as for plain grooved track.

Ballasted track:

All turnouts were supplied by VAE and fabricated from S 49 rail using timber sleepers and Vossloh Type KS fasteners, and installed on a ballast track bed, as shown in Figures 3.15 and 3.16. Cess drainage is used. There are no fixed rail lubrication systems fitted at turnouts.

Examples of switch rail tips and crossing nose wear are given in Figure 3.17 and 3.18.

The nominal plain ballasted turnout (design) dimensions are given in Table 3.13.

Table 3.13 Croydon Tramlink plain ballasted turnout dimensions

Gauge	1435mm
Radius	(25m in Depot) 50m and 100m
Switch rail type	Flexible
Crossing flangeway gap	22.5mm
Switch opening	60mm (Reduced from 100mm)
Additional sleeper bracing to maintain alignment	Fitted to about 4 turnouts

Turnouts are maintained to the same limits as for plain ballasted track.

An example of sleeper bracing and over-rail check plate are shown in Figure 3.19

3.3.3 Switch operation

Grooved track (street running):

Hanning & Kahl supplied the electrical and mechanical point setting mechanisms for throw-over and sprung points, as set out in Table 3.14 below.

Table 3.14 Croydon Tramlink Hanning & Kahl turnout mechanisms for grooved rail track

Quantity	*Type*	*Description*
9[1]	HWE 60/100 AVV-ZVV	Electro-hydraulic units
3	HWU 40 D-Z	Manual units
7	HWU 40	Manual units for sprung points

Notes:
[1] HN0F point controls with HFP-HFK track circuit protection was supplied for these units

Ballasted track:

Hanning & Kahl also supplied the mechanical point setting mechanisms for throw-over and sprung points for flat bottom rails, as set out in Table 3.15 below.

Table 3.15 Croydon Tramlink Hanning & Kahl turnout mechanisms for ballasted track

Quantity	*Type*	*Description*
19	HWU 160 D-Z	Manual setting mechanism for sprung points
10	HWU 160	Manual setting mechanism for sprung points

Schreck-Mieves roller supports, as shown in Figure 3.20, have been fitted beneath switch rails to reduce frictional effects previously incurred with switch operation.

Switch detection system (all track):

Hanning & Kahl proximity switches are fitted to all facing points. These are a four switch configuration that checks the open/closed condition of both switches.

Maintenance regime (all track):

Gauging and other checks are made every 28 days.

Permitted open gap (all track):

The switches are set to make at 3mm and break at 4mm.

3.3.4 Track maintenance

There is no ultrasonic rail inspection.

No rail corrosion has yet been found.

Long straight sections of ballasted track are tensioned with curves being unstressed. There is no intention to undertake further stressing.

3.4 VEHICLES

All vehicles are to the same design and consist of two similar main bodies (A & B), with motor bogies at the outer ends. They are connected by a short central section (C) that sits on a central unpowered axle-less truck, as shown in Figure 3.21 and 3.22, and carries the inner ends of the A and B car bodies. Bombardier Transportation manufactured the vehicles at their Vienna factory. Classified as CR-4000, they are closely based on the proven K-4000 trams, over 120 of which are in use in Cologne, Germany. They are 76% low floor at 400mm above rail height with entrances at 350mm. As a consequence of the low floor all the traction equipment is located on the roof of the tram. Kiepe Electrik GmbH & Co., Düsseldorf, supplied the electrical and traction equipment.

The vehicles run on resilient wheels manufactured in Germany by Bochumer Verein Verkehrstechnik GmbH. The advantages claimed for these wheels are that they absorb structure-borne sound, improve ride quality by absorbing shock loads and reduce tread wear.

The vehicle passenger capacity (normal load) is 70 seated and 138 standing.

Leading dimensions: See Table 3.16.

Table 3.16 Croydon Tramlink vehicle dimensions

Length over body	31.00m
Body shell width	2.650m
Height of body shell	3.360m[1]
Floor height above head of rail	400mm[1]
Distance between bogie/truck centres	11.550m
Bogie/truck axle spacing	(Bogies and truck) 1.800m
Wheel diameter	630mm[1]

Notes:
[1] With new wheels

Bogie/truck details: See Table 3.17.

Table 3.17 Croydon Tramlink vehicle bogie details

Motor bogie	Two motor bogies (one each end) Two powered axles per bogie (not coupled) Conventional wheelsets (two wheels per axle) Bogie centre bearing/pivot is friction damped One traction motor per wheelset Traction motors attached to the bogie frame Rubber/metal primary suspension Coil spring secondary suspension See Figure 3.23
Trailer truck	Unpowered Independent four wheel truck (four stub axle/wheel units) Adjacent axle boxes connected by linkages at ends Rubber/metal primary suspension Coil spring secondary suspension See Figures 3.24 & 3.25

Vehicle weights:

Tare weight (nominal) = 36500kg

Wheel details: See Table 3.18.

Table 3.18 Croydon Tramlink vehicle wheel details

Type	Type BO 54 (Bochum single-ring resilient wheel) (See Figure 3.27)
Manufacturer	Bochumer Verein Verkehrstechnik Gmbh (previously VSG Verkehrstechnik)
Diameter	630mm (new) 550mm (worn)
Profile	See Appendix 15 for details
Re-profiling criteria	Maximum hollow wear of tread = 3mm Minimum flange thickness (measured at 14mm above tread) = 15mm No check made of flange angle Figure 3.26 shows a worn profile
Vehicle running distances between wheel re-profiling (approximate)	40000km
Wheel discard criteria	Minimum 550mm diameter (machined tell-tale on outer wheel face)
Wheelset back-to-back	1380(+4/-0)mm
Lubrication	Flange lubrication by 'solid stick' units on all four wheels of the centre (trailer) bogie (See Figure 3.25)

3.5 OPERATIONS INFORMATION

Vehicle operations

The maximum line speed is 80km/h, though 60-70km/h is normal. The on-street maximum is 50km/h.

The maximum speed through turnouts is 25km/h, except straight routes into facing spring turnouts when 40km/h is permitted.

Acceleration and braking is limited to $1.1 m/s^2$ and $1.3 m/s^2$ respectively.

Operating environment

In significant hot periods there is some track distortion on curves.

The vehicles are fitted with auto sanding equipment to control slip/slide.

3.6 OPERATING CHALLENGES

Rail wear

No information is available on the rates of rail wear.

Up to 3mm of wear on the gauge side of 50m curves has been observed.

Track quality

No evidence has been found of gauge spreading.

Rail corrugations, of random pitch, are found either side of tram stops.

3.7 FIGURES

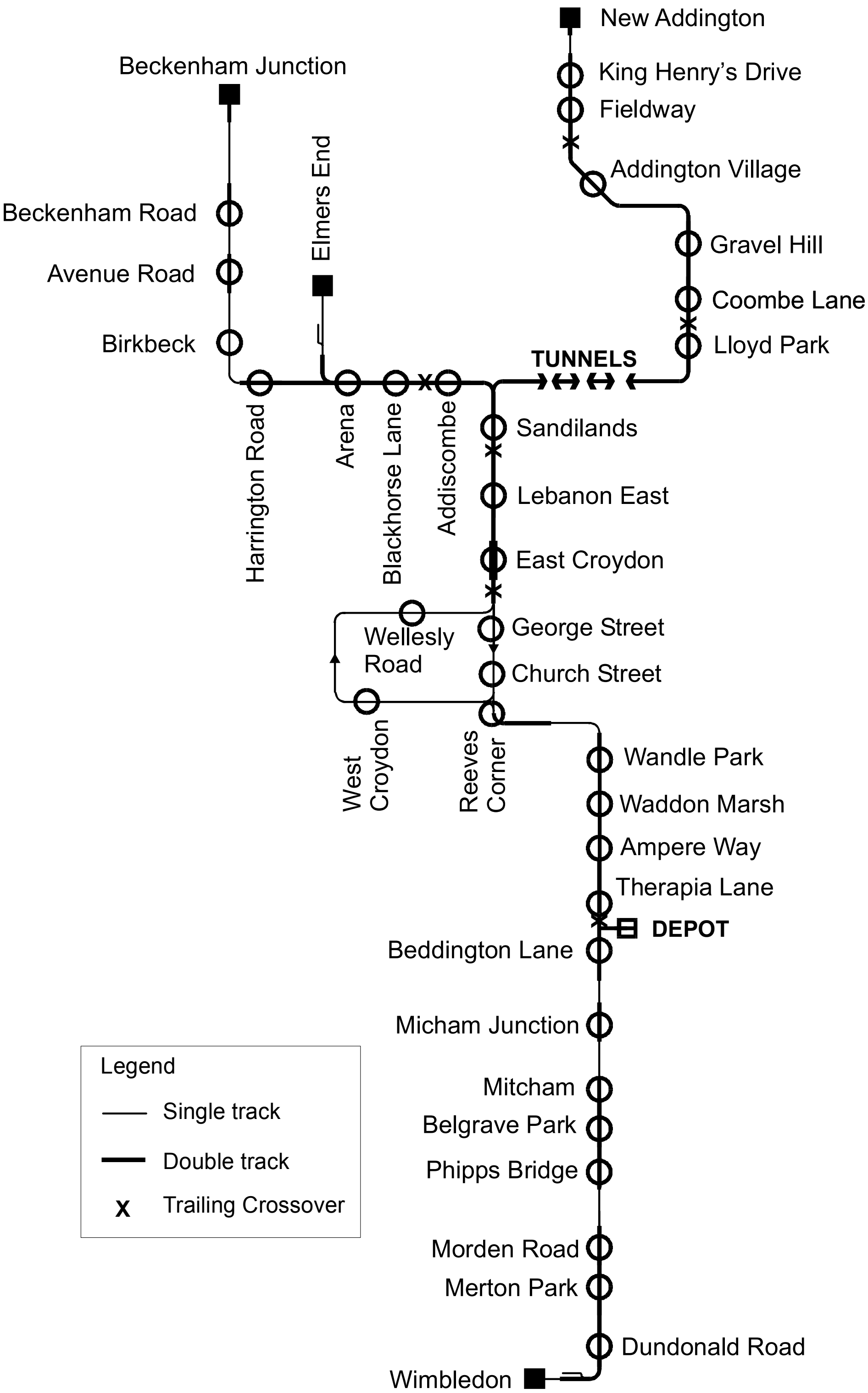

Figure 3.1 Schematic route map of Croydon Tramlink

J Brown

Figure 3.2 Ri 59 and Ri 60 grooved rail wear gauge, Croydon Tramlink

J Brown

Figure 3.3 Grooved rail track at Croydon, Croydon Tramlink

FES0402-01/24

FES0402-01/23

Figure 3.4 Example of grooved rail drainage at East Croydon station (12.02.04), Croydon Tramlink

