The Docklands Light Railway

GEC

Transportation Projects

Aerial view showing the Docklands Light Railway crossing the West India Docks with the Delta Junction and the Operations and Maintenance Centre at the top of the picture.

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THE DOCKLANDS LIGHT RAILWAY

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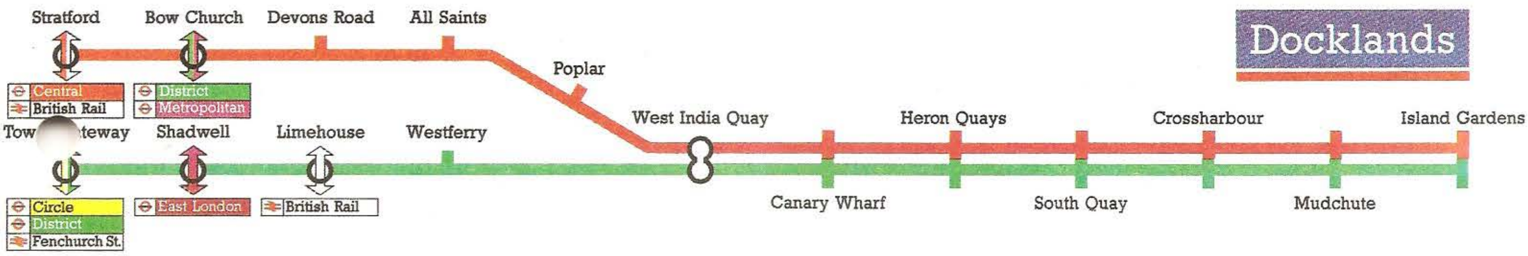
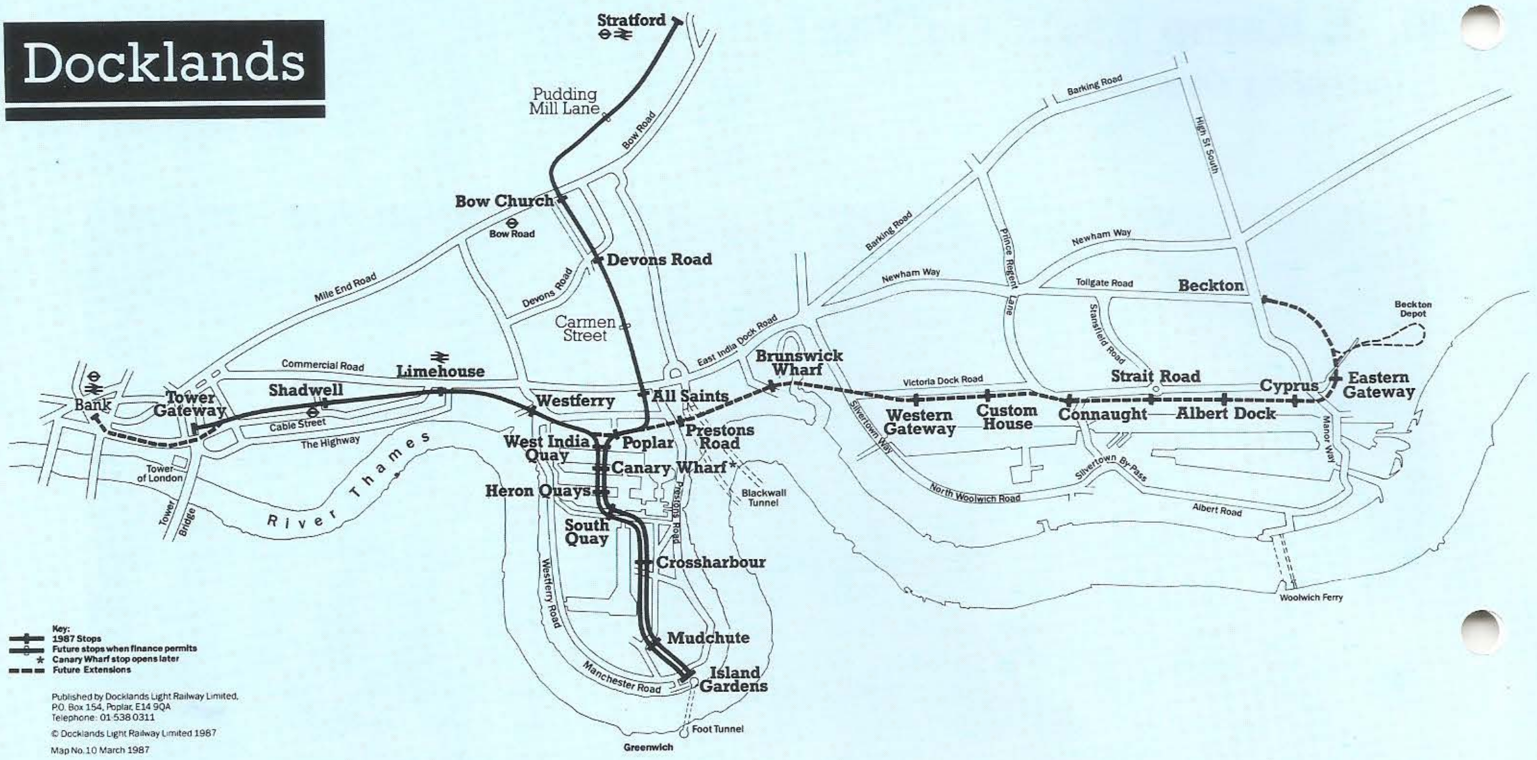
The Docklands Light Railway is a fully automatic electrically powered light railway which runs on a 15km route between the City of London and the recently rejuvenated Docklands Development Area. The railway uses articulated vehicles which are very quiet and of modern design. Individual vehicles are controlled by on-board microprocessors containing stored route data and the whole system is regulated and monitored from a central computer system.

