Vehicles

Trams supplied by Siemens and DUEWAG

With a length of 34.8 m and a width of 2.65 m, the Supertram is one of the largest articulated cars ever built for public transport. Only the articulated DT 8 type for the Stuttgart light rail system and GT8-100 two-system articulated cars for Karlsruhe are larger. The size of the tram resulted from the requirement that the whole of the expected ridership was to be handled by single cars in order not to cause any undue hindrance to other city traffic by trams running in multiple or at excessively frequent intervals. A further complication that affected the design of the tram was the need to accommodate gradients of up to 10%, curve radiuses down to 25m and vertical curves of 100m.
The result is an all-steel, double-ended car in three articulated sections with eight powered axles. It can comfortably hold 88 seated and 162 standing passengers and travel at up to 50 mph.

Easyaccess entrances, four on each side, are 420mm high, gently sloping up a further 30mm to the centre of the car. This arrangement has resulted in a tram with some 40% of the floor area at low level with plenty of room for entry and exit out to provide ample room for luggage or pushchairs.

The door sill height is matched in Sheffield by the raised-pavement type platform at each stop which also have gentle ramps for easy access (max. 1 in 20), there is dedicated space for wheelchairs immediately next to the doors. The middle all-seater Section is 880 mm (35 ins) high and reached internally by three steps (it has no external doors). The greater clearance allows under-floor space for electrical and auxiliary equipment such as batteries, air compressor and static converters. (Most of the traction control equipment is mounted on the roof.)

The varying floor geometry helps satisfy differing types of use. The raised centre "saloon" section will probably be favoured by passengers travelling longer distances, whereas the two raised seated end sections may be better for medium distances. The two sections with double doors and ample entry-level space are likely, despite their more limited seating, to be suited for shorter journeys or by mobility-impaired passengers or mothers with push-chairs and small children.

The Supertram vehicle is clean, quiet and spacious with generous seat widths which allows for easy internal movement. Its construction is of high quality with safety and security as high priorities. Excellent lighting is provided and the general layout is arranged to provide passengers with the greatest amount of personal space. The unchallenging interior colour scheme emphasises the creation of an environment intended to make passengers feel at ease. Grab rails are provided in abundance to assist standing passengers.

In emergencies, buttons on the passenger grab bars enable two-way communication between the driver and the point of activation. Microphones in the PA system also allow the driver to monitor what is happening in the passenger compartment - a useful early warning system, each vehicle is also in direct contact with the Control Centre. There are also emergency mechanical couplings at each end of the tram for recovery purposes. (These are normally covered, as the trams are not intended to run in multiples)

The driving cabs at each end have glazed rear partitions to ensure that the driver has good visibility throughout the tram. There is air-conditioning for the driving cab and a high-capacity ventilation and heating system for the passenger area. With the exception of two enclosed equipment cubicles in the area of the two articulations to accommodate the electronic control system with easy access for commissioning and maintenance, all of the electrical equipment is distributed underneath the centre section and as is common with low-floor vehicles, the traction control equipment is located on the roof of the end sections. There must therefore be access to the car roof for maintenance purposes.

A proven technology DC chopper control system with GTO semiconductors was selected for the drive equipment it was possible to do without braking series resistors as a result of a suitable motor design, which will bring considerable regenerative energy savings during braking. The drive system is a longitudinal DC monomotor, fully suspended in the bogie, with both axles in the bogie being driven.

Special importance was placed on the tram exterior design to achieve a pleasing appearance in the cityscape and also on the design of the tram's interior, the fittings and colour scheme of which have been selected, after market research, to suit the requirements of the users.

The Mechanical Part

The mechanical part consists of three sections, with the two end sections A and B being joined to the centre section C via two articulations. Each end of the tram has its own driving cab and the complete vehicle is designed for unrestricted bi-directional operation.
In the centre section (C), including the articulation areas, the height of the floor is 880 mm as it is over the end bogies in sections A and B. However sections A and B also have a low-level floor area at a height of 480mm, which is reduced via a ramp to 420mm at the door sill.
The vehicle has four door areas for alighting and boarding on each side. The pneumatic swingplug doors open outwards to provide an opening 1300 mm wide and 2045 mm high.