J Brown

Figure 3.5 Submerged track at Croydon (April 2002), Croydon Tramlink

J Brown

Figure 3.6 Road surfacing at West Croydon (12.07.02), Croydon Tramlink

J Brown

Figure 3.7 S 49 flat bottom rail wear gauge, Croydon Tramlink

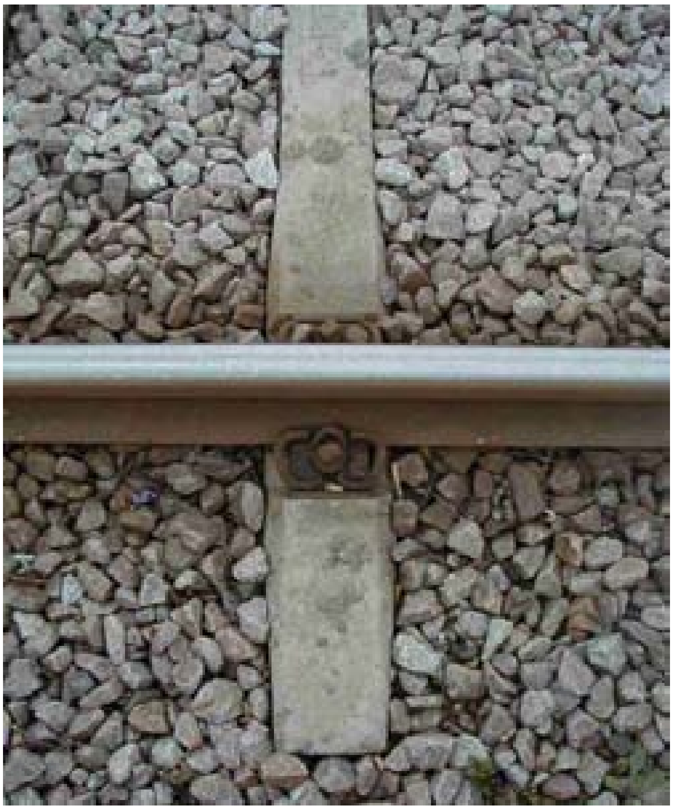

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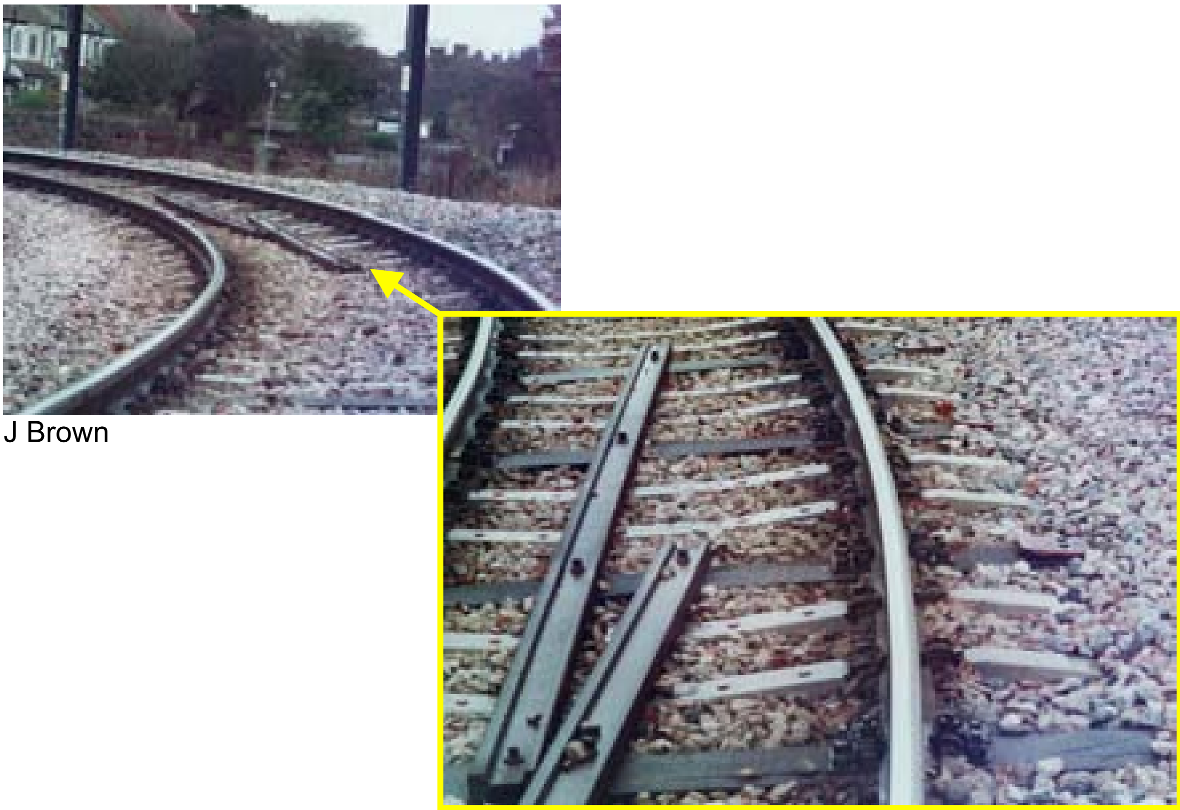
Figure 3.8 An example of ballasted track construction with S 49 rail, concrete sleepers and Vossloh Type W14 fastenings (12.02.04), Croydon Tramlink

J Brown

Figure 3.9 Curved ballasted track on the line to Beckenham Junction, Croydon Tramlink



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J Brown

Figure 3.10 Bracing fitted to ballasted track, Croydon Tramlink

J Brown

Figure 3.11 Irregular vertical track geometry at Mitcham Junction (07.08.02), Croydon Tramlink

J Brown

Figure 3.12 Ballasted track expansion switch (07.08.02), Croydon Tramlink

FES0402-01/2

(a) Crossing

FES0402-01/28

(b) Switch rails

Figure 3.13 Grooved rail turnout on the approach to the East Croydon Tram Stop from Wimbledon (12.02.04), Croydon Tramlink

J Brown

(a) Crossing

J Brown

(b) Switch rail at East Croydon

Figure 3.14 Switch and crossing turnout detail, Croydon Tramlink

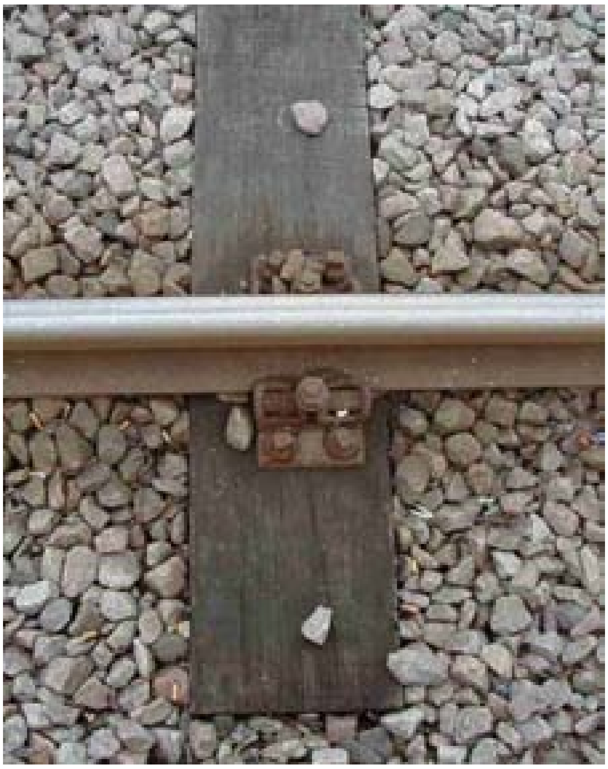

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Figure 3.15 An example of ballasted track turnout construction with S 49 rail, timber sleeper and Vossloh Type KS fastenings (12.02.04), Croydon Tramlink

J Brown

Figure 3.16 Arena Junction looking towards Elmers End (17.07.02), Croydon Tramlink

J Brown

(a) Blade tip in good condition (07.08.02) at Elmers End

J Brown

(b) Worn blade tip (10.07.02)

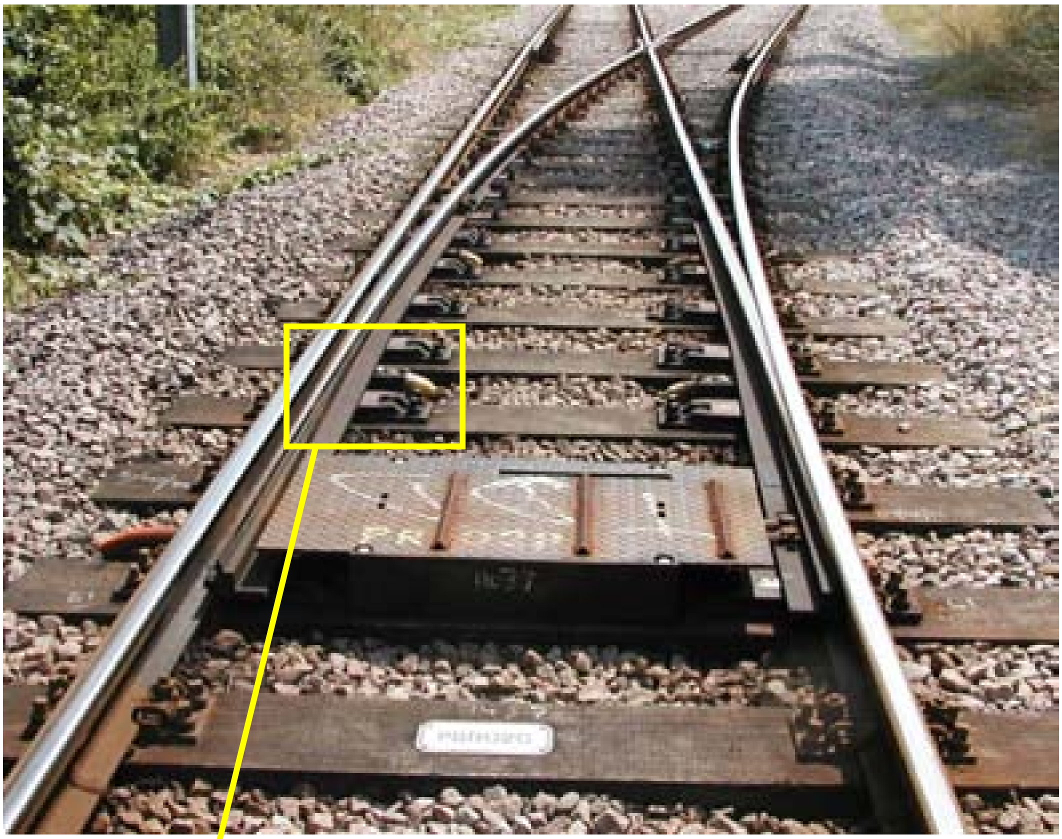
Figure 3.17 Switch rail tips, Croydon Tramlink