The GEC-Mowlem Railway Group (a Joint Venture of Mowlem (Civil Engineering) Limited and GEC Transportation Projects Limited) was awarded a turnkey contract to design, construct and commission the railway. This type of contract, which is novel in the railway industry in the United Kingdom, offers the Railway Authority the advantage of a centralized management structure covering all aspects of the project from initial design studies to final acceptance tests for the complete railway including civil works, fixed systems and rolling stock.

The Light Rail technology chosen for the railway offers several advantages. Capital costs are low because the light-rail vehicles are not only cheaper themselves but also do not require massive civil works; they also allow rapid installation and commissioning. Running costs are lower because the vehicles use less energy than conventional rolling stock and incur lower maintenance costs. The small vehicles can negotiate tighter curves and steeper gradients, which allows the most economical use of land in a congested urban environment. All these features have been utilized to provide an economic and modern transportation system in keeping with the image of the Docklands Development Area.





Route map of the initial system showing proposed extensions westwards to the City and eastwards to the Royal Docks and STOLPORT.

THE ROUTE

The first phase, commissioned in 1987, provides regular 7.5 minute services between Tower Gateway and Island Gardens and between Stratford and Island Gardens. The second phase will extend the Western route into a new station in the heart of the City where it will connect with existing Underground lines. Subsequent routes are planned to Beckton and the STOLPORT being constructed on the Royal Docks site in East London.

The capability of LRT vehicles to run round tight curves has been fully exploited in the design of the North Quay Junction which is laid with 40m radius trackwork. (For comparison the tightest curves on BR passenger routes are 120m radius.) Curves of 50m radius are used between South Quay and Crossharbour, where the route winds through the new developments, and also where the line leaves the old North London Railway (previously known as the East and West India Dock and Birmingham Junction Railway) to joint the BR route to Stratford.

The other feature of LRT vehicles that has been exploited in Docklands is their ability to climb steep gradients. Between Poplar Station and North Quay Junction the gradient is 5%. (This compares with the steepest BR gradient of 3%). On the Western extension there will be 300m gradient of 6% as the line descends from the elevated track section at Tower Gateway to run below the LUL District and Circle lines at Tower Hill.

The combination of the ability to climb steep gradients and the ability to negotiate sharp curves has allowed the

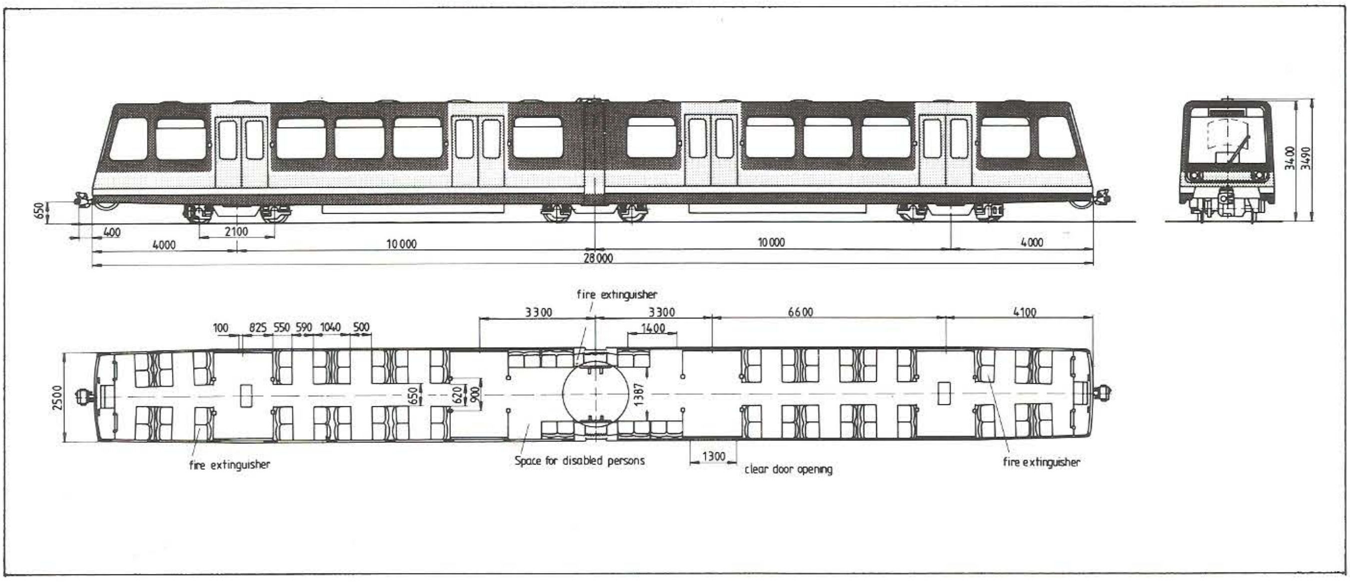
The steep gradient and sharp curvature is clearly seen on this section of the northern route.

DLR to utilize long-derelict rights of way and (for new construction) to avoid property development. From Tower Gateway to Limehouse the route runs parallel to the BR Fenchurch Street Line; at Limehouse it runs on the course of the London and Blackwall Railway that opened in 1840 and was closed to traffic in the 1960s. South of North Quay the route uses new light concrete structures and eventually joins the course of the Millwall Extension Railway to run into Island Gardens. This section of the route is over a viaduct, built in the 1870s, which is a listed structure and which is only wide enought to carry a single track. The inclusion of a single line section on a route which carries 16 trains/hour in each direction provided a challenge to the designers of the operating system!

Looking towards the Delta Junction from Poplar Station.

One of the new bridges across the docks.

THE VEHICLES



Layout of the articulated light rail vehicle.

The initial system is operated by 11 vehicles — 9 are in service and 2 are on standby or under maintenance at any time. The extension to Bank will involve an increased service frequency on the Western leg of the network and the ultimate fleet size will be much larger. Auto-couplers allow trains to be formed of up to three vehicles.

