TRAMWAY DESIGN AND CONSTRUCTION

This section provides guidance on the design of trams and the construction of tramways.

General Guidance

- A tram should be designed so that it is safe for its users (passengers as well as members of staff) and does not endanger other users of the highway (including pedestrians) as well those in the immediate vicinity of off-street sections.

- Although trams are not subject to the mandatory requirements for road vehicles, they should nevertheless include features in their construction and performance that make them safe for use on the highway and in other places where they share the infrastructure with other users.

- In general, a tram that operates on-street should conform to the current Road Vehicles (Construction and Use) Regulations 1986 for road vehicles **here** so far as appropriate. These Regulations cover all aspects of road vehicles including weights, dimensions, safety items and environmental standards and are updated progressively by the UK Government alongside updates to any rules on vehicle safety or operation.

- Much of this regulation derives from Directives of the EU, and these in turn derive largely from United Nations Economic Commission for Europe (UNECE) Regulations **here** and are globally agreed standards.

- The website of the UK Vehicle Certification Agency (VCA) has a list that shows which of these UNECE regulations have been translated into EU Directives **here** and which in turn are (or will be) implemented in the UK through amendments to the Construction and Use Regulations. The UK withdrawal from the EU has not affected the content or locus of the UK Regulations.

- The VCA website also has useful summary diagrams for buses and goods vehicles that show which Directives / Regulations apply to which aspects of those road vehicles.

- The guidance given in the section below is in line with the above Regulations.

Compatibility

The relationship between road traffic light signal and point controllers should be integrated.

A tram to be used on the highway should be equipped with a system of communication to permit it to be detected by road traffic signal controllers so that the appropriate stage and phase can be called on the road traffic signals.

The system should also be able to request a specific route at junctions and actuate the safe operation of the points.

External Lighting

The external lighting of trams which run on-street should conform so far as practicable with the Road Vehicle Lighting Regulations 1989 (as amended) **here** to achieve the following objectives:

(a) in the forward direction, it should uniquely identify the vehicle as a tram,
(b) bi-directional trams should carry the full range of lights and reflectors for running in either direction, and
(c) lights and reflectors on the sides of the tram should be similar to those required for large goods vehicles rather than those for PCVs.

The arrangements shown in Table 9.1 below as provided in the above Regulations are considered to meet the objectives:

Table 9.1: External Lighting

	Facing Forward	Facing Rearward	Along the Sides
Headlights	Two white dippable and a third white dipped mounted centrally above them	-	-
Position Lights	Two white	Two red	-
Outline Marker Lights	Two white	Two red	-
Side Marker Lights	-	-	At least three for a 30 m long tram - amber
Direction Indicators	Two amber	Two amber	Amber (combined with side marker lights)
Reflectors	Two amber (may be combined with direction indicators)	Two amber (may be combined with direction indicators)	At least three for a 30 m long tram - 1 m above road level - amber
Brake Lights	-	Two or two clusters - Red	-
Fog Lights	-	Two high-intensity - Red	-
Hazard Lights	Two amber	Two amber	Flashing amber side markers

As an alternative to a third centrally-mounted high-level white light (the ‘cyclops’), a suitably large and well illuminated destination indicator may be able to perform the same function, as long as it is always lit.

Further Regulations include:

- Community Directive 76 / 756/EEC **here** addresses overall road vehicle lighting installations and is implemented in the UK through the Vehicle Lighting Regulations 1989 (as amended), and
- UN / ECE Regulation 113 (Uniform provisions concerning the approval of motor vehicle headlamps emitting a symmetrical passing beam or a driving beam or both and equipped with filament, gas-discharge light sources or LED modules) defines dimensions, colour of light output and luminous intensity. UN / ECE Regulation 48 (Uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices) defines positioning, alignment and visibility.

Lamp Positions

Lamps should be positioned as close as practicable to the positions prescribed within the Road Vehicle Lighting Regulations 1989 (as amended) **here**.

Due allowance should be made for the construction and shape of the ends of the tram in permitting variations from the specified heights and distances from the sides.

Whilst exempt from the requirements of the Construction and Use Regulations trams should be designed to follow, as far as possible, the requirements placed on PCV and goods vehicles. This provides consistency of visibility for other road users.