J Brown

Figure 3.18 Crossing nose wear at Morden Road (07.08.02), Croydon Tramlink

J Brown

Figure 3.19 Over-rail turnout check plate at the Croydon Depot (07.08.02), Croydon Tramlink



J Brown

(a) Turnout looking towards Croydon

J Brown

(b) Detail of a Schreck-Mieves roller support

Figure 3.20 Ballasted turnout at Phipps Bridge fitted with switch blade roller supports (07.08.02), Croydon Tramlink

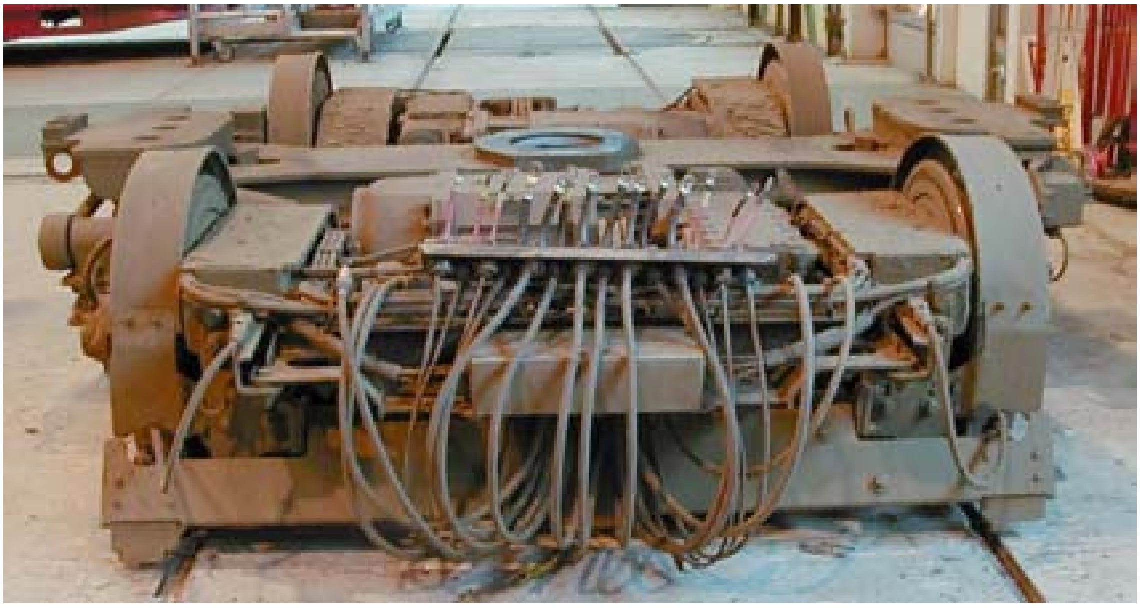
Figure 3.21 Bombardier Transportation CR-4000 tram

HSE0305-10/6

Figure 3.22 Croydon Tramlink tram No. 2543 at East Croydon railway station (16.08.01)

FES0402-1/02

(a) Side view



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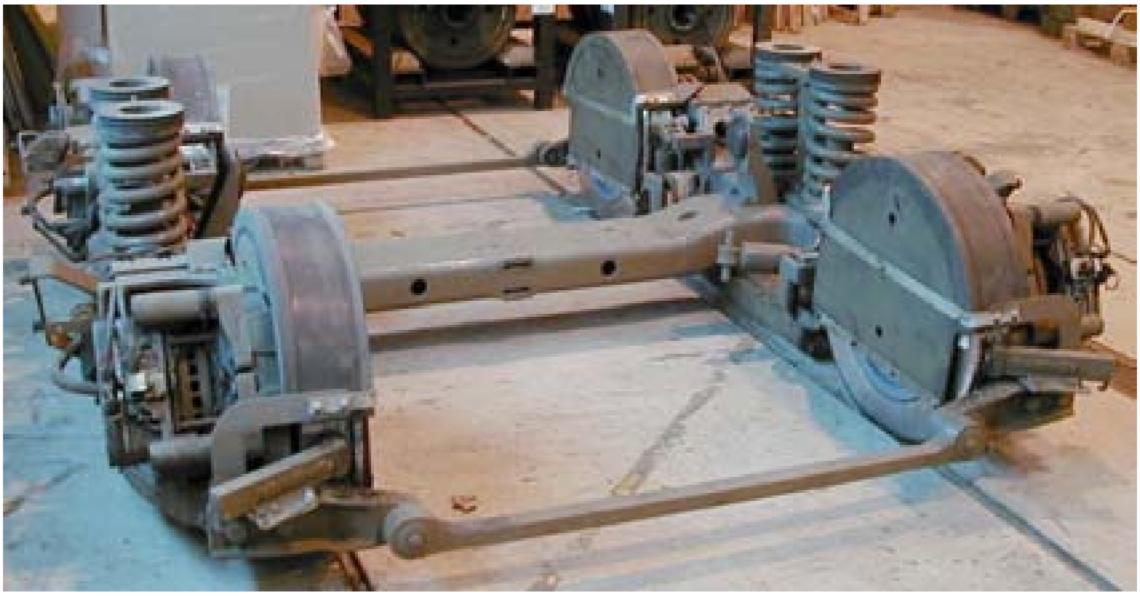
(b) End view

Figure 3.23 Croydon Tramlink CR-4000 motor bogie (12.02.04)

FES0402-1/08

(a) Side view



FES0402-1/10

(b) End view

Figure 3.24 Croydon Tramlink CR-4000 trailer truck (12.02.04)

FES0402-1/11

Figure 3.25 Trailer truck wheel/stub axle detail showing solid stick lubricator bearing on wheel flange root, Croydon Tramlink (12.02.04)

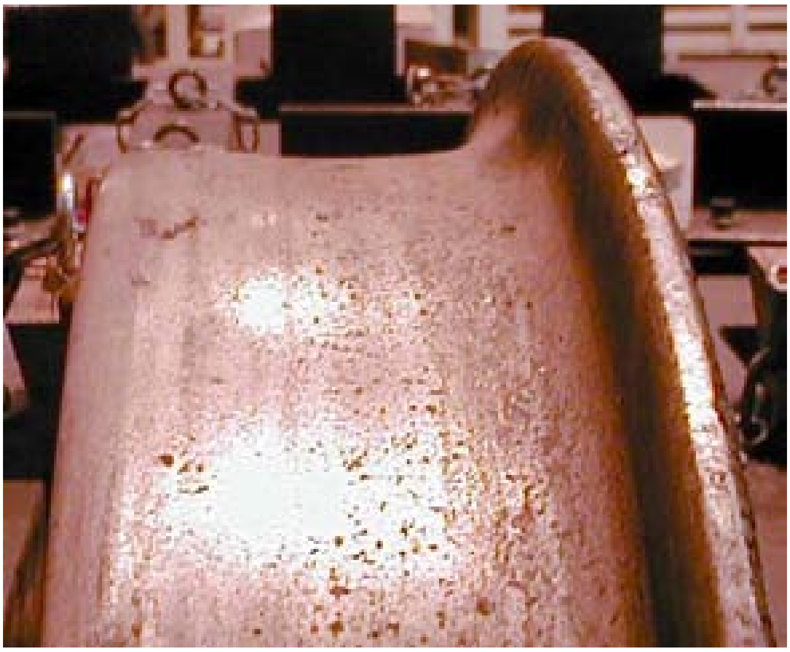


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Figure 3.26 Croydon Tramlink wheel tread profile prior to re-profiling (12.02.04)

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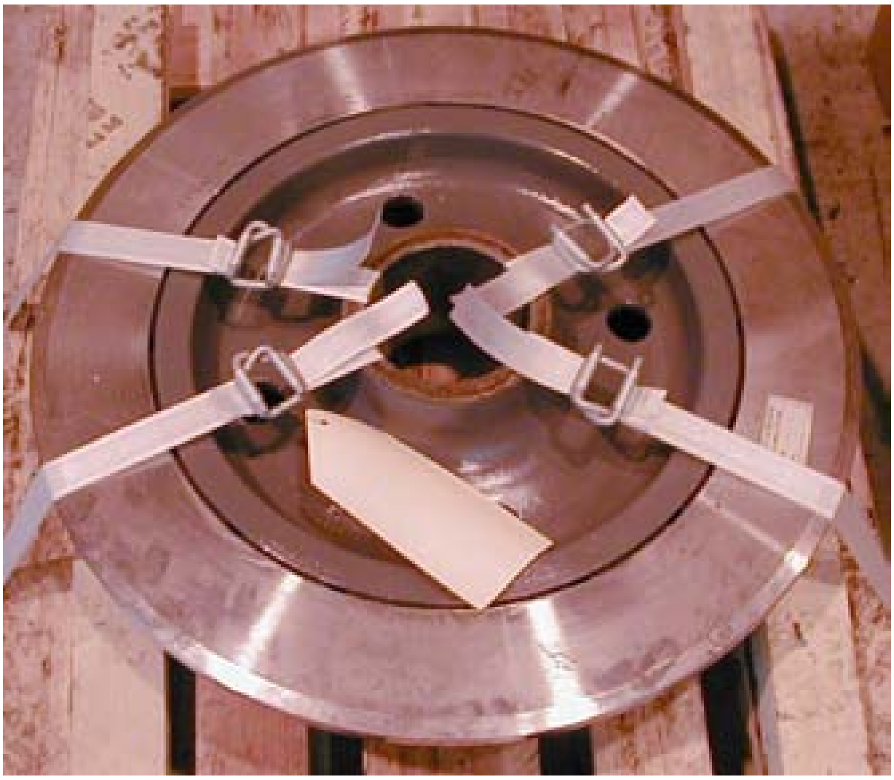
(a) View showing tread profile



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(b) Back face of wheel showing construction

Figure 3.27 New wheels awaiting installation, Croydon Tramlink (12.02.04)

4 DOCKLANDS LIGHT RAILWAY

4.1 INTRODUCTION

Starting in 1972 the London Docklands Study Team investigated the possibility of redeveloping the 8.5 square miles of London's docks area that were suffering from urban dereliction. Future transport demands for the area were considered insufficient to justify the construction a heavy railway or Underground line. Instead a light rail system connecting with the existing rail systems was proposed as being appropriate.

The Greater London Council together with the Boroughs Greenwich, Lewisham, Newham, Southwark and Tower Hamlets formed the Docklands Joint Committee in 1974 with the object of quickly developing the Docklands area. However, the light rail options proposed at this time were viewed as too expensive. A further study encouraged London Transport to obtain parliamentary powers for an extension of the Underground, but following a change of government in 1979 the scheme was abandoned, and a review of lower cost options ordered. The formation of the London Docklands Development Corporation (LDDC) in July 1981 focused the need for a solution. London Transport was commissioned to examine low-cost rail-based solutions to satisfy the needs of the development. Capacity problems ruled out direct links to existing rail systems. The final proposal in June 1982 was for a 'west-south' line from the City to the Isle of Dogs and a 'north-south' route from Mile End Station to the Isle of Dogs. Three months after this government funding was committed for construction of the Docklands Light Railway, prior to parliamentary powers being obtained, which were given in April 1984.