Each vehicle is 28m long; it has 84 seats and standing room for up to 140 passengers. The doorways have been designed so that the floor is level with the platform edge to cater for wheelchair-bound passengers and two spaces have been allocated for wheelchairs. Because the vehicles are automatically driven they do not have cabs and passengers in the front seats can enjoy a panoramic view through the full width window.

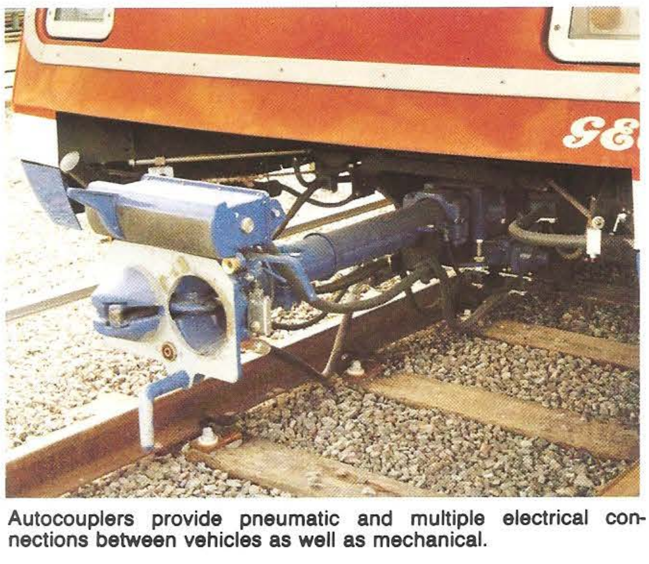
The lightweight vehicles (39 tonnes tare, 53 tonnes laden) are articulated and supported on three bogies by air suspension. The outer bogies are powered whilst the centre bogie is unpowered and supports a turntable carrying the articulation section. The weight balance is such that, under fully loaded conditions, 70% of the weight is on the powered bogies; this assists the hill-climbing ability of the trains. The vehicles have auto-couplers and the controls are designed so that all coupling and uncoupling can be carried out by one person from inside one of the vehicles.

Large picture windows and clean internal lines provide a pleasant environment for passengers.

The spacious interior provides ample room for standing passengers and the wide vestibule by the articulation enables them to move freely through the vehicle.

The clean interior lines are carried through the articulation section.

Passengers with impaired mobility are catered for with special wheelchair alcoves on the vehicles and minimum gaps between the vehicles and the edges of platforms. Hydraulic lifts are available to carry the disabled from platform level to street level.



Autocouplers provide pneumatic and multiple electrical connections between vehicles as well as mechanical.

The vehicles *(continued)*

The vehicle bodies are of steel welded construction made from rolled and folded sections and sheets. The recessed roof has concealed drains preventing both water running over passengers boarding and alighting and unsightly streaking caused by dirt being washed off the roof onto the walls. The floor is a high density wood composite for sound absorbance covered with a non-slip synthetic material. Internal trim is glass reinforced plastic with stainless steel lighting diffusers.

The power system uses chopper control with **gate turn-off** (GTO) thyristors. Unlike conventional thyristor choppers these do not require heavy and bulky commutation circuits. The two motors are fed from a common chopper and drive the axles in each powered bogie via two right-angled gearboxes and flexible couplings. Extensive use is made of rubber in the suspension and drive system to minimise noise transmission and there is also rubber between the wheel rim and the hub to reduce wheel/rail noise. Electrical braking is rheostatic with the energy being dissipated from naturally cooled resistors on the underframe of the vehicle.

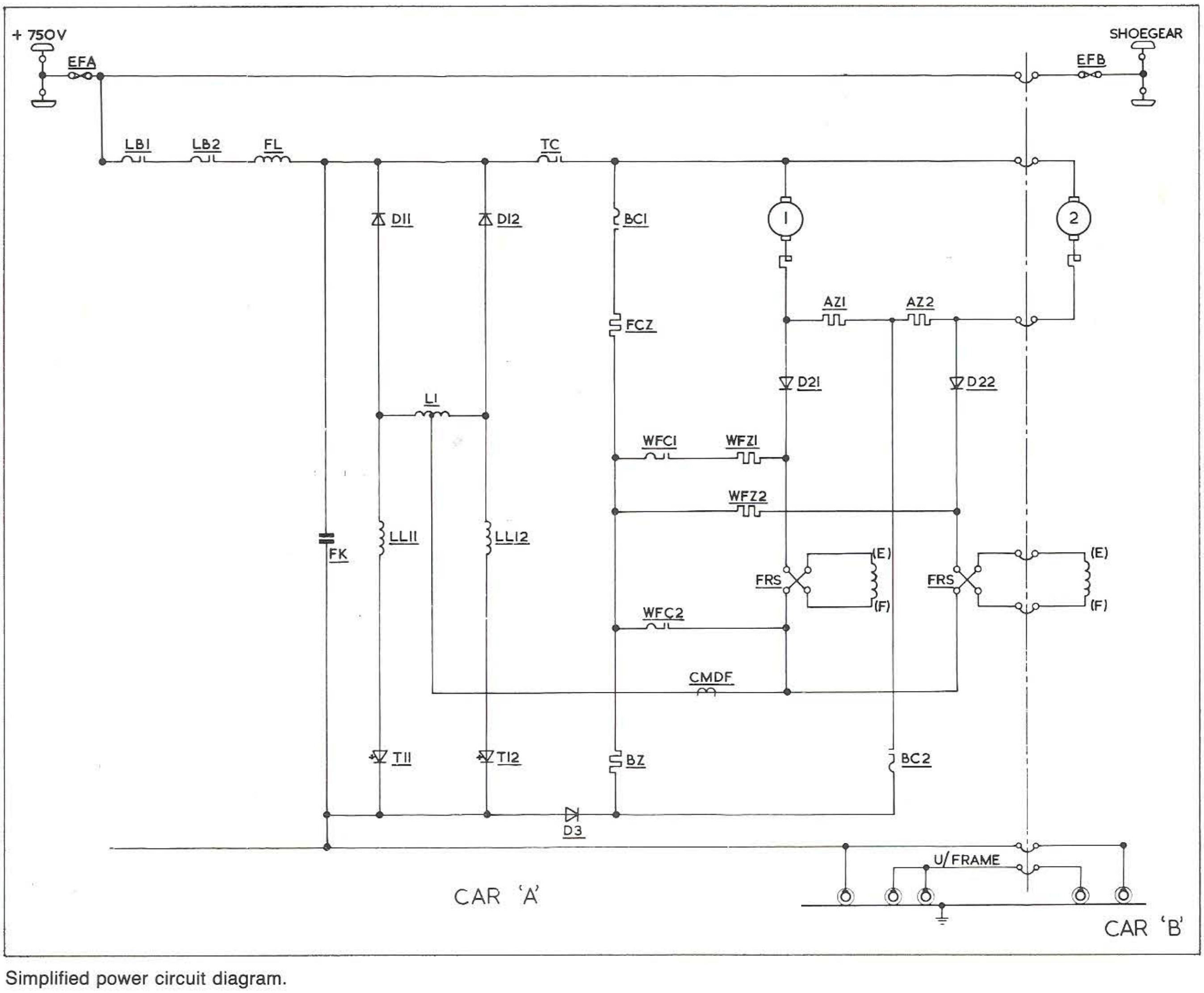
The line filter comprises inductor FL and capacitor FK. This filter performs three functions: it presents a low impedance source to the chopper, presents a high impedance to the ac voltage in the third rail supply and filters out chopper generated ripple. On some rail projects it has been necessary to use large filter components to cope with power frequency signalling, but the DLR uses audio frequency track circuits and benefit has been taken of this in the selection of filter parameters.