Body Construction

The vehicle body is a welded construction made of Corten-B steel. The outer skin provides the frame with additional strength. Maximum clearance and optimum safety is provided at the articulations between the individual sections. This is achieved by the passageways having the same high quality for the inside skin as the tram sections themselves. Particular attention was paid to ensuring that the articulation areas were weather-tight and enjoyed the same type of ventilation, heating and lighting as the rest of the tram.

Special rubber seals are used to prevent any dirt entering the tram from the articulation via the articulation skins. All the external surfaces of the tram body have been primed and painted. The inside surfaces have been specially primed to provide additional protection against corrosion and a layer of sound-proofing material has been fitted.

Public address system

The PA system comprises two vehicle amplifiers, 14 loudspeakers, 8 emergency communication points and microphones for passenger compartment monitoring. The PA announcements are fully automated.

The vehicle amplifiers have a voice control system that is noise-dependent and thus automatically ensures good clarity when there is a high noise level in the passenger compartment.

The emergency communication points are located on the grab bars in the passenger compartment and permit driver/passenger communication in case of emergencies.
Interior Fittings

The vehicle interior has been designed from an aesthetic point of view and to meet stringent safety requirements. The interior fittings have no sharp edges to prevent any injury to passengers or to the operating and maintenance staff during normal operation and also in emergencies.

Particular emphasis has been placed on providing passengers with sufficient holding possibilities. The floor consists of a layer of wood that has been bonded to the under-frame. A layer of rubber with corundum chips for additional anti-slip protection is laid on top of the wood. The edges of the panels and any joints have been suitably water-proofed, as have all the openings for cable ducts and piping. The interior lining for the ceiling consists of an aluminium honeycomb design, to which coloured melamine resin panels have been bonded. The lining is attached to suspension points warded to the roof section. The inside walls are made of coloured melamine material. The complete lining for the articulations consists of coloured fibreglass reinforced plastic. The rear wall of the driving cab is made of laminated wood with a melamine veneer and there are 88 comfortable seats covered with material. The seats are double seats secured on frames. In the low-floor areas in sections A and B, space is provided for wheelchairs directly adjacent to the doors. The dimensions of the wheelchair areas and the passages to them are in accordance with the requirements laid down by the Disabled Persons Transport Advisory Committee (DPTAC) in the United Kingdom.

List of the Supertram's most important details

8-axle low-floor light rail vehicle for South Yorkshire Supertram Ltd. (SYSL)
Type of construction Bi-directional double-articulated vehicle with four motored bogies
Axle arrangement Bw 'Bx 'By 'Bz'
Track gauge 1435mm
Width of vehicle 2650mm
Length of vehicle 34750mm
Height of vehicle 3645mm
Line voltage 750V DC
Rated output 4 x 277 kW (1 hour rating)
Max. speed 80km/h (50m/h)
Tare weight 46.5t
Passenger capacity 88 seated
155 standing at 4 passengers per m2
232 standing at 6 passengers per m2
Propulsion 4 longitudinal traction motors each driving two axles
Gear ratio 4.833 : 1
Wheel diameter 670 mm (new), 590 mm (worn)
Brake system Electric brake blended regenerative and rheostatic brake (service brake).
Spring-applied pneumatic brake as standby, emergency and parking
brake.
Track brake to backup emergency brake.
Auxiliary voltage 24VDC
Performance data Maximum acceleration: 1.3 m/s2
Maximum deceleration (service brake): 1.5 m/s2
Maximum emergency deceleration: 3 m/s2

Driving Cab

The driving seat and controls in the cab are arranged ergonomically. The driver has a clear view of the route and excellent access for monitoring and operating the controls and indicators.
The driving cab extends across the whole width of the tram and is completely separated from the passenger area to prevent unauthorised access. The driver enters the cab either via a side door

on the left-hand side of the cab or via a door in the middle of the bulkhead behind the driving cab from the passenger area- The top part of this bulkhead is fully glazed so that the driver has a clear field of view through the tram. This also creates a spacious modern impression of the whole of the tram's interior.

The driving seat, including the back, can be adjusted in all directions. The height of the seat can be adjusted to suit the drivers weight. There is a tip-up seat next to the driving seat for an assistant or supervisor & the driving cab is fully air-conditioned to provide ideal working conditions for the driver.