It was necessary to gain further parliamentary powers with Royal Assent in April 1985 for a change to the proposed Mile End section of the route, where street running had been initially proposed. This allowed for a totally segregated line that would now run to a disused bay platform at Stratford Station. A segregated system was favoured by the LDDC as this would readily permit the use of a high-tech automated system, their preferred solution.

Following government direction in mid-1984 tenders for a single design and build contract were invited. A contract was placed with GEC-Mowlem Railway Group in August 1984 for a fully segregated railway with automatic train operation. During the three years of construction it became clear that the planned passenger capacity had been underestimated and planing work to upgrade the system began before the public opening. This required a remodelling of the main junction at Poplar and longer platforms to accommodate two-unit trains.

The system when opened to the public on 31 August 1987 ran from Tower Gateway to Island Gardens and Stratford.

Two-thirds of the 12.1km of the initial 1987 double track system uses former disused or under-used heavy rail alignment. The original terminus at Tower Gateway is built on a reinforced concrete viaduct.

A further design and build contract was awarded to Edmund Nuttall Ltd in July 1987 for the 1.5km westward extension of the line from a junction at Royal Mint Street, which was close to the Tower Gateway terminus, to Bank station below the Underground station of the same name. This was opened on 29 November 1991.

The 8.4km extension from before Poplar to Beckton consists of approximately one-third each of ground level, underpass level and elevated double tracks. This was opened on 28 March 1994.

The 4.4km extension from beyond Crossharbour to Lewisham was opened on 20 November 1999.

A 4.5km extension to the London City Airport and King George V has recently been opened on 2 December 2005 which joins the Beckton branch a short way south of Canning Town (towards Royal Victoria), as shown in Figure 4.6. The City Airport Rail Enterprise (CARE), a consortium of AMEC and the Royal Bank of Scotland, undertook the design, build and maintenance of the extension. A further 2.5km extension tunnelling beneath the Thames is now under construction to Woolwich Arsenal, which is due to open in 2009.

A Stratford International route, linking Canning Town and Stratford with a link to the Channel Tunnel Rail Link (CTRL) Stratford International station, is currently the subject of a Transport and Works Act (TWA) application by Docklands Light Railway Limited.

4.2 SYSTEM DETAILS

Schematic route map: See Figure 4.1

Route distances: See Table 4.1 below.

Table 4.1 Docklands Light Railway route details

From	*To*	*Route (km)*[1]
Bank	Shadwell	2.377
Tower Gateway	Shadwell	1.273
Shadwell	Westferry	2.063
Westferry	West India Quay	0.593
West India Quay	Lewisham	6.029
West India Quay	Poplar	0.295
Westferry	Poplar	0.736
Poplar	Stratford	4.689
Poplar	Canning Town	2.170
Canning Town	Beckton	6.196
Canning Town	King George V	4.5[2]

Notes:
[1] Based on the average inter-station run distances
[2] Approximate distance

On double tracks left hand running is normal, but there is provision for bi-directional operation if required.

Power supply:

Traction current is distributed at 750 Vdc by means of an I-section aluminium conductor rail with a stainless steel contact surface bonded to the underside. This conductor rail is of the bottom contact type as shown in Figure 4.27, with an inverted U-section plastic shroud, and is supported on brackets fastened to the top of every fourth sleeper. This helps to reduce electrocution risks and minimises problems with snow and ice. Vehicle motor bogies are fitted with centrally mounted glass reinforced plastic arms on both sides that carry carbon collection shoes that contact the underside of the conductor rail.

There are eight sub-stations as detailed in Table 4.2 below.

Table 4.2 Location of Docklands Light Railway electrical sub-stations

Distance (km)[1]	***Location***
3.629	Royal Mint Street
0.0	Poplar[2]
1.943	Crossharbour
3.655	Cutty Sark
5.877	Elverson Road
2.683	Bow Church
3.717	Custom House
8.366	Beckton[2]

Notes:
[1] Approximate distances from Poplar
[2] These substations feed both the main line and depots

Tunnels:

The 1.2km underground section between the Royal Mint Street junction and Bank station consists of twin bore tunnels of 5m internal diameter with precast concrete segmental linings, at depths greater than 30m below ground level. There is a raised walkway at one side. The Bank terminus station, which has an island platform, is within a 7m-bore tunnel section that is 42m below ground level. To the west of the station, beneath the Mansion House, is a step-plate junction (constructed as a series of decreasing tunnel diameters) that accommodates the junction of the Up and Down lines with a headshunt beyond, which gives Up trains (towards central London) access to the Down line.

On the approach to Bow Church, in the direction of Stratford, is a rectangular concrete tunnel containing double tracks built to allow the air space above the railway to accommodate housing.

At Mudchute, on the line to Lewisham, the line goes underground for 1.5km starting with two single bore tunnels constructed by cut and cover, that then enter Island Gardens station, which is in a below ground box and partially roofed over. After Island Gardens the twin bore tunnels take the line beneath the River Thames, with gradients of up to 6% at each side. Each tunnel has a raised side walkway, and they are interconnected at the central lowest point where a sump and pumping equipment are located. On reaching the south bank of the river the tunnels enter Cutty Sark station, which is contained in a box, constructed by cut and cover. A further section of bored tunnels ends with double tracks in a covered way beneath the Greenwich heavy rail station.

The approach to the Lewisham terminus is in tunnel, which passes beneath the earlier elevated Lewisham heavy rail station, to reach the ground level platform area.

The further extension to the City Airport branch will include a tunnel under the Thames to Woolwich Arsenal station.

Elevated Sections:

The North Quay Viaduct, to the west of the North Quay Junction adjacent to Poplar station, is a standard steel and concrete composite structure, as shown in Figure 4.2. The elevated double track sections of the Beckton extension (totalling approximately 2.8km), principally in the Poplar to Brunswick Wharf, Connaught and near Gallions Reach areas, are carried on substantial all concrete structures, as illustrated in Figure 4.3.

To the south of the North Quay Junction are three 65m span fabricated steel bridges that carry the double tracks over three docks with an 8m headroom.

Between Greenwich and Deptford Bridge stations the double tracks are carried on a 20 span 800m long post-tensioned concrete viaduct that follows the banks of the Deptford Creek and Ravensbourne, which it also crosses.

From the junction with the Becton line the City Airport extension climbs onto an embankment and then onto 3.7km of viaduct with elevated stations at West Silvertown, Pontoon Dock and London City Airport before ramping down to street level.

Passenger Service Vehicles

Seventy two vehicle units out of a total of ninety four are required to operate the full service. The units are operated in pairs.

Journeys per route:

The service plan shown in Table 4.3 commenced on 07.02.04 and is expected to operate until opening of the London City Airport extension in 2005.

Table 4.3 Docklands Light Railway service plan

Service	*Headway in minutes*						
	Early	*am Peak*	*Off Peak*	*pm Peak*	*Evening & Late*	*Weekend & Early/Late*	*Weekend Middle*
Bank-Lewisham	10	3.5	10	4.2	10	10	10
Bank – Canary Wharf			10				
Stratford – Lewisham		10.5	10				20
Stratford – Crossharbour	10	21		7	10 (until 20:30)		20
Stratford – Canary Wharf					10 (until 20:30)	10	
Tower Gateway – Lewisham							20 (11:00-18:00)
Tower Gateway – Beckton	10	7	10	7	10	10	10
Units required	32	70	42		38/30	30	40

<u>Stations:</u>

Trains stop at each station. The average inter-station run distances are given in the following tables:
Table 4.4 - City to the West India Quay
Table 4.5 - West India Quay to Stratford
Table 4.6 - West India Quay to Lewisham
Table 4.7 - Westferry to Beckton
Table 4.8 - Canning Town to King George V

Table 4.4 City to the West India Quay

From	*To*	*Distance (m)*	*Track*
Bank	Royal Mint Street Junction	1547	Double/twin bore tunnel
Tower Gateway	Royal Mint Street Junction	443	Double/ballasted on viaduct
Royal Mint Street Junction	Shadwell	830	Double/ballasted on new & ex-heavy rail viaduct
Shadwell	Limehouse	1118	Double/ballasted on ex-heavy rail & new viaduct
Limehouse	Westferry	945	Double/ballasted on ex-heavy rail viaduct (listed 1840 brick built)
Westferry	West India Quay	593	Double/ballasted (with ballast mats)

Table 4.5 West India Quay to Stratford

From	*To*	*Distance (km)*	*Track*
West India Quay	Poplar	295	Double/ballasted
Poplar	All Saints	714	Double/ballasted
All Saints	Devons Road	1347	Double/ballasted
Devons Road	Bow Church	623	Double/ballasted (short tunnel)
Bow Church	Pudding Mill Lane	996	Single/ballasted & slab track
Pudding Mill Lane	Stratford	1010	Single/ballasted

Table 4.6 West India Quay to Lewisham

From	*To*	*Distance (m)*	*Track*
West India Quay	Canary Wharf	199	Quad & treble/slab track on viaduct
Canary Wharf	Heron Quays	280	Treble & double/slab track on viaduct
Heron Quays	South Quay	451	Double/ slab track on viaduct
South Quay	Crossharbour	810	Double/ slab track on viaduct
Crossharbour	Mudchute	489	Double/ slab track at ground level
Mudchute	Island Gardens	447	Double/ slab track in twin bore tunnels
Island Gardens	Cutty Sark	775	Double/ slab track in twin bore tunnels
Cutty Sark	Greenwich	661	Double/ slab track in twin bore tunnels
Greenwich	Deptford Bridge	744	Double/ ballasted & slab track on viaduct
Deptford Bridge	Elverson Road	817	Double/ slab track at ground level
Elverson Road	Lewisham	446	Double/ ballasted & slab track (short tunnel)

Table 4.7 Westferry to Beckton

From	*To*	*Distance (km)*	*Track*
Westferry	Poplar	736	Double/ballasted (with ballast mats)
Poplar	Blackwall	677	Double/ballasted & viaduct slab track
Blackwall	East India	391	Double/viaduct slab track
East India	Canning Town	1102	Double/viaduct slab track
Canning Town	Royal Victoria	982	Double/viaduct slab track
Royal Victoria	Custom House	565	Double/ballasted
Custom House	Prince Regent	519	Double/ballasted
Prince Regent	Royal Albert	917	Double/viaduct slab track
Royal Albert	Beckton Park	649	Double/viaduct slab track & ballasted underpass track
Beckton Park	Cyprus	627	Double/ballasted underpass track
Cyprus	Gallions Reach	738	Double/ ballasted underpass track & viaduct slab track
Gallions Reach	Beckton	1197	Double/ballasted track (some in trough)

Table 4.8 Canning Town to King George V

From	*To*	*Distance (km)*	*Track*
Canning Town	West Silvertown	-	Double/ballasted/viaduct slab
West Silvertown	Pontoon Dock	-	Double/viaduct slab
Pontoon Dock	London City Airport	-	Double/viaduct slab
London City Airport	King George V	-	Double/viaduct slab/ballasted

Start of services:

31.08.87 Tower Gateway to Poplar
Poplar to Stratford
Poplar to Island Gardens

29.11.91 Bank to Royal Mint Street junction

20.11.99 Mudchute to Lewisham (making the earlier Mudchute to Island Gardens section redundant)

28.03.94 Poplar to Beckton
02.12.05 Canning Town to King George V

A further contract has been awarded to continue the City Airport (King George V) extension beneath the river to Woolwich Arsenal.