The interphase inductor, L, is used to minimise motor current ripple and to share the current between the two interlaced GTOs T_{11} and T_{12}. Each GTO operates at a chopping frequency of 264Hz which produces a line supply ripple of 528Hz. The choppers are controlled by a microprocessor and a frequency watchdog circuit ensures that the chopper frequency does not deviate into signalling frequencies.

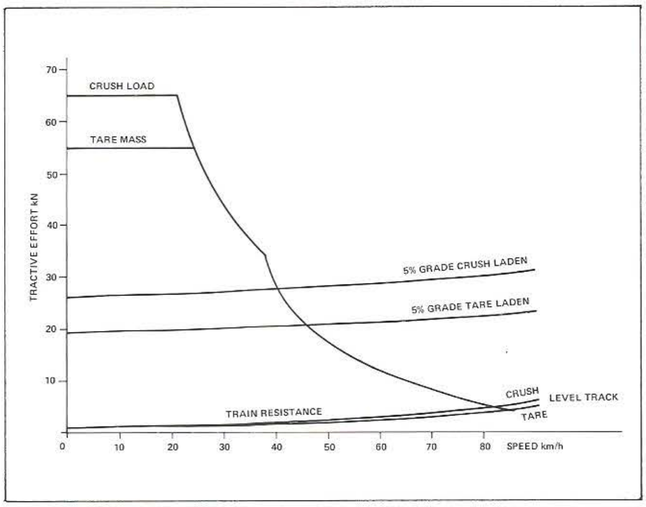
A GTO thyristor static auxiliary convertor is used to provide a nominal 24V dc supply for charging the vehicle battery and providing control and auxiliary supplies.

Trains are braked by a fully blended system using rheostatic electric and pneumatic brakes on the motored bogies and pneumatic brakes on the centre bogies. The blending is designed to minimise the amount of air braking and hence to extend brake pad life. Parking brakes are spring applied and released by air pressure.

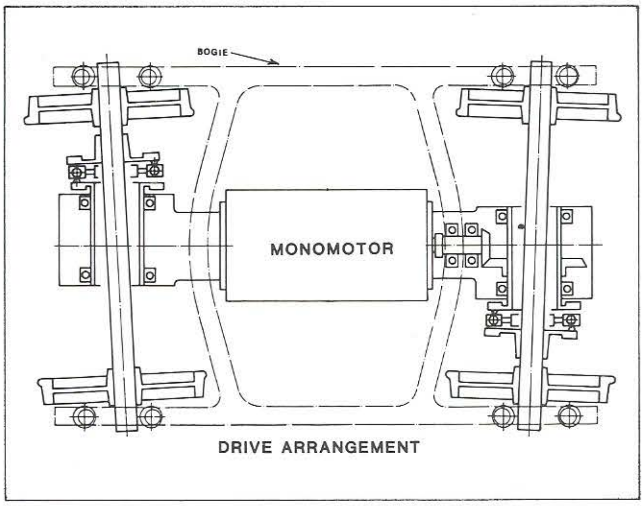
The vehicles are fully automatic and, in normal conditions, the only responsibility of the operator, or train captain, is to close the doors. At each end of the cars is an **emergency driving position** (EDP) from which the trains can be controlled in the sidings or during emergency workings. Controls for operating the doors are available both on the EDP which is locked in normal service, and on the door lintel.



Simplified power circuit diagram.

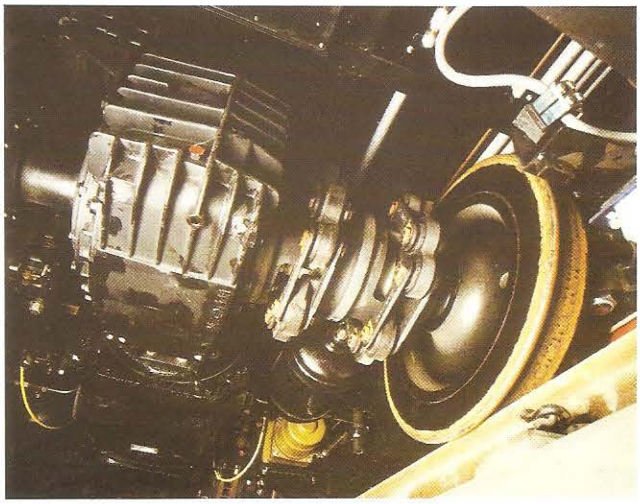


Vehicle performance.