Given the above, the following guidelines are generally considered to offer a suitable arrangement:

(a) all the lamps, except the centrally-mounted headlight and the side-mounted lights, should be placed as close as possible to the side of the tram, preferably at a distance of not greater than 400 mm,
(b) front and rear position lamps and direction indicators should be approximately 1500 mm from the ground,
(c) the end outline marker lamps should not be below the top of the windscreen at either end, and
(d) the main pair of headlamps should be placed between 500 mm and 1200 mm from ground level and the central headlamp, above the windscreen.

In addition, trams running on-street should feature the following:

(a) all the headlamps, the position lights, end outline lamps and the side marker lights should be lit. The other lamps should be lit as the occasion demands,
(b) all the white lamps and none of the red lamps should show forward in the direction of travel and vice versa to the rear,
(c) the front, rear and side direction indicators should all flash together. If combined side marker lights and side direction indicators are provided, the indicators should be substantially brighter than the marker lights,
(d) the normal road vehicle configuration for hazard warning lights should apply, and
(e) for safety purposes, it should be possible to leave the hazard warning lights on with the driver's key removed.

The following lamps should be provided:

(a) three headlamps, front position lights and rear position lights,
(b) brake lights, and
(c) higher-intensity rear fog lamps (which may be used in place of the rear position light, but care should be taken not to override the visibility of the brake lights).

The side marker lamps required for other sections of tramway do not need to be lit on the off-street sections. It is not necessary for the direction indicators to operate on off-street sections unless required to do so by the operating requirements of the system.

Where different arrangements apply for on-street and off-street sections of a tramway system, a single selector switch should be provided in each driver's cab to change the configuration of the lights when changing from one type to the other.

The light output of the various lamps and size of reflectors should conform as near as practicable to those specified in the Road Vehicle Lighting Regulations 1989 (as amended). The following points relating to these Regulations should be noted:

(a) care should be taken not to oversize the side marker lamps,
(b) external 'door open' lights may be provided, but these should be designed so as to give no confusion with the lights required to be shown when the tram is in motion, and
(c) a tram should not display a red light or reflector at the front.

The Regulations provide for the use of light emitting diode (LED) light sources instead of filament lamp sources.

In the event of failure or loss of the low voltage supplies from the auxiliary converter or generator (as appropriate to electric or diesel-powered trams) the trams on board batteries should be capable of maintaining the external lighting, including the dipped beam headlamps. This should allow sufficient

time for the tram to be driven to a place where it can safely be removed from service if appropriate, or to allow time for it to be recovered by another vehicle.

The adequacy of light output should take account of the environments within which the tram will operate, for example, if running on unlit reserved sections of tramway.

Driving Mirrors and Rear-View CCTV

Except when trams run solely off-street, mirrors or other devices must be provided to give the tram driver a rearward facing view along both body sides when the tram is in motion. Such mirrors or devices should be included within the SE.

At tramstops, the tram driver should be able to clearly observe passengers boarding and alighting, to confirm no passenger has been trapped by a closed door and all pedestrians are adequately clear of the tram before it starts.

Whilst setting off and in motion, the tram driver should be able to observe traffic on either side of the tram, particularly in regard to under or over-taking vehicles. This is especially the case when ahead of commencing a turn off the main carriageway or when joining the carriageway.

The images presented to the driver should not be unduly affected by darkness, low angled sun, or prevailing weather conditions for example rain in dark conditions.

Consideration should also be given to providing drivers with visibility of any external parts of the tram which may be susceptible to surfing activity for example the rear end of the vehicle.

Where either CCTV or mirrors are used for rear viewing then consideration should be given to the ergonomic issues that arise in the driver's cab layout. The CCTV displays or mirrors should be placed so that they are easily visible to the driver from their normal position, without the need to unduly divert his attention from the road ahead.

There should be no significant loss of view alongside the tram between what can be seen directly from the driver's cab and through CCTV / mirror i.e. no blind spot.

From within the driver's cab the driver should be able to adjust the position or angle of any rear view mirrors, or the image quality of any CCTV displays.

The height of the mirrors or CCTV cameras relative to pedestrians, and in particular those standing on tramstop platforms, should be considered carefully so as to obtain the best compromise between visibility to the tram driver and the risks of pedestrians standing close to the platform edge being struck by them.

For CCTV systems, some further guidance may be derived from UN / ECE Regulation 46 (Devices for indirect vision and motor vehicles with regard to the installation of these devices).