4.3 TRACKWORK

4.3.1 Plain track

Slab track:

The rail used for slab track is flat bottom BS 80A (see Appendix 10) secured by Pandrol e1809 clips to resilient baseplates except on the City Airport extension were Pandrol Fastclip FC1501 clips are used. These are in turn fixed to the track slab by studs secured in drilled holes by grout, which is also used beneath the baseplates for levelling. Four designs of resilient baseplate are installed two of which incorporate coil springs, as illustrated in Figures 4.8 to 4.11. Pandrol VIPA-SP resilient baseplates are used on the City Airport extension as shown in Figure 4.12 and 4.13. A type of resilient baseplate, known as 'Cologne Eggs' after the German city where they were first installed, are shown in Figures 4.14(a), 4.19, 4.20, 4.22 and 4.23. These are used at locations were noise reduction is required.

British Steel supplied the original rail.

Rail joints are made using welding or fishplates. Expansion joints are widely used as a consequence of the many viaduct and slab track sections. Two types of expansion joints are used. The original switch design is shown in Figure 4.14(b), and the more recent type in Figure 4.14(a).

Guard rails, as shown in Figure 4.8, are used on curves below 75m radius together with rail lubricators.

Concrete slab base construction is used at both ground level and elevated locations, as illustrated in Figure 4.4 and 4.7. Much of the curved track below 120m radius is constructed as slab track.

On the Beckton line drain holes (225mm x 100mm), on the track centreline, are cast into the concrete trackbed at 3m spacing and are connected to drain units located between the trackbed and structural deck.

There are no level crossings.

The nominal Dockland Light Railway slab track dimensions are given below in Table 4.9:

Table 4.9 DLR nominal slab track dimensions

Gauge (straight & curved track)	1435mm
Rail inclination (including expansion joints)	1 in 20
Minimum track radius	Running lines 40m Depot 39m
Maximum track cant	150mm
Maximum track gradient	Bank station approach & Thames tunnels 6%
Working face of guard rail inner rail gauge face	1380(+4/-8)mm

<u>Ballasted track:</u>

Rail types: - Flat bottom BS 80A (see Appendix 10), on curves of 100m and less the rail has been head hardened)
- Flat bottom BS 110A and BS 113A (as Appendices 11 & 12) is used on part of the Bank/Tower Gateway to Poplar route

British Steel were the original rail suppliers.

Rail joints are made using welding or fishplates.

Pre-stressed concrete and some timber sleepers are used for ballasted track. The concrete sleepers have cast-in malleable iron shoulders either side the rail positions into which type e1809 Pandrol rail clips are inserted to secure the rail, as shown in Figure 4.15(b). Timber sleepers are fitted with steel baseplates for securing the rail clips, as shown in Figure 4.16(a).

To reduce noise levels the concrete sleepers of some track sections are fitted with ‘rubber boots’.

Track bed construction is of ballast (minimum 200mm) with cess drains, as shown in the typical section through ballasted tracks at ground level in Figure 4.17. Ballasted track is also used on some of the viaduct sections, and the form of these and the ballast mats used beneath the ballast are shown in Figure 4.5. A transition from ballasted to slab track is shown in Figure 4.15(a).

In station areas timber spacers are used as shown in Figure 4.16(b). These ensure that the minimum vehicle/platform clearance is maintained by butting up to the face of the platform wall. They are located approximately 2.5m from platform ends, and with a 5m intermediate pitch.

The design of expansion switch used on the Beckton line is shown in Figure 4.18.

There are no fixed rail lubricators associated with ballasted track, but some guard rails do have lubricators for the wheel backflange.

The exposed rails on the gradient from Bank to Royal Mint Street junction are heated over about 100m to help keep them dry to assist trains restart following a signal check.

There are no level crossings on the main lines.

The nominal Dockland Light Railway ballasted track dimensions are given below in Table 4.10:

Table 4.10 DLR nominal ballasted track dimensions

Gauge (straight & curved track)	1435mm
Rail inclination (including expansion joints)	1 in 20
Minimum track radius	120m
Maximum track cant	150mm
Maximum track gradient	6%

<u>Standards applicable to both slab and ballasted plain track</u>

Reverse curves have no intervening straight section.

Vertical curves are not less than 1000m radius.

The plain track main line maintenance tolerances are given in Table 4.11

Table 4.11 DLR slab and ballasted plain track maintenance tolerances

Gauge - target value	+4/-3mm
- maintenance threshold	+8/-4mm
Horizontal alignment (straight line)	
- target value	+/-5mm
- maintenance threshold	+/-9mm
Horizontal alignment (curve - 5m intervals/10m chord))	
- target value	+/-5mm
- maintenance threshold	+/-9mm
Vertical alignment (running rails)	
- target value	+/-5mm
- maintenance threshold	+/-9mm
Cant (maximum divergence from theoretical)	
- target value	+/-5mm
- maintenance threshold	+/-9mm
Twist - on 3m base (additional to cant)	
- target value	1 in 750
- maintenance threshold	1 in 400
Voids – Max deflection of rail under traffic on concrete plain sleeper track	
- target value	3mm
- maintenance threshold	5mm
Voids – Max deflection of rail under traffic on rubber boot sleeper track	
- target value	7mm
- maintenance threshold	8mm
Voids – Max deflection of rail under traffic on slab track with soft pads on a grout base	
- target value	3mm
- maintenance threshold	5mm

4.3.2 Switches & Crossings

Slab track:

All turnouts are constructed from flat bottom BS 80A rail (see Appendix 10) and are of vertical design.

The method of construction, including drainage, was similar to that for plain track.

The nominal Docklands Light Railway slab track turnout dimensions are given in Table 4.12:

Table 4.12 DLR slab track turnout dimensions

Gauge	1435mm
Radius	(Curved & straight crossings) 40m & 100m[1] (Pivoted swing nose crossing) 100m, 200m & 245m[2]
Switch rail type	Flexible
Crossing flangeway gap	44mm
Check rail flangeway gap	44mm
Minimum flangeway through switches	50mm
Switch opening	105mm
Flange tip running	None

Notes:
[1] Also SV-245 (=CV-9.25) & DV-10.75
[2] Pivoted swing nose turnouts designated SV-100 (6 units), Y-200 (2 units) & SV-245 (1 unit)

Figure 4.19 shows turnouts and diamond crossing forming part of the Delta Junction close to West India Quay. Turnouts with pivoted cast manganese crossing noses, as shown in Figure 4.20, are located at Canary Wharf and Bow Church to help reduce noise levels. These replaced turnouts originally fitted with swing nose crossings, such as that shown in Figure 4.21.

The construction of turnouts on the City Airport extension is illustrated in Figures 4.22 and 4.23.

Ballasted track:

All turnouts and diamond crossings are constructed from flat bottom BS 80A rail (see Appendix 10 and are of vertical design fastened to timber sleepers with type e1809 Pandrol rail clips and steel baseplates, as shown in Figure 4.24 and 4.25.

The nominal DLR ballasted turnout dimensions are given in Table 4.13:

Table 4.13 DLR ballasted track turnout dimensions

Gauge	1435mm
Radius	(Curved & straight crossings) 40m (Curved crossing) 100m (Straight crossing) 245m (Depot) 40m
Switch rail type	Flexible
Crossing flangeway gap	44mm
Check rail flangeway gap	44mm
Minimum flangeway through switches	50mm
Switch opening	105mm
Additional sleeper bracing to maintain alignment	Bracing blocks used on Depot 40m radius units

<u>Standards applicable to both slab and ballasted turnouts</u>

A summary of the standard design dimensions associated with turnouts on the Beckton line is given in Table 4.14 below, which is associated with Figure 4.26.

Table 4.14 DLR standard dimensions for ballasted turnouts on the Beckton line

Turnout Type	*Turnout Radius*	*Angle at IP*[1]		*Lead to fine point*	*Fine point to nose*	*Crossing Heel*	*Stock rail front*	*Stock rail front to IP*	*IP to crossing heel*	*Tangent length*	*Overall length*
	R(m)	*1 in N*	*degrees*	*A(m)*	*B(mm)*	*C(m)*	*D(m)*	*E(m)*	*F(m)*	*G(m)*	*H(m)*
Sv-40	41.585	3.798	15.00	10.210	66	2.724	1.000	5.760	8.240	5.475	14.000
Cv-40	41.585	3.000	18.93	10.210	66	2.724	1.000	7.205	6.795	6.930	14.000
Cv-100	100.000	4.611	12.38	16.283	96	3.923	1.650	10.667	10.633	10.844	21.300
Sv-245	245.564	9.250	6.19	24.877	148	4.110	1.650	13.253	17.532	13.274	31.785

Notes:
[1] IP - Intersection Point

The maintenance tolerances for turnouts and crossings are given in Table 4.15

Table 4.15 DLR slab and ballasted turnout and crossing maintenance tolerances

Longitudinal position of switch tip from design position (level with first slide chair)	
- target value	+/-5mm
- maintenance threshold	+/-8mm
Max wear on dry slide chairs	
- target value	1mm
- maintenance threshold	2mm
Switch tip fit (max gap between switch point & stock rail in closed position)	
- target value	2.0mm
- maintenance threshold	3.5mm
Head wear on crossing wing rails	
- target value	3mm
- maintenance threshold	5mm
Head wear on crossing nose	
- target value	3mm
- maintenance threshold	5mm
Max wear of crossing flangeway gap (from 44mm) at 50mm from crossing nose along the vee	
- target value	2mm
- maintenance threshold	4mm
Max wear of check rail flangeway gap (from 44mm)	
- target value	2mm
- maintenance threshold	4mm
Swing nose crossing max gap between swing nose & swing rail at 50mm from swing nose along vee	
- target value	2.0mm
- maintenance threshold	3.5mm
Max gauge variation at the switch point & crossing nose	
- target value	+/-2mm
- maintenance threshold	+4/-2mm

4.3.3 Switch operation

All tracks:

British Rail type clamp lock machines with hydraulic drive operate all conventional turnouts.