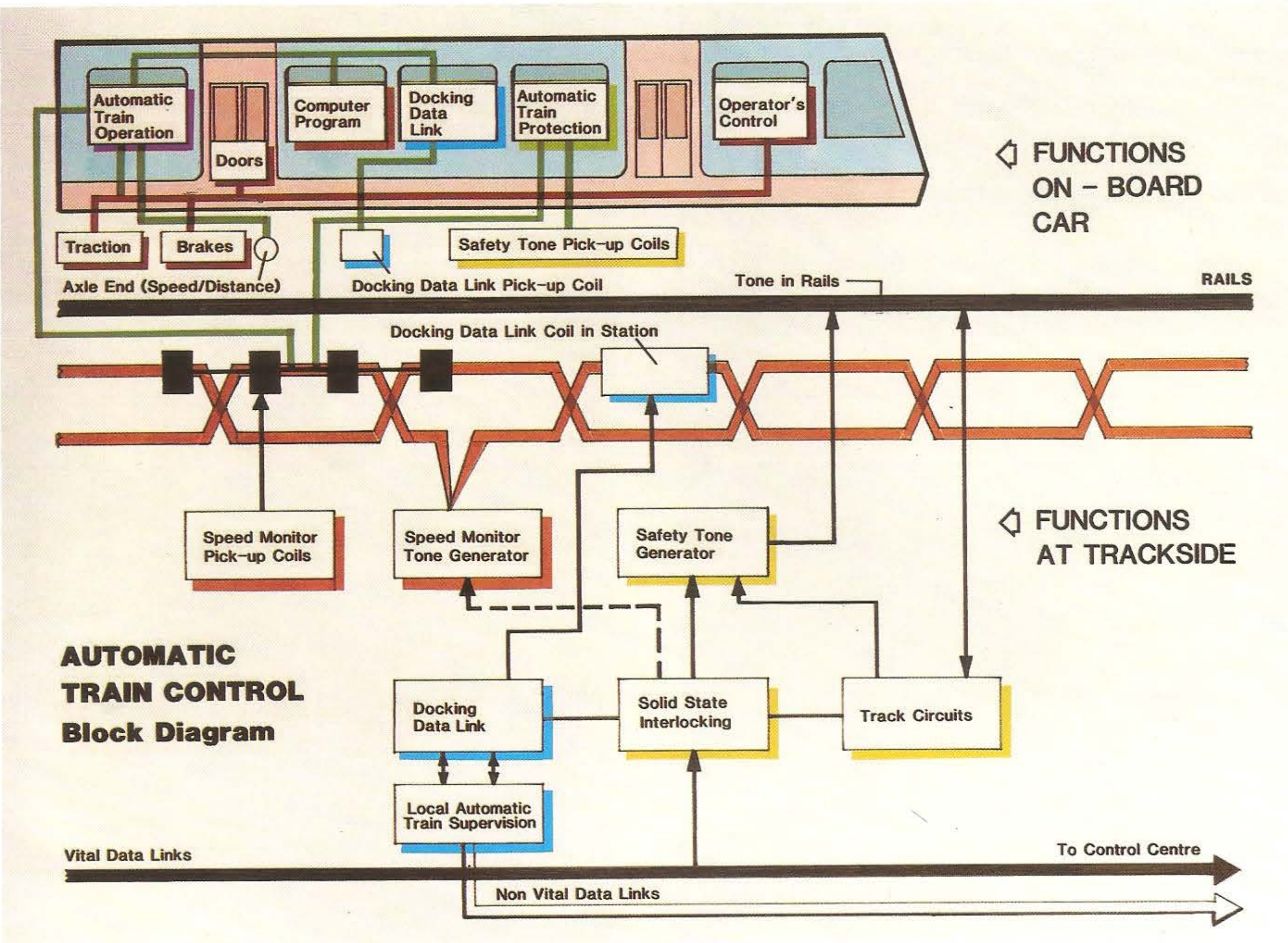
Arrangement of the powered mono-motor bogies (above) and a close-up of the flexible final drive.

The train captain can speak to his passengers using the on-board public address system located on the articulation section whilst his door controls are located above each doorway.



The trains can be operated from an Emergency Driving Position (EDP) at each end of the vehicle. Normally the EDP is covered by a locked lid and is used only in the depot area or if there is an equipment failure.

AUTOMATIC CONTROL



Block diagram showing the inter-related functions of the automatic train control equipment.

The operation of the DLR depends on two automatic systems — the **automatic train operation** (ATO) system drives the train from station to station as required by the timetable and the **automatic train protection** (ATP) system supervises the railway, ensuring that trains observe speed limits and only proceed when safe to do so.

The timetables for the railway are held in computer memory in the **Operations and Maintenance Centre** (OMC). At the start of each day the controller selects a timetable from the memory (e.g. Weekday, Sunday, Bank Holiday) as the working timetable for that day. By radio he or she calls up vehicles and instructs their operators to drive them to a **docking data link** (DDL) at the exit of the OMC. Once over the DDL the central computer can, after some safety checks, communicate with the ATO computer on the train and instructs it to run to the first station.

At each station the train's ATO computer re-establishes communication with the central computer system via a DDL. Once it is established that the train is safely docked at the platform the doors on the appropriate side are automatically unlocked. The passengers are then able to open individual doors by pushbuttons. A few seconds before the scheduled departure time (or 10 secs after arrival if the train is running late) the train operator is warned to close the doors by a short audible signal on the train's public address system. Once the doors are closed and locked the central control system instructs the train's ATO computer to run to the next station.

Close-up of the signalling controller's vdu screens.