The two driving cabs are completely separated from the passenger compartment and have independent air-conditioning systems. The two systems are fitted under the floor of the individual cabs.

Bogies

The tram is equipped with four 2-axle bogies, each with their own drives. In view of gradients of up to 10% in Sheffield, un-powered bogies were not viable. The wheel base of the powered bogies with their longitudinal monomotors driving both axles is 1800mm.

Two bogies are located under the centre section C. and one bogie each under the outer ends of end sections A and B. It was decided not to have the bogies under the articulations so that the low-floor section of the tram was not restricted even further.

All the bogies are interchangeable and the outer bogies of four trams will be supplied with wheel flange lubrication to reduce wheel wear.

The tram body is supported on the bogies via bail bearing ring races. The bogie bolster has a secondary air-bag suspension system that is designed to cope with the transverse forces that occur with trams. The air-suspension system is supplemented by elastomer stops that can support the tram body should the air bags deflate.

The primary system for axle suspension uses rubber chevrons.

The bogie frame is of a hollow box girder design. The load-bearing elements and the welds are designed to ensure that the bogie frame will be able to cope with all stresses that occur, including continuous loading.

The shock absorbers for vertical and transverse forces operate hydraulically. The tram wheels have resilient rubber inserts (Type 13 ochum 84) and have diameter of 670 mm that can be worn to a diameter of 590 mm.

Air-brake system

The air-operated disk brakes are of the spring-applied, air-released type, with each axle having one disk brake.

The electric brake is sufficiently dimensioned to obviate the need for blending the electric and air brake during service braking. The air brake is used as a second service brake should the electric brake fail to take over braking at speeds below approx. 6 km/h and as a parking brake.

The air supply is provided by a screw-type compressor that is driven by a 380 V AC/ 100 Hz motor.

The compressor unit is designed for under-floor installation and has a flexible three-point mounting.

The brake cylinders are of the spring-accumulator type that each act on one disk brake per axle. The braking force acts on the disk brake when the pressure in the cylinder is reduced. All of the braking cylinders have an automatic adjusting device to ensure that there is a constant clearance between the brake block and disk despite any brake block wear. The brake cylinders have a manual mechanical release that is accessible from outside the tram, in addition, the brake cylinders can be released in an emergency by an auxiliary air system.

Instrumentation and control

The vehicle is controlled primarily via the central control unit (CCU) and the traction control unit (TCU). These units are part of the SIBAS® 16 family and are connected via serial data buses. A separate brake control unit (BCU) is used to control the pneumatic spring-release brake. The control units are installed in two cubicles at the articulation which extend over the height of the vehicle.

Traction control unit

The two TUCs each control a drive circuit. This redundancy arrangement ensures that the vehicle can still operate should one of the drive circuits fail. TCU control functions are:

- Stepless braking and accelerating
- Mixed regenerative and rheostatic braking depending on system receptivity
- Slip/silde protection
- Monitoring the line-current upper limit of 1280 A
- Diagnosis and monitoring of traction components.

Brake / Track brake control unit

The BCU controls the pneumatic spring-release brake that takes over from the regenerative brake at low speeds and which is used as a parking brake. The spring-release brake is a fall-back level for the regenerative brake over the entire speed range, the BCU also has a slide protection function.

Each bogie has two magnetic track brake magnets, each with a contact force of 50 kN, that are controlled by the CCU, the TCUs or the BCU during emergency braking.

The Electrical Part

Requirements

The requirements for the electrical equipment on the tram can be summarised as follows:

- All axles powered
- Operation on gradients of up to 10%
- High reliability with redundant design of important tram components
- Low fire risk with the use of halogen-free Sienopyr cables.

Traction equipment

The demand for a high degree of reliability and operation on steep gradients has been met by having the power circuit after the main circuit-breaker in a redundant design. All eight axles of the vehicle are driven and braked.

The traction equipment of the two drive circuits is accommodated in stainless-steel containers on the roof of the two end sections.

A simple design for the power circuit has been achieved by incorporating the braking resistor in the motor circuit, thus obviating the need for a braking series resistor.
The forced air-cooled brake resistor pulsed from a parallel-connected brake chopper in accordance with the resistance required. Shunt resistor R2 is switched during braking between 80 km/h and 50 km/h.