The swing nose crossing units are operated by GEC/Alstom type HW mechanisms.

Switch detection system (all track):

Micro-switches provide detection.

Maintenance regime (all track):

A two level inspection regime is in operation, depending on use, based on a six-week cycle.

Permitted open gap (all track):

The switches are set to make at 3mm and break at 5mm

4.3.4 Track maintenance

Ultrasonic rail inspection, using hand held units, is carried out at least annually.

No abnormal rail corrosion has been found.

Standard rail stressing is carried out based on a temperature of 27deg C.

4.4 VEHICLES

The fleet is made up of 94 units of class B92 three bogie articulated vehicles all manufactured by BN Constructions Ferrovaires et Metalliques, Brugge, Belgium (now Bombardier BN). Typical examples are shown in Figure 4.28. They consist of two similar bodies with motor bogies at the leading/trailing ends, and articulation at the central unpowered bogie, as shown in Figure 4.29. The ‘H’ bogie frames (motor and trailing bogies) sit within the wheels, such that the axles run on internal bearings. The floor height throughout is 1025mm.

The vehicles run on rubber-cushioned Bochum 54 or Bochum 84 wheels manufactured by Bochumer Verein Verkehrstechnik GmbH in Germany. No sanding units are fitted to vehicles.

The seating capacity of a unit is 70, though a Passenger Services Agent (PSA) may take up two seats if present, and two wheelchairs can occupy four tip-up seat locations. A maximum of 228 standing passengers can be accommodated, though this has been increased for 20 of the units (numbers 32, 45 & 50-67) by removing ten seats around the centre door area in each car. These cars are used on train formations used on services to Bank at peak times. The vehicles are currently undergoing interior refurbishment that will include changes to the seating arrangements.

Leading dimensions: See Table 4.16.

Table 4.16 Docklands Light Railway vehicle dimensions

Length over couplers	28.800m
Length over body	28.000m
Body width over doors	2.650m
Body shell width	2.500m
Height (rail to roof)	3.468m
Floor height above head of rail	1025mm
Distance between bogie centres	10.000m
Bogie axle spacing	1.900m
Wheel diameter (new)	740mm

<u>Bogie details:</u> See Table 4.17.

Table 4.17 Docklands Light Railway vehicle bogie details

Motor bogie	Two motor bogies (one each end) Internal 'H' frame with internal axleboxes Two powered axles per bogie One brake disc per axle One 140kW mono-motor per bogie Motors are mounted longitudinally Motor continuously rated at: 675V/230A/1783rpm Rubber springs either side the axleboxes form the primary suspension Air bags provide secondary suspension
Trailer bogie	Similar in basic design to the motor bogie One brake disc per axle

<u>Vehicle weights:</u> See Table 4.18.

Table 4.18 Docklands Light Railway vehicle weights

Tare weight (two car unit)	36000kg
Weight of crush laden two car unit (M3 load)	54000kg
Crush laden distribution:	
Car body A	27000kg
Car body B	27000kg

Vehicle braking systems: See Table 4.19.

Table 4.19 Docklands Light Railway vehicle braking systems

Disc brakes	One disc per axle on motor bogies One disc per axle on the trailer bogie (Total of six disc brakes)
Track brakes	None
Rheostatic brake	Regenerative that automatically becomes rheostatic if the line is not receptive

Wheel details: See Table 4.20.

Table 4.20 Docklands Light Railway vehicle wheel details

Type	Type BO 54 & 84 (Bochum resilient wheel)
Diameter	740mm (new) 660mm (worn)
Profile	DLR1 profile (similar to BR P8 as Appendix 24) - prone to high wear DLR2 profile (based on the worn DLR1 profile, as Appendix 16) - prone to sidewear of rail/flange DLR5 profile (developed from the DLR2 profile) - profile now used, as Appendix 17
Wheel discard criteria	Telltale on wheel rim (660mm diameter) (Tyre scrapping thickness following the German Eschede rail incident(1998))
Wheelset back-to-back	1362(+0.5/-1.5)mm
Lubrication	Flange lubrication by 'solid stick' Applied to the flange root radius bearing on wheels of the leading /trailing axle of the motor bogies on each unit

4.5 OPERATIONS INFORMATION

Vehicle operations

The maximum service speed on level and down gradients is 70km/h and 60km/h on up gradients. Service acceleration and braking is limited to 1.1m/s^2 (average) and 0.8m/s^2. The maximum hazard braking rate is 1.3 m/s^2.

Operating environment

Points are fitted with heaters. On damp mornings in autumn low adhesion can give rise to difficulties with braking.

4.6 OPERATING CHALLENGES

Rail wear

On the sharper curves head hardened rail has been introduced. There has also been an increasing use of guard rails.

Excessive cyclic rail side wear is occurring on straight sections of track and is controlled by rail grinding. An investigation is underway to help develop improved control methods.

Track quality

A programme of progressive track refurbishment is taking place at Canning Town and Lewisham (on viaducts) to overcome poor construction quality giving rise to loose rail fastenings. At Tower Gateway the crossover with 100m radius turnouts is receiving attention to rectify loose rail fastenings and crumbling concrete.

Rail corrugations are found on all sharp curves, which is treated by rail grinding.

Poor ride quality is associated with the three bogie design of the vehicles, the monomotor bogie design, and the problems with wheel profile and rail wear.

An annual noise survey is carried out which highlights any remedial action required.

Braking on some early morning trains can be problematic. A braking rate as low as $0.4m/s^2$ can still be too large to prevent slide, and a rate of $0.3m/ s^2$ has now been added to the Automatic Train Control system.

4.7 FIGURES

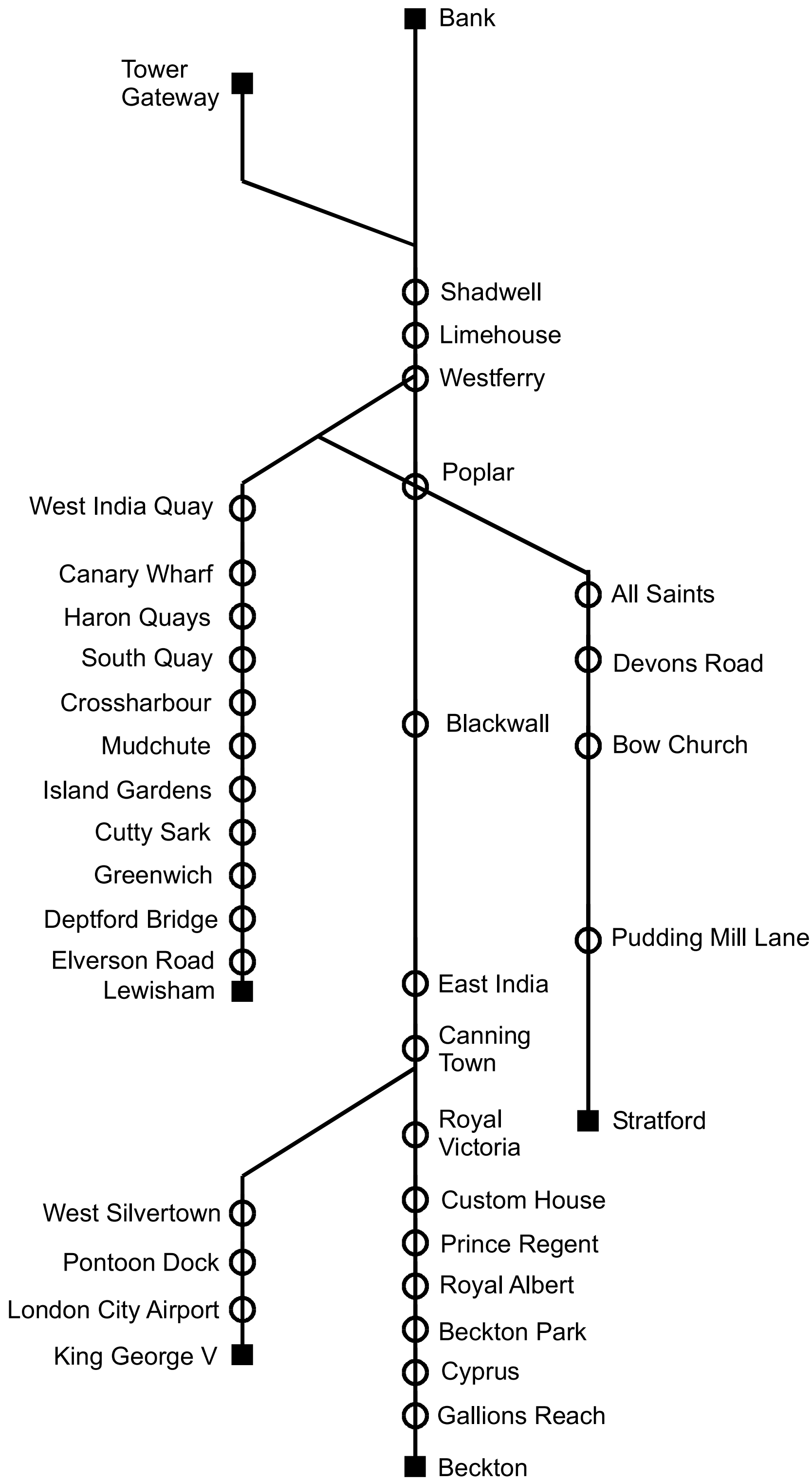

Figure 4.1 Schematic route map of the Docklands Light Railway

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Figure 4.2 The North Quay Junction and North Quay Viaduct (background), Beckton Link (foreground) and the New West India Down Viaduct (right, background) of the Docklands Light Railway (22.10.04)