Data docking link (DDL)

General view of the control room. The signalling control screens and keyboards are in front of the operator, the power control screens (SCADA) are on his left side and the closed circuit television (CCTV) monitors are on the upper part of the desk. The master time clock is in the centre of the desk.

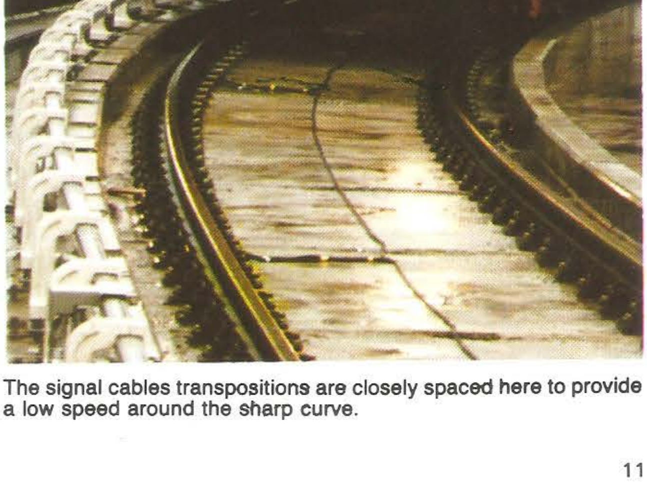
The ATO computer on each train contains two alternative **run profiles** to drive it from one station to the next. Each run profile contains instructions like **"accelerate to 60 km/h, hold that speed for 600 metres then brake and stop after a total distance of 945 metres"**. One run profile is for the **minimum journey time** and the other is an energy saving profile that uses **coasting** and takes about 10% longer (saving some 30% energy in the process). Normally the central computer system instructs all trains to use the coasting profile to save energy but, if a train is late, it is instructed to switch to the minimum journey time profile until it has caught up with the timetable.

The central computer control system contains logic to route trains into a preferred platform at terminal stations and it automatically establishes priorities at the North Quay Junction and over the single track sections into Island Gardens and Stratford stations. The controller monitors the performance of the system on colour VDUs in the OMC and can intervene to change priorities, hold trains or insert special paths (for example for track maintenance vehicles) from the keyboard.

The Automatic Train Protection (ATP) system is separate from the ATO system described above. It has two functions: to ensure that the trains observe speed limits and to prevent unsafe train movements (for example to prevent two trains entering the same track section or to prevent conflicts on the single track sections or at junctions).

The speed limits are enforced by detecting the transpositions of a pair of cables laid in the track. These are laid so that when the train is running at its maximum permitted speed the train crosses a transposition once a second. A 470Hz signal is transmitted along the cables., On the centre bogie of the trains coil pick up the signal by induction and detect the phase-reversal caused by the cable transposition. This starts a timer and, if the next transposition is detected within one second, the emergency brakes are applied. (If the ATO is operating correctly the vehicle speed should always be below the ATP speed limit.)

The movement of trains is monitored by a conventional signalling system. Audio frequency reed track circuits detect the presence of trains and transmit the information to a central group of **Solid State Interlockings** (SSI). This is a safety signalling



The signal cables transpositions are closely spaced here to provide a low speed around the sharp curve.

SSI (solid state interlocking) cubicles and line printer.

system that has been adopted by BR in place of the traditional relay systems. Two SSI cubicles are used for the Initial System with a third being used for the additional interlocking needed for the Bank Extension. On a main line railway the SSI trackside units drive coloured light signals; on the automatic DLR the equivalent of a **Green** aspect is sent to the train by transmitting a 408Hz signal along the rails which is detected by two coils placed ahead of the leading axle. This is the **permission to proceed** signal which is detected by the ATP system on the train. Without this signal present the train emergency brake is applied.

Under normal operating conditions the ATP information is input to the central ATO system to ensure that the trains are not despatched towards occupied sections which would result in emergency brake applications. Trains normally run from station to station. However, near junctions and on long sections when one train does not leave a station until the following train is approaching, special **pseudo-stations** are used. These are located just before the real station or the junction and a train can be instructed to drive to the pseudo-station. Then, when the route is clear, a signal is sent down the rails which causes the ATO to switch from a profile that would cause the train to stop at a psuedo-station to one that runs through to the next real station.

During maintenance possessions on the track and for unscheduled train movements it is necessary for the train operator to take control of a vehicle. Two manual modes are provided: one is supervised by the ATP system and the operator is allowed to drive at any speed up to the line limit. The other is unsupervised and the train speed is limited to 20km/h. The former is intended for use on the main line and the EDP has two lights, one (driven by the ATP system) indicating that the permission to proceed tone is present on the track and the other (operated from the ATO system via the DDL) shows that the route is clear to the next station.

Fibre optic indicators and ground signal at the exit from the OMC.

TELECOMMUNICATIONS

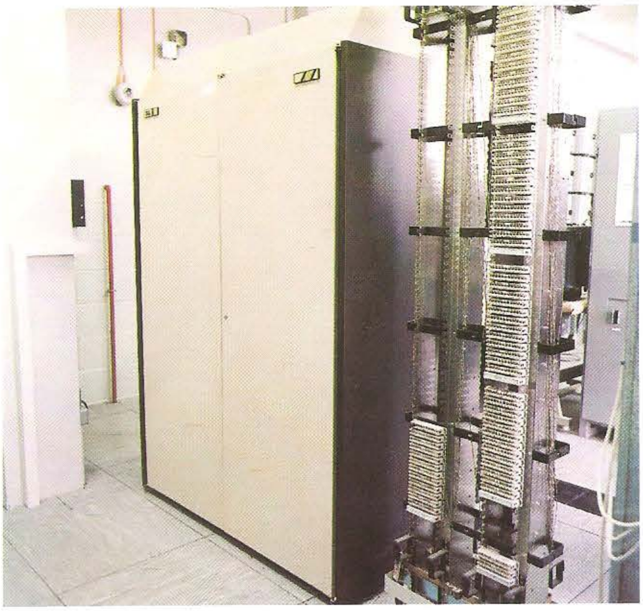
The DLR has been equipped with comprehensive telecommunications and surveillance systems. Stations are unmanned and have closed circuit television (CCTV) monitoring every platform. The controller in the OMC has the ability to monitor any platform. Each platform is equipped with a passenger alarm which comprises an alarm button and two-way speech communication. When a passenger alarm is detected from any station, the appropriate video channel is automatically displayed on the controller's console and a video recorder is automatically started. The video signals from remote stations are transmitted to the OMC by optical fibres.