Audible Warnings

Trams should be fitted with an adequate audible warning device at both ends of the vehicle. The warning emitted should be in keeping with the environment in which the tram runs. The warning should be loud enough to indicate the approach of a tram without causing injury or undue alarm to those in the proximity.

Audible levels for warning devices should meet the recommendations in BS EN 15153-2 (Railway applications. External visible and audible warning devices. Warning horns for heavy rail) and BS EN 15153-4 (Railway applications - External visible and audible warning devices - Part 4: Audible warning devices for urban rail). Guidance for the testing of audible warning devices is also provided in LRG 5.0 Tramway Audible Warning Acoustic Test Guidance.

Where trams run on-street and off-street the warning device should have two levels of sound as they have different needs and applications.

For on-street sections of the system there should be a lesser level of sound to alert people of the tram's presence. The sound produced should be distinctive compared with that emitted by other road vehicles.

The greater sound level is for use in the event of an emergency when on-street and when the tram is off-street.

The warning device for use on-street might be provided by using a single stroke gong which can be rung at different rates depending upon how rapidly the operating pedal or button is depressed.

The warning device for use off-street and in emergencies on-street a horn similar to those on buses or cars would be considered suitable for this function.

It is desirable for warning horns to provide a spectrum which is rich in harmonics, to optimise audibility for people with partial hearing loss.

Pedestrian Protection and Obstacle Deflection

The following collision protection should be provided for pedestrians:

(a) both the tram ends and sides should be continuously skirted. The bodywork and skirting should be designed to deflect people who may come into contact with the tram and stop them from passing beneath,

(b) there should be a fixed guard in front of the leading wheels designed to prevent people or objects being run over by the tram, with adequate clear space to prevent crush injuries, and

(c) the guard should be positioned as close to the highway surface and to the wheels as is reasonably practicable. It may have a deflecting lower edge of pliable material to close the gap to the surface of the highway.

The outside of the trams should be designed to deflect pedestrians away from the path of the tram wherever possible.

Effective obstacle deflection equipment should be provided to reduce the risk of derailment. This equipment may be attached to the running gear or to the tram underframe. Such protection is in addition to that provided in relation to pedestrian collision although the same equipment can serve both purposes.

Consideration should be given to installing systems that provide additional warnings to the driver of potential hazards within the forward path of the tram, for example, camera based obstacle detection.

Structural Integrity

As a minimum, the underframe and body, including any articulation joint, should be designed to:

(a) have sufficient mechanical strength to withstand the anticipated loads in normal operating conditions,

(b) mitigate against the known effects of a collision with another tram, road vehicle or buffer stops in a way which minimises injury to passengers, staff and other road users, and

(c) have adequate jacking points, with their positions clearly identified on the outside of the tram and accessible for use by the emergency services.

Reference should be made to BS EN 12663-1 (Railway applications. Structural requirements of railway vehicle bodies. Locomotives and passenger rolling stock (and alternative method for freight wagons) classes P-iv or P-v as appropriate and also BS EN 15227 (BS EN 15227:2008: Railway applications. Crashworthiness requirements for railway vehicle bodies) in regard to crashworthiness. Class P-v may be considered generally appropriate for tramway operations using (normally) single

trams under line of sight operation at speeds up to 80 km/h. Class P-iv may be considered more appropriate for operations at speeds greater than 80 km/h and / or where a substantial proportion of operation is undertaken under fully signalled conditions on fully segregated alignments.

Consideration should also be given, where possible, to mitigating the effects of body side collisions from other road vehicles.

Windows

Windscreens and other forward-facing windows should be able to resist impact from projectiles or other objects falling onto the tram. Other tram windows should conform to current UN / ECE standards for passenger carrying vehicles on the highway.

Further guidance may be found by reference to UN / ECE Regulation 43 (Uniform provisions concerning the approval of safety glazing materials and their installation on vehicles) relating to provisions concerning the approval of safety glazing materials and their installation.

It should not be possible or necessary for people to lean out of windows.

Driver's cab windows should not open in such a manner as would allow the tram driver to extend any part of the body, including the head, beyond the SE while the tram is moving, unless full clearances exist throughout the tramway system.