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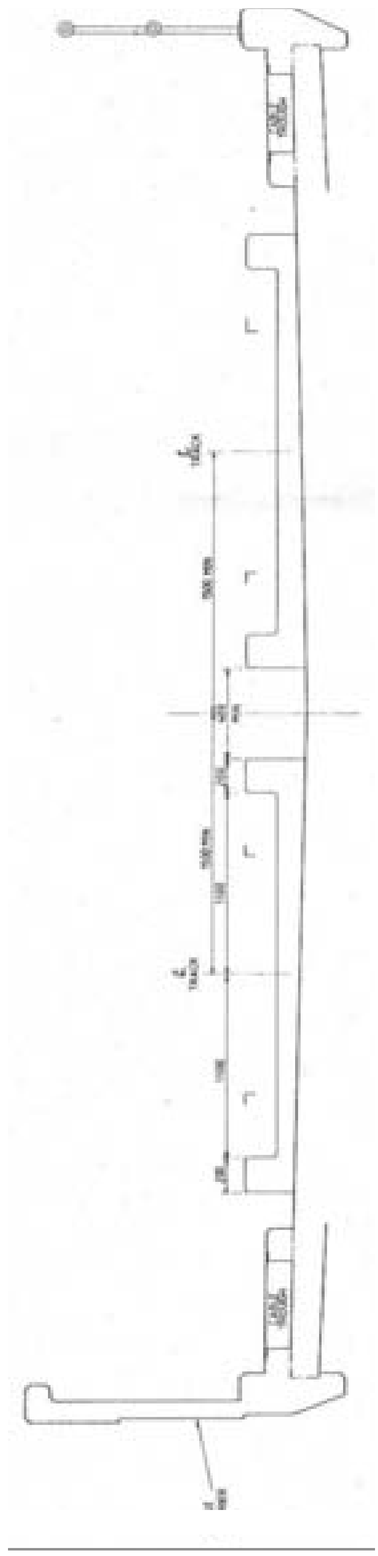
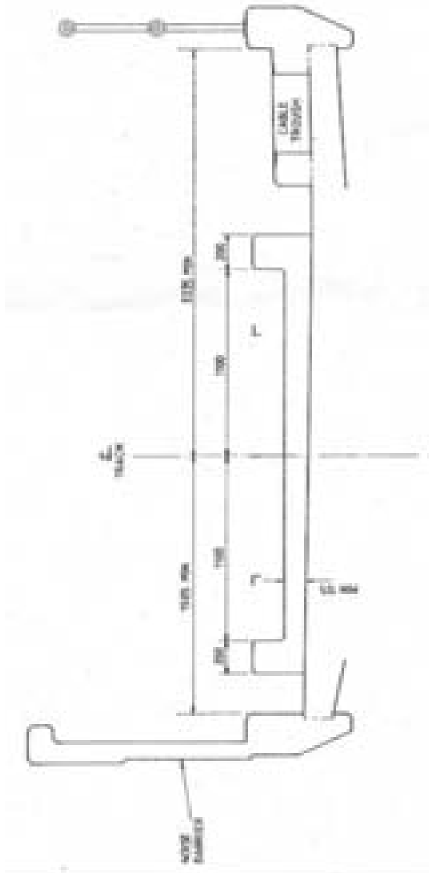
Figure 4.3 Elevated section of the Docklands Light Railway Beckton line (22.10.04)

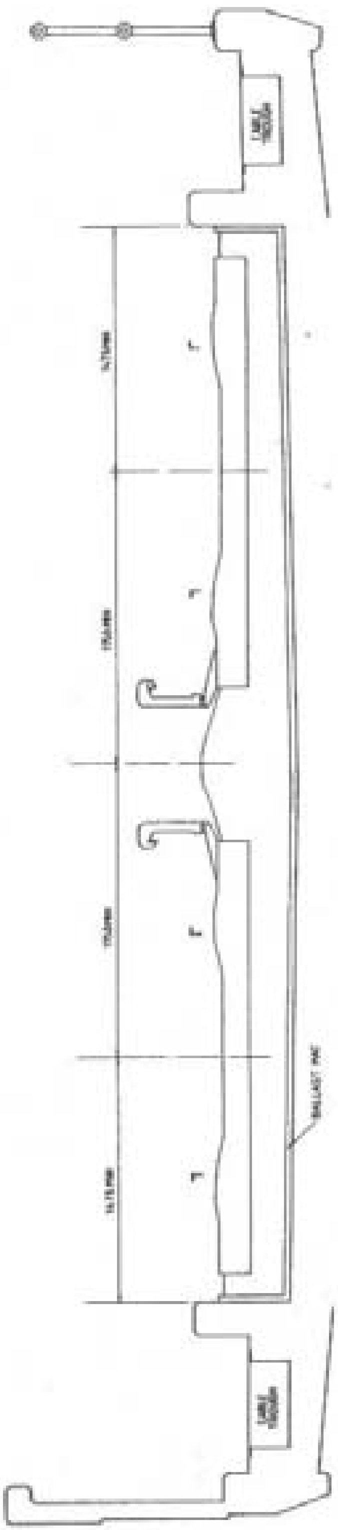




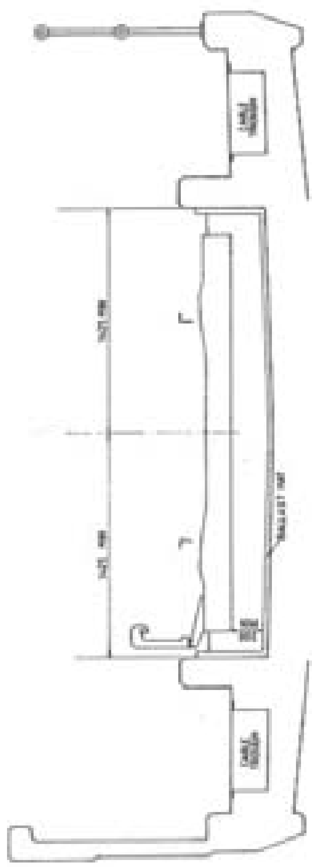
(b) Single slab track

(a) Double slab track)

Figure 4.4 Typical viaduct sections for slab track (straight, level & uncanted) on the Docklands Light Railway Beckton line



(a) Double ballasted track)



(b) Single ballasted track

Figure 4.5 Typical viaduct sections for ballasted track (straight, level & uncanted) on the Docklands Light Railway Beckton line

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Figure 4.6 Docklands Light Railway City Airport extension under construction beyond the overbridge (22.10.04)

Photo courtesy of Pandrol UK Ltd

Figure 4.7 Slab track under construction, City Airport extension of the Docklands Light Railway

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Figure 4.8 Slab track plain line and guard rail resilient fastenings on the Docklands Light Railway (22.10.04)

FES0410-04/13

Figure 4.9 Alternative plain line slab track resilient fastenings on the Docklands Light Railway (22.10.04)

FES0410-04/14

Figure 4.10 Slab track resilient rail fastening on the Docklands Light Railway (22.10.04)

FES0410-04/14

Figure 4.11 Slab track resilient rail fastening on the Docklands Light Railway (22.10.04)

(a) Pandrol VIPA-SP resilient track fastening

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(b) Baseplate positioned for grouting

Photo courtesy of Pandrol UK Ltd

(c) Formwork around baseplates prior to pouring grout

Photo courtesy of Pandrol UK Ltd

Figure 4.12 Pandrol VIPA-SP track fastenings used on the City Airport extension of the Docklands Light Railway

Photo courtesy of Pandrol UK Ltd
(a) Baseplate grouting completed

Photo courtesy of Pandrol UK Ltd
(b) Baseplate grouting completed

Figure 4.13 Completed slab track on the City Airport extension of the Docklands Light Railway

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(a) ‘Cologne Egg’ resilient rail fastenings

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(b) Plain line

Figure 4.14 Slab track rail expansion joints on the Docklands Light Railway (22.10.04)

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(a) A transition between ballasted and slab track on

FES0410-04/04

(b) Plain track

Figure 4.15 Ballasted track on the Docklands Light Railway (22.10.04)

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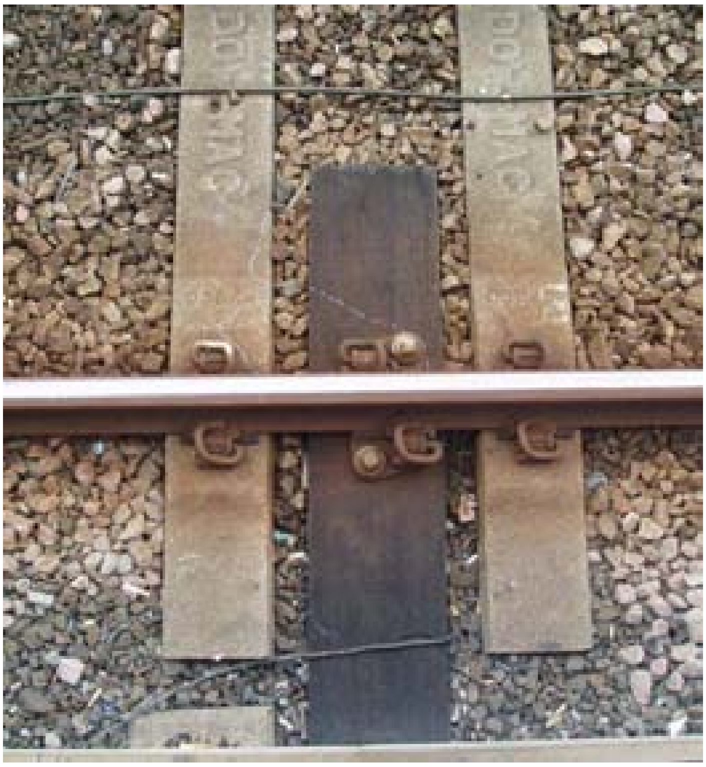
(a) Timber sleepers



(b) Timber platform spacer

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Figure 4.16 Ballasted track on the Docklands Light Railway (22.10.04)

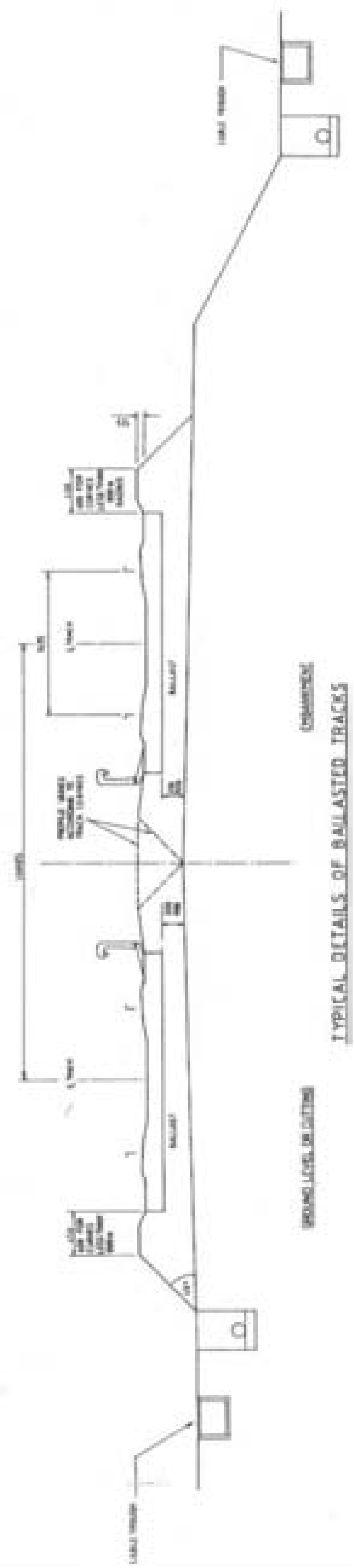

Figure 4.17 Typical section through ballasted tracks at ground level, Docklands Light Railway