In addition to the video recorder on the CCTV system, a multi-channel audio recorder automatically records alarms and all radio and telephone messages to and from central control. These in conjunction with the data logger installed in the signalling control computer, allow the DLR management to review the sequence of events in any incident.

All train captains and maintenance supervisors are in touch with the OMC controller by two-way radios. Because the train captains are expected to move around the vehicle, they have been supplied with personal radios rather than fitting a radio to one point on the vehicle.

Direct line telephones have been provided between stations and also between critical power supply installations. An electronic PABX provides modern communications between all the offices, the platforms and the station equipment rooms. Special telephone arrangements have been made between the DLR controller and the signal boxes and power controllers of adjacent BR routes to ensure quick communication in the event of an accident on those sections of track.

On the stations automatic destination indicators are driven from the central computer system to indicate the time, the destination and time of arrival of the next train. A public address system, also driven from the central computer, can make announcements of the next train's destination. Both of these systems can be manually overridden by the central controller or by staff at the station equipment rooms.



PABX automatic exchange.

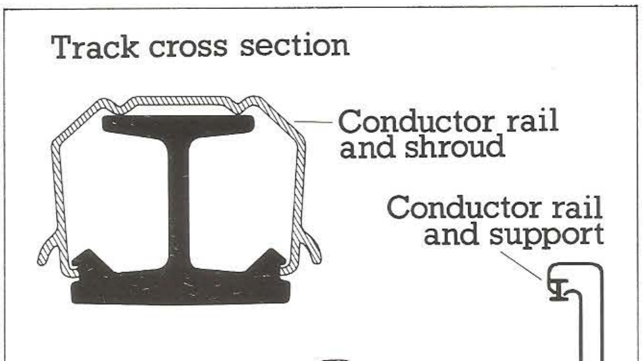
The vehicles are fitted with public address systems that can be used by the operator — like all train systems they are enabled by a special key to prevent unauthorized use. There is also a destination indicator, visible from both inside and outside, controlled from a central location on the vehicle..

Illuminated platform indicators give information about the next train as well as general information.

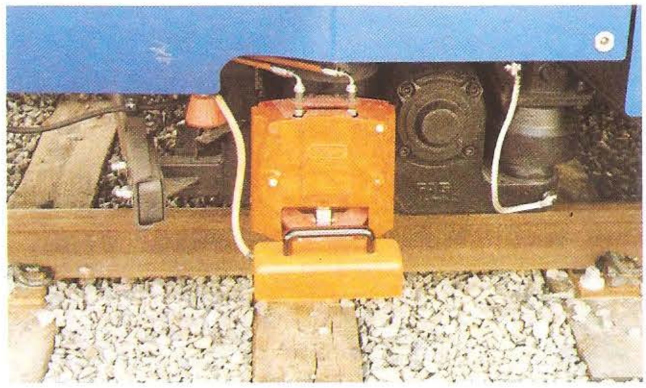
POWER SUPPLY

For the Initial System the 750V power supply is provided by a single substation located at Poplar. Track paralleling breakers are provided at the ends of the double-track sections on each leg of the initial system to reduce voltage drop. Additional substations will be located at Royal Mint Street, Crossharbour and Bow to reinforce the system to cope with the greater loads of the Bank extension. The power is transmitted to the train by a laminated conductor rail. The main part of the rail is aluminium which, for a given weight, has an electrical conductivity ten times better than steel. The running surface is stainless steel to give a very smooth interface with the shoegear.

The bottom-contact collector rail was chosen to reduce the effects of ice and snow that plague conventional top-contact systems and it is fitted with an insulating shroud to reduce the risk of inadvertent contact. The voltage drop is much less than would be obtained from an overhead system. The visual intrusion on lightweight civil structures was also an important consideration.



Cross-section of third rail with its protective plastic shroud and also showing the relative position of the conductor rail to the running rail.



Top The conductor rail is curved upwards to provide a smooth transition. In this view the copper collector above is shown in its lowered position.
Above The power collection shoes can be fitted with a protective cover when not in use.
Below The protected conductor rail on a curved section of the main line.

Power supply *(continued)*

Control of the OMC is from two VDUs in the control room. The supervisory, control and data acquisition system (SCADA) enables the controller to identify the state of each circuit breaker, monitor the power consumption of the system and receive alarm and trip indications. Each circuit breaker on the 11kV and 750V dc systems can be controlled by a **mouse** or via the keyboard. All events are logged and are recorded on a printer.

Power control (SCADA) screens. The left hand screen is showing a system overview and the right hand screen is showing the DC switching diagram for Poplar substation. Control can be from the keyboard or from a "mouse".