Couplers

Couplers and drawgear may be one of two different types:
(a) for regular service use if the operation of the tram system demands it, or
(b) for emergency use only in all other cases.

Any coupler fitted to a tram operating on an on-street tramway should be designed to fold away or otherwise be retracted when not in use. The extended position of the coupler should be included within the SE.

On trams fitted with couplers, adequate fenders or protective covers are required to mitigate damage to other road vehicles in the event of an accident. The end of any folded or retracted coupler should be within the bodywork. Any sharp edges or points should be covered and provided with suitable fenders.

The use of fixed couplers is not recommended.

Couplers should be designed to sufficiently withstand the loads for which they are in place for operational need. Intended loads should consider also any instantaneous 'snatch' loads that might occur when a rescue tram has to pull away with a dead tram.

Service loads might also have to consider situations where trams being rescued have some brakes still applied.

The coupler should be designed to accept at least the load imposed when hauling or propelling a dead tram anywhere on the system, i.e. the highest gradient, tightest curve etc.

Consideration should be given to coupler failure and subsequent mitigation to prevent uncontrolled movement or run-away (as well as operationally).

Driver's Cab

The driver's cab should be designed on ergonomic principles. All the controls and indications needed while driving should be convenient to use for the driver's wellbeing and to assist any quick reactions, and also located so as to minimise the risk of error.

The interior layout of the driver's cab should be designed to prevent portable objects being placed where they would obscure the tram driver's visibility or interfere with the controls. This includes adequate stowage provided for the driver's personal effects, and a convenient location for any timetables, documentation or notices to which drivers may need to refer frequently.

The design of the driver's cab should offer optimum internal and external visibility for the driver.

Consideration should be given to the driver's access to and egress from the cab. If the driver's cab does not have an external door, an external saloon door located immediately behind the driver's cab should be provided. Such a saloon door should be provided with separate internal and external controls for the use of staff.

Any door between the driver's cab and the passenger saloon should be either sliding or open into the driver's cab in order to avoid the problems of blockage by passengers and / or their baggage.

Where access and egress is only possible via the passenger saloon, a removable or breakable driver's cab side window should be fitted for emergency egress.

Consideration should also be given to which driver's cab side window is to be breakable in emergency. If the driver's saloon exit door is to the right, then the breakable window should be on the left side. This will maintain at least one exit in the event of overturning.

Tram signals, signs, passengers waiting at tramstops and other road traffic should be clearly visible from the driver's cab under all credible operating conditions.

Suitable means of obscuring the sun and for preventing distraction as a result of reflected light from driver's cab instruments or saloon lighting should be provided.

An internal mirror or other devices may be provided to enable the tram driver to observe passengers within the tram saloon.

The driver's cab should afford sufficient heating, cooling and ventilation to allow the driver to remain comfortable under all credible operating conditions and not impede driving of the vehicle, including the driver being able to control the temperature. Where the driver will be required to change ends, the system should ensure that both of the driver's cabs offer the same comfort level.

On double-ended trams, where the driver will be required to change ends, the driver's cab ventilation and / or heating systems should be capable of being left operational in the unoccupied driver's cab and / or a system that automatically sets both cabs to the same levels to ensure a suitable working environment is maintained for the next time that the driver needs to change ends.

Driving Controls and Indications

The driving controls and indications available to the tram driver should enable the tram to be operated safely whether in normal operating conditions or in emergency situations. The controls for any signalling system and / or displays of them should not detract from this or impair it.

The driver's controls should be laid out with consideration for ergonomic issues and to minimise the risk of incorrect operation. It is suggested that a human-factors study is undertaken at the design stage to verify this. DIN 5566-3 (DIN 5566-3 Railway vehicles - Driver cabs - Part 3: Additional requirements for urban and suburban rolling stock) may be of assistance for ergonomic matters.

It should be possible to easily recognise and / or read the displays on the driver's desk under all credible lighting conditions. If necessary, the brightness of illuminated displays should be capable of adjustment by the driver.

Recognised standard road vehicle markings should where appropriate be used for controls, indications and icons.

Illuminated displays and controls should be positioned such that they are not reflected in the windscreen or driver's cab side windows such that the driver's ability to see ahead and to either side would be impaired.

Consideration should be given to the position of the driver. The driver should normally be located in the centre of the driver's cab or to the right of centre. The seat should have sufficient adjustment such that the tram driver can observe the nearside footway.