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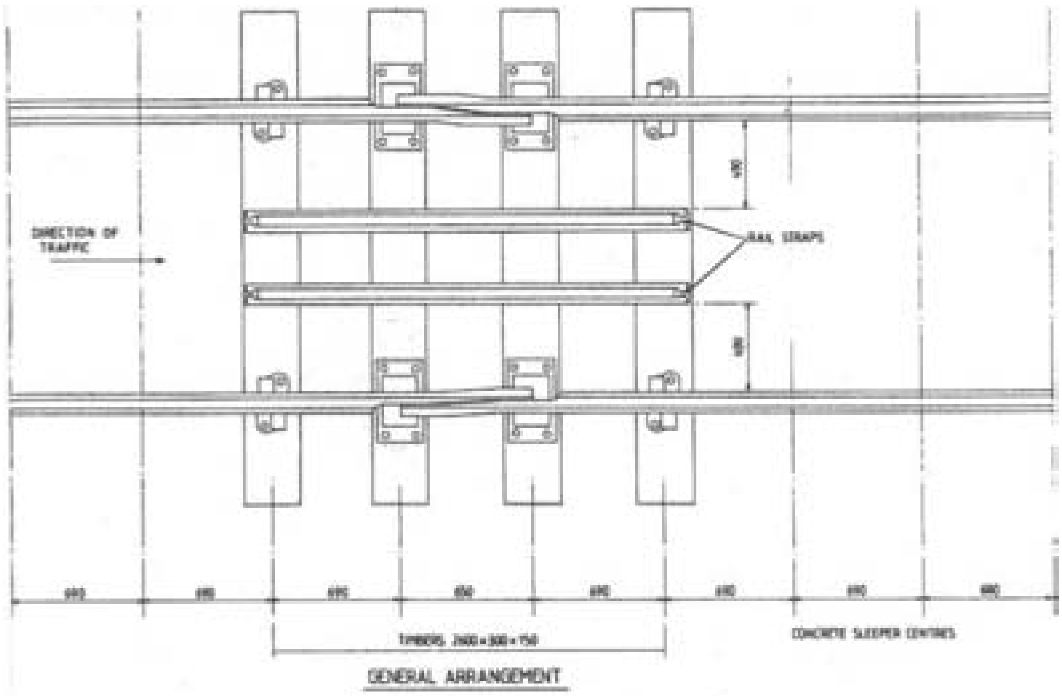
(a) Expansion joint (22.10.04)



(b) Plan view of expansion joint

Figure 4.18 Typical rail expansion joint for ballasted track, Docklands Light Railway

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Figure 4.19 Slab track turnout at the North Quay Junction on the Docklands Light Railway (22.10.04)

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Figure 4.20 Slab track pivoted crossing nose turnout at Canary Wharf on the Docklands Light Railway (22.10.04)

DL Bateman

Figure 4.21 The original design of slab track swing nose turnout Docklands Light Railway

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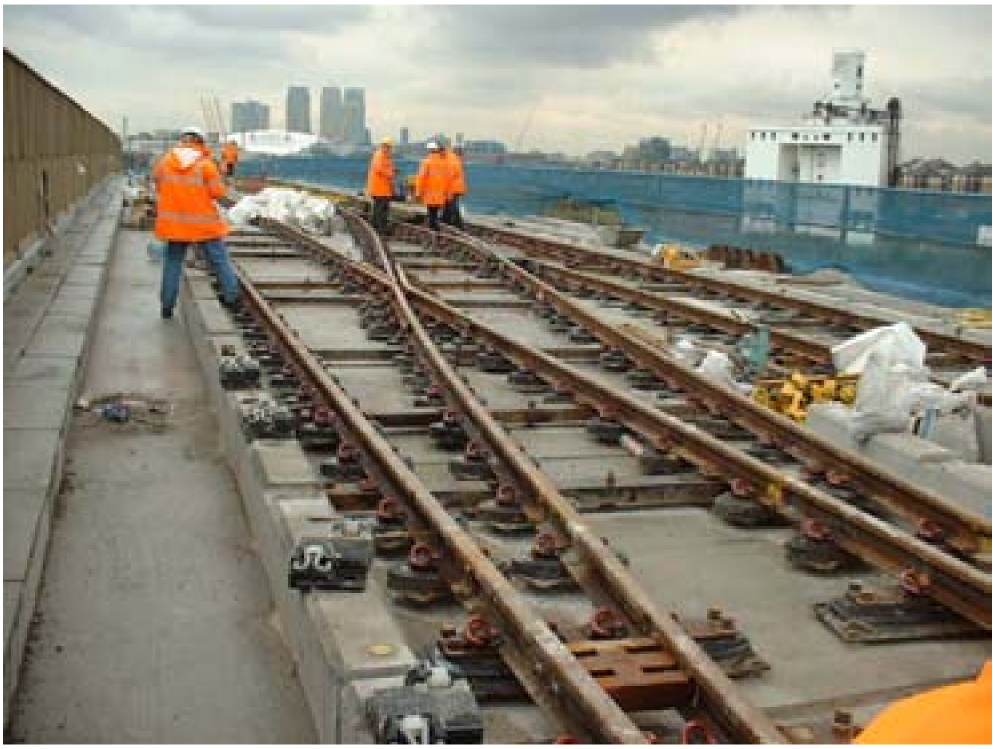
Figure 4.22 Slab track turnout ‘Cologne Egg’ rail fastening, City Airport extension of the Docklands Light Railway



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(a) Crossing

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(b) Switch rails

Figure 4.23 Slab track turnout under construction using 'Cologne Egg' rail fastenings, City Airport extension of the Docklands Light Railway

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Figure 4.24 Ballasted track turnout linking the Beckton Up line to the City Airport extension of the Docklands Light Railway

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Figure 4.25 Scissors crossover at Lewisham on the Docklands Light Railway (22.10.04)

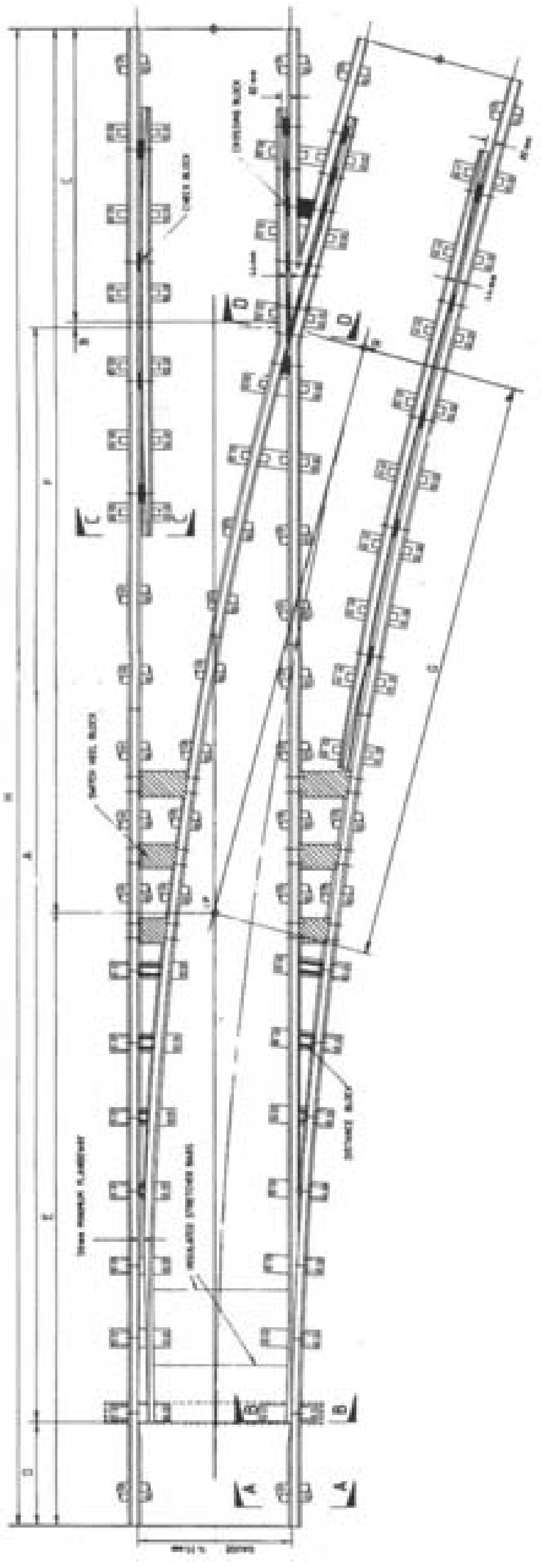

Figure 4.26 Docklands Light Railway standard turnout form with terminology

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Figure 4.27 Conductor rail expansion joint prior to installation of the protective shroud, City Airport extension of the Docklands Light Railway

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Figure 4.28 Docklands Light Railway Class B92 Units 58 & 79 at Poplar (16.08.01)

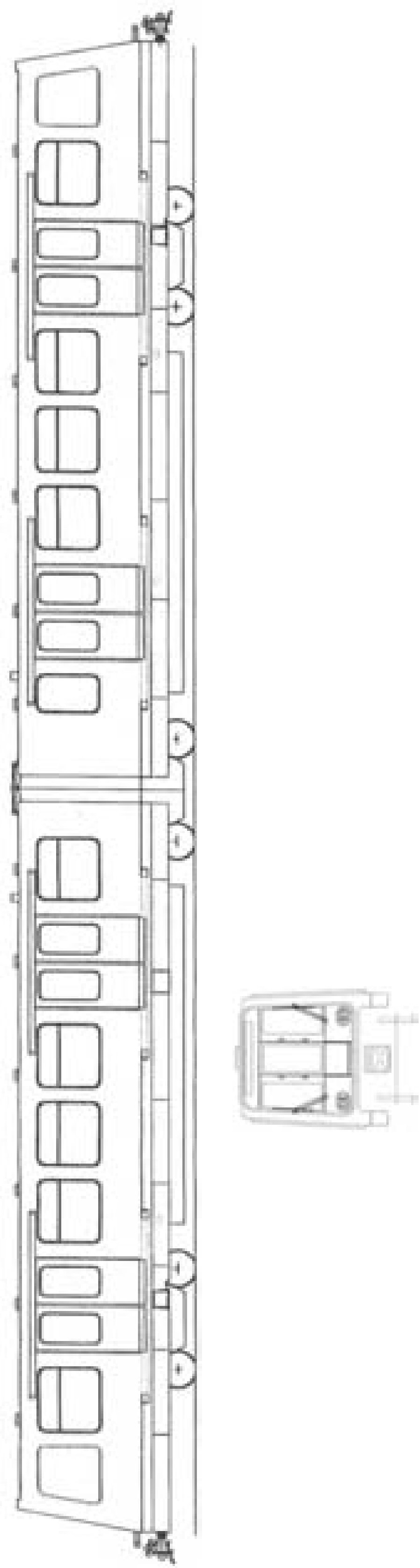

Figure 4.29 Docklands Light Railway Type B92 articulated vehicle