THE OPERATIONS AND MAINTENANCE CENTRE

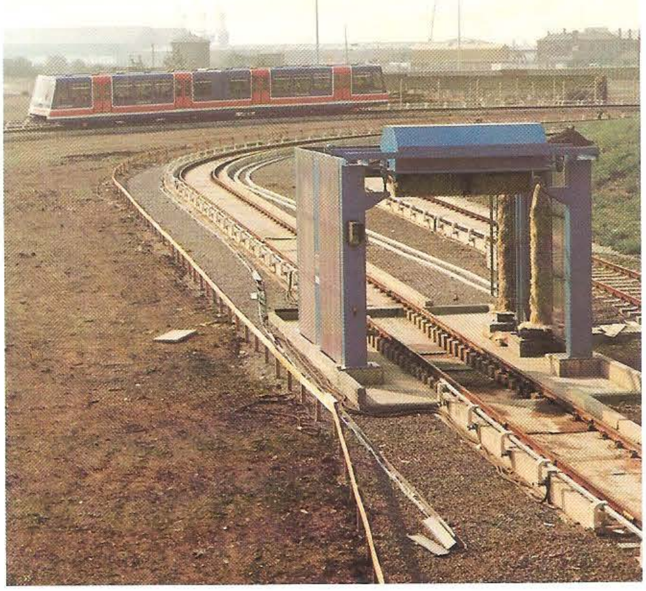
The Operations and Maintenance Centre (OMC) and stabling sidings as seen from Poplar Station.

The Operations and Maintenance Centre (OMC) houses all the administrative functions of the DLR, the control centre and the maintenance facilities. It is a modern building situated close to Poplar passenger station. The control room, situated on the first floor, has a glass wall through which the controller can see the Delta junction and the Western approach to the depot. On the lower floor, also airconditioned, is the computer room containing the signalling, telecommunications and SCADA computers and their associated equipment.

The OMC has a workshop area with accommodation for three articulated vehicles. One track, allocated to heavy maintenance, has lifting jacks and turntables to facilitate the removal of bogies. A 750V shore supply is provided in the workshop for testing of power equipment. Stabling sidings, a bogie steam cleaning plant, a carriage washer and stabling sidings are also provided out of doors in the OMC.

Poplar station from the controllers' desk in the control room showing the passenger alarms, CCTV monitors and public address controls on the desk.

Part of the workshop section of the OMC showing a vehicle jacked-up during commissioning.



The vehicle washing plant immediately outside the OMC

The GEC-Mowlem Railway Group.

Joint venture contractors for the Docklands Light Railway turnkey contract.

GEC Transportation Projects Ltd were responsible for all electrical and mechanical aspects of the project. Principal sub-contractors included:-

GEC Traction Ltd.
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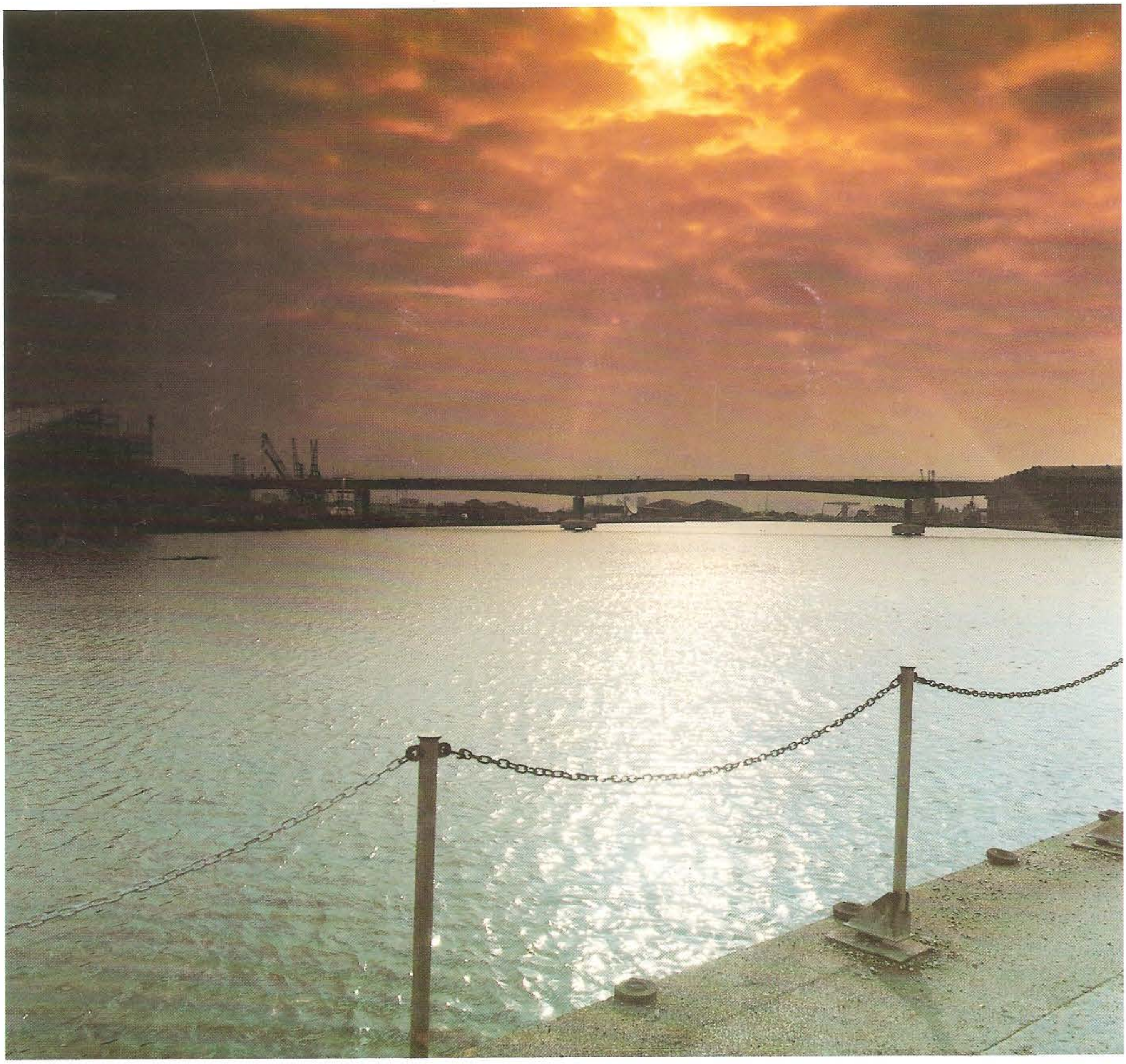

Crossing the West India Docks.

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