The following features should be provided within the vehicle:

Traction Braking Controller (TBC)

It is recommended that the convention of Forward for Power and Backwards for Stop is used for UK tramway systems.

Movement of the Traction / Braking Controller (TBC) handle in the backward direction should result in a gradual increase in the braking effort, with full service braking reached at a decent position at a point short of the full travel of the TBC. Movement of the handle beyond this point should result in an Emergency 3 (hazard brake) application being made. Moving the handle forward from Emergency 3 should revoke this hazard braking mode.

A Driver's Vigilance Device (DVD)

This should be designed to ensure constant driver vigilance, and is in addition to the Driver's Safety Device (DSD - colloquially referred to as the 'Dead-Man's Function).

The current BS EN 13452 (BS EN 13452-1:2003: Railway applications. Braking. Mass transit brake systems. Performance requirements) for braking systems is aligned to Mass Transit systems and as such, does not accord with UK tramway terminology. For instance, this standard recommends that instead of the term 'Driver's Safety Device' the term 'Driver's Vigilance Device' is used.

An emergency brake button

This is in addition to a traction and brake controller (as above).

Emergency 'Pantograph Down' Button for Pantograph Systems (or Equivalent Button)

The pantograph down button (or its equivalent) should be of a distinctively different colour to any control provided for the emergency brake.

Once operated, release of this button should not allow the pantograph(s) to be raised until the normal pantograph raise / lower control has been operated.

The button controls for the emergency brake and emergency 'pantograph down' (as above) should be different in shape to other button controls and should be mushroom-shaped. They should also be distinctively coloured.

The emergency brake button should be red.

A Speedometer

This should be calibrated in km/h.

A Data Recorder

This should have sufficient channels and capacity to record information pertinent to the investigation of accidents involving the tram and capable of being calibrated, downloaded and presented as evidence.

Switches To Operate the Main Tram Traction Power Supply Circuit-Breakers
Means to Disable the Controls At Non-Active Driving Positions

This is to prevent interference with them whether accidently by the driver or another crew member, or by any unauthorised person (for example a member of the public).

In addition to all of the above, if a reverse function is provided, it should not be possible to be selected without requiring it to be a conscious action on the part of the driver. This can generally be achieved by requiring the driver to use both hands, for example by the need to depress a push-button at the same time as turning the selector switch to the Reverse position.

Systems, controls and indications should also be considered to have the following functions:
(a) protect against wheel slip when accelerating or wheel slide when braking,
(b) operate sanding gear, and
(c) control the functions of the internal and external communication equipment to prevent mutual interference and cross-talk.

In addition, when reasonably practicable they should be considered to have:
(d) systems to limit the speed generally for on-street sections of the tramway alignment such as small radii curves, and
(e) systems to provide additional warnings to the driver of hazards in front of the tram using, for example, cameras and / or radar.

Design of Passenger Saloon

The interior layout and fittings of trams should be designed to minimise injuries to passengers and tram crew when in normal operating conditions as well as in the case of an emergency situation.

The ratio of seating to standing passengers is a matter for the operator, but for planning purposes the density of standing passengers should not normally exceed 4 passengers/m2 of available standing space.

Gross laden weight calculations and floor strength requirements should be based on a standing passenger density of 8 passengers/m2 of available standing space.

Any internal steps and stairways must meet the requirements of the Rail Vehicle Accessibility Regulations (RVAR) **here**.

Interior lighting in trams should meet the lighting levels provided in other passenger carrying vehicles. In common with these vehicles, additional lighting in doorways, steps and internal stairways should be considered.

Lighting should be maintained in the event of electric traction power being lost. Emergency lighting should be provided to automatically illuminate upon loss of traction power and battery power. Lower lighting levels are acceptable, they should be sufficient to enable the tram to be evacuated safely.

Interior Fittings

Interior fittings of trams should be designed so as not to cause injury in normal operating operations and to minimise secondary injuries to passengers should the tram be involved in an accident. Interior fittings should include the following:

(a) adequate grab-rails and stanchions
(b) appropriately sized grab-rails and stanchions for mobility-impaired passengers and for standing passengers,
(c) appropriately coloured grab-rails and stanchions easily seen by the visually impaired,
(d) hanging straps, if fitted, should have limited movement and be secure under load,
(e) interior glass which conforms to current passenger carrying vehicle standards and has protected exposed edges, and
(f) passenger-operated buttons (door opening, alarm, stopping request).