The DC chopper consists of the brake chopper already mentioned and an armature chopper. The brake and armature chopper have two parallel GTOs with staggered pulling. The GTOs of the armature chopper have overlapping firing in order to achieve degree of control of a = 1. The DC chopper has floating cooling busbars with the power semiconductors being insulated on coated ceramic disks. The semi-conductors with maximum loading are monitored so that power can be reduced in the event of prolonged over-loading.

The traction equipment is ventilated by blower with a 100 Hz three-phase motor. The cooling chain consists of the chopper, combination and brake resistor. Air flow is monitored so that the drive power can be reduced should a blower fail or with reduced air flow.

The traction motor used, Type 1KB2121, a further development of the standard motor 1KB2021. The dimensions of both motors are identical but the 1KB2121 motor has been improved as follows:

- By using a rotatable brush ring. This enables all commutator brushes to be changed from the pit and there is no longer any need for a flap in the vehicle floor.

By increasing the rotor diameter and air-gap power.

Destination display

The name of the destination is displayed on a roller blind at the front of the vehicle. Two-sided LCD displays in the passenger compartment show the name of the next stop. The LCD displays are fitted underneath the ceiling in the low-floor area at right-angles to the direction of travel so that they are clearly visible from anywhere in the passenger compartment.

Central control unit

The CCU is the highest level of vehicle instrumentation and control and has the following functions:

- Set-point processing for motoring and braking with plausibility check
- Time monitoring of the deadman function
- Bus management of the serial data buses
- Control and diagnosis of the peripherals via 'intelligent terminals'
- Time-based history memory
- Control of passenger heating and ventilation.

The driver issues a continuous set-point for motoring and braking via the motoring/braking lever of the master controller. The CCU reads this set-point value via an intelligent terminal in the cab and passes it to the TCU and the BCU. In addition to set-points, discrete signals are also passed to the CCU, TCU and BCU for motoring, braking and emergency braking and are checked against the set-point issued for plausibility.

The motoring/braking lever has an integrated deadman switch, operation of which is timemonitored by the CCU. The CCU is connected to the vehicle peripherals via a serial data bus and intelligent terminals. The intelligent terminals function as output and input modules of the CCU and convert the parallel signals for the serial data bus. The vehicle has intelligent terminals in both cabs, in the electronics cubicles and in equipment compartments under the floor of the central body-section. They control the connected peripherals such as heating, ventilation, compressor and static converter and permit diagnostic functions. In the event of a fault, the location and type of fault are displayed on a fault annunciation panel for the driver. The CCU has a history memory that can store up to three analogue and eight digital signals which can be selected for continuous storage on a first-in/first-out (FIFO) basis.

Vehicle supply

The vehicle Power supply is provided by two static converters and a NiCd battery.
Rating details of the converters are:

- Three-phase output: 3 x 380 V, 100 Hz, 13 kVA
- DC output: 24 V, 5 kW

The three-phase outputs of the converters are galvanically isolated from the 750 V input voltage and supply separate three-phase systems. The redundant design ensures that traction blowers and compressor can continue to operate without a reduction in drive power should a converter fail. These loads are then switched to the intact converter.

The DC outputs supply the LV vehicle system in parallel and charge the battery. The battery charging current is limited automatically. The battery can also be charged via an external 24 V supply. Each converter has an emergency starting facility for use should the battery be completely discharged. In this case, the converter control electronics is supplied from an internal sintered battery. The self-cooled converters protect themselves against excessive input voltage by firing a short-circuit thyristor. They also have internal temperature monitoring.

Passenger heating and ventilation

The passenger compartment is divided into three heating circuits and is heated by under-seat heaters using air-circulation. The heating circuits are controlled independently of each other by the CCU. The heaters have two temperature monitors with separate response settings. At the lower response, the CCU switches off the appropriate heating circuit. The second sensor at a higher setting acts as a fire monitor and shuts down the complete vehicle heating system if activated. At high external temperatures the vehicles are ventilated via roof fans fitted in each section. They are switched on by the CCU when required. The fresh air is ducted via the lighting strips and via a gap between the cantrail and windowpane in the passenger compartment.