Facilities must be provided for mobility-impaired passengers in accordance with the RVAR.

Emergency Equipment

Equipment for emergency use should be carried on each tram. Suitable provision should be made for stowing emergency equipment so as to be reasonably accessible to the tram driver. The following should be carried:

(a) a fire extinguisher,
(b) a position for a hand lamp sited so that in emergency, the lamp can be used as a temporary tail light, and
(c) a first-aid kit

Access and Egress

Doors and Controls

Tram doors should be designed to operate safely in all operating conditions.

BS EN 14752 (BS EN 14752:2005: Railway applications. Body entrance systems) **here** gives some guidance on the design of passenger doors and doorways. The requirements of the RVAR must be met where relevant.

Doors and associated areas should be designed to minimise the danger of any trapping injury. They should be fitted with obstacle detection equipment and should not operate with excessive force. It should be possible to release limbs or other objects trapped by the doors without difficulty.

Where fitted, folding steps or sliding plates should be interlocked with the electric traction power controller and brakes to prevent movement of the tram when they are deployed.

When the tram is moving, external passenger doors should be secured in the closed position. It should not be possible for the tram to start unless all external passenger doors are closed and secured. In the event of doors or their control system moving from the Closed position while the tram is moving, traction power should be removed automatically, and the brakes should be applied.

Passenger door controls and the method of operation should be clearly and unambiguously signed. The door arrangements should enable passengers and tram crew to evacuate safely. It should be possible for passengers to open external doors once the tram is stationary. Emergency door releases should be operable to allow the opening of external and internal doors even if there is a failure of any tram equipment including the power supply.

Door Controls

If passenger-operated door control buttons are provided, they:

(a) must be compliant with the RVAR, and

(b) should only be enabled when the tram is correctly located at a tramstop and / or it is safe to disembark or in the case of an emergency evacuation.

Emergency opening devices fitted inside the tram should be able to be used by the passengers without the help of the tram driver. When these devices are operated, this should be brought to the attention of the driver. It should not be possible to open the doors until the tram is at (or nearly at) a standstill.

There should be a means of releasing designated external doors from the outside in an emergency.

The design and labelling of internal and external door emergency releases should deter non-emergency use. Bylaws may be used to display penalties for improper use.

The tram driver should be able to easily identify which emergency door-opening device has been operated. After operation, the device should be able to be cancelled only by the driver or other members of the tramway staff.

If the external emergency release device is also intended to be used as a means of opening tram-crew access doors, it should be possible to reset it from both inside and outside the tram.

Communications

Alarm points conforming to the RVAR should be provided so that in an emergency, it is possible for passengers to communicate to the tram crew, and for the crew (or where required the tramway system controller) to communicate to the passengers.

Where there are request stops, facilities for requesting the tram to stop should be provided, and the use of this facility clearly indicated both in the driver's cab and in a prominent position in the passenger compartment and accompanied by audio announcements in the vehicle and at the tramstop. Such equipment must comply with the RVAR.

Electrical and Power Supply Systems

The electrical and other power supply systems and equipment on trams should not endanger other systems or people in either normal operating conditions, maintenance, emergency or failure modes. Consideration should be given to the location of equipment that the tram driver may need to access for resetting, to ensure that it is easily accessible for the tram driver, but not exposing them or passengers to potential risk.

Safety critical systems should be designed to fail to a safe mode, either by redundancy or before safety critical levels are reached. Suitable alarms or interventions should be provided as necessary and located in an appropriate position.

Preventative measures should be provided to guard against fire as a result of power supply or electrical system overload under fault conditions.

In the event of power failure, preventative measures should also be in place to enable a tram to be either operated safely under emergency situations, or to be recovered / removed from causing an obstruction on the highway.

A battery should be installed so in the event of failure of the electric traction power supply, it can provide sufficient interior and exterior lighting (as appropriate to the tram system) and other essential subsystems such as radio. The battery and control system should be independently capable of supporting the electrical load for a minimum of 30 minutes.

The power supply system on board the tram should provide an adequate, protected path for the return current, and should be protected against the effects of accidents, power system failure and unauthorised access to the live parts.

The power systems should be appropriately guarded against unauthorised access.

Electric Traction Power Supply

The design and construction of the collector for the electric traction power supply and associated isolators and protective devices should consider the need to avoid hazard, either to tram operating staff or to the public.

Of particular consideration is the pantograph; BS EN 50206-2 (EN 50206-2:1999: Railway applications. Rolling stock. Pantographs: characteristics and tests. Pantographs for metros and light rail vehicles) **here** gives additional guidance on pantographs for tramway use.

Over current protection and isolation arrangements should be provided as close to the source as possible. The main traction power circuit breakers and line fuses should be roof-mounted for overhead electric traction systems.

Overhead systems should be fitted with roof-mounted lightning surge arrestors.

Sufficient and effective bonded paths to the tyres of the wheels from the superstructure should be provided on any tram used on an electric tramway system or on an alignment shared with an electric railway. The return path, if this is through the rails, should be designed to ensure that conductivity remains sufficient through the wheels at all times.

Isolating Devices

The following means of isolating the tram from the traction supply should be provided:

(a) a control by which the tram driver may isolate the power supply between the current collector(s) and the electrical equipment without leaving the cab,

(b) a control by which the tram driver may disengage the current collector(s) from the source without leaving the cab, and

(c) a control by which the current collector(s) may be disengaged from the traction supply which is accessible from ground level outside the tram; its position should be clearly marked.

In the case of trams powered or assisted by a battery or other on board energy sources, equivalent provisions to the same standard as required by the PCV Regulations should be provided, to allow the energy source(s) to be shut down by the tram driver from within the tram. A similar facility should be provided on the exterior of the tram that is accessible from ground level and its position(s) should be clearly marked.

Once operated, it should not be possible to reinstate the functionality of the tram's control systems simply by resetting isolation switches. Returning the tram to operational status should only be possible once the tram has been shut down and re-initialised using the normal driver's cab controls.

A means of isolating any traction battery should be provided, which is accessible from ground level outside the tram. Its position should be clearly marked.

Other electrical circuits should also be protected by isolating switches and circuit breakers, which may be combined as appropriate.

Where there is a means of isolating the battery or other sources of stored energy, operation of this facility should not result in the immediate loss of communication between the tram driver and the system controller. Neither should there be any loss of emergency lighting. Communication requirements may be met by providing the on board radio equipment with a local back up battery

with sufficient capacity to ensure that the tram driver is able to adequately communicate in an emergency, or to ensure that the tram driver has access to a separate independently powered means of communication to both the tramway control centre and the passengers.

On trams that use overhead lines as the power source, it should be possible to raise and lower the current collector manually when the tram has discharged batteries. After raising the current collector manually, the tram should then be capable of being re-energised and charging the batteries using only the supply from the overhead line.

Electrical Equipment Protection

Electric traction power cables should be routed so that they are protected from mechanical damage. In addition, the following precautions should also be taken (not exclusively):

(a) where the cable route passes through a fire barrier, adequate fire stopping should be provided,
(b) if the cable route passes through the passenger compartment, this should be by the shortest practicable route. Consideration should also be given to protecting power cables against damage that could occur as a result of a collision, and
(c) a lightning arrestor should be fitted to protect the cables and equipment.

The operating voltage of electrical equipment in areas accessible to passengers should not exceed 50 V.

Cubicles containing equipment at electric traction power supply voltage which have to be in the driver's cab must be locked or appropriately secured. Warning notices must be displayed, refer to Electricity at Work Regulations 1989 **here**.

Cubicles containing power control equipment that could emit toxic fumes if set on fire should not be ventilated into the passenger compartment.

Control Systems

Traction Power Controller

The traction power control system should be of robust design, using safety critical techniques in hardware and software systems to guard against unsafe conditions in failure modes.
Whatever traction control system is used, it should be designed so as to prevent the following (not exclusively):

(a) the taking of power or release of the brakes when any external doors are detected as not closed, or when folding or sliding steps or ramps are deployed and not properly retracted,
(b) the taking of power when the braking systems are not available,
(c) the enabling of controls, except the emergency brake, from more than one driving position at a time, and
(d) the movement of the tram in a direction opposite to that selected by the tram driver.

A combined traction and brake controller should be fitted.

Where a single microprocessor is used for safety critical functions in the tram control system, it should be designed to appropriate safety critical standards.

Jerk rates during starting and acceleration should not exceed those set in BS EN 13452 **here**.

Brakes

For braking systems, reference should be made to the guidance given in BS EN 13452.

In relation to the brake, trams should be fitted with the following:

(a) a continuous system for the control of the service brake that is operable from the driving position in service on trams coupled in service conditions,
(b) a parking brake which is automatically applied when the tram is shut down, and
(c) brakes that remain partially applied when the tram is brought to a standstill until the controller is operated to take power to move the tram.

An electromagnetic brake or brakes acting directly on the track should be fitted to achieve the required performance.

The braking system should be designed so that:

(a) an assisting vehicle (another tram or a recovery vehicle) can operate the brakes on a failed tram if they are operable, and
(b) if the brakes on a failed tram are inoperable (including if they are stuck on), the brakes of the assisting vehicle should be such as to enable it to haul and to control the failed tram at slow speeds.

Consideration should be given to the location and accessibility of brake release controls if a tram is standing in a platform area.

An irrevocable brake application (one which cannot be reset until the tram has stopped) should, but not exclusively, result from the following incidences:

- a lack of correspondence between vital control systems,
- insufficient air pressure, hydraulic pressure or electrical supply to operate the service brakes or traction control system,
- the loss of brake activating pressure,
- the accidental parting of articulated or coupled trams, and
- the unintended deployment of steps or boarding devices, or when an external passenger door is no longer detected as closed.

Brake Performance

The guidance in BS EN 13452 defines the different levels of braking in standardised terminology which may differ from that used by some UK operators. For clarity, this guidance uses the terminology of BS EN 13452, for which the common UK equivalents are as follows:

- Service braking: being the normal operating conditions, generally using only the primary braking system, supplemented as necessary under heavy loads and / or at low speeds by the mechanical braking system.
- Emergency 1: Emergency braking - where the requirement is simply to bring the tram to a standstill by any means, irrespective of the position of the traction and brake controls. Once applied, the Emergency Brake should remain thus and be capable of release only once the tram has come to a standstill. BS EN 13452 calls for this to be at service braking performance level, i.e. it is the brake mode that a tram system might apply if the door loop was broken or the driver was found to be incapacitated.
- Emergency 3: Hazard braking - where the maximum braking effort is applied in order to bring the tram to a standstill in as short a distance as practicable. The Hazard brake is an ‘all or nothing’ brake and should be revocable by the action of the driver deselecting it.
- Security brake: A brake with a higher level of system integrity than emergency 3, applied by the use of an emergency button and irrevocable until the tram is at a standstill and a specific reset is undertaken.

The parking brake should be able to hold a fully laden tram, or to hold it (in any load condition) and another (unladen) tram with failed or isolated brakes on the steepest gradient on the system.

A brake application should occur automatically if a tram rolls back after stopping on an uphill gradient. The tram should stop within 500 mm under all loading conditions on the steepest gradient on the system.

Equipment should be provided to optimise traction and braking performance under credible adhesion conditions. Such equipment is likely to include sanders and slip / slide regulation systems.

Assessment should be made to confirm that any magnetic track brakes are physically compatible with the infrastructure of the systems over which the tram is intended to operate. This should confirm that when operated, will not result in any untoward operation of signalling or communications equipment as a result of transient electromagnetic effects. Consideration should be given to potentially reduce braking performance on rails formed from austenitic steel.

Fire Safety

In general, and unless otherwise specified, it is sufficient for any tram operating under line of sight principles to be designed to a fire standard which is equivalent to that required for buses, as set out in the PCV Regulations.

Circumstances in which a higher standard, such as BS EN 45545 (EN 45545: Railway applications. Fire protection on railway vehicles) **here**, would be appropriate would include (not exclusively):

- operation under absolute signal control (i.e. as a railway),
- operation of trams with high floors that restrict passenger evacuation, and
- operation over bridges or through tunnels, where there are not easily accessible places of safety for passengers and tram crew.

Operation through a tunnel does not automatically call for a higher fire standard to be applied in the following situations (inclusively):

- the tunnel is double tracked, provided with a suitable walkway (which may be at track level) and of a length short enough to allow escape to a place of safety away from any smoke or fumes; and
- the tunnel is designed and equipped to the same standards as are applicable to road tunnels.