NEW "Z-CLASS" TRAMS FOR MELBOURNE

Production is now well underway in the contract for 100 'Z' class trams now being built by Commonwealth Engineering (Victoria) Pty. Limited for the Melbourne and Metropolitan Tramways Board. 97 trams have been delivered to M.M.T.B.'s Preston Workshops up to the beginning of March, 1978, and 90 are already in service; the remainder are still undergoing fitting out by M.M.T.B., final testing by Comeng, and commissioning by ASEA Pty. Limited, Comeng's subcontractor for traction and auxiliary electrical equipment and for mechanical transmissions, wheels and axles.

The project was first conceived by M.M.T.B. in 1968 when design studies began for a prototype 'new' tram based on recent developments in tramways in other parts of the world, especially Europe. The result was Car No. 1041, designed and built by M.M.T.B., incorporating traction equipment by ACEC of Belgium, and with American PCC bogies. Other features included:

1. Steel basic structure for underframe, sides and roof.

2. Aluminium exterior wall cladding.

3. Extensive use of fibreglass for exterior roof covering, body-end moulding and many parts of interior fittings.

4. High quality of appearance and of interior seating and other appointments.

5. Open plan arrangement including seated positions for both driver and conductor.

6. Distinctive colour scheme.

7. Electronic control of the modern, though conventional, traction equipment.

8. Thermostatically controlled heating and ventilation of the pa-senger compartment.

9. Electrically operated folding doors.

10. Public address system.

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The primary aim was to introduce to Melbourne an example of the progress made in trams and to project a new image of tramways as affording an efficient and comfortable means of public transport.

After its inevitable teething problems, 1041 went into service in 1973 and has been almost trouble-free since, while attracting a good deal of favourable comment from the public.

In the present contract, the responsibilities for design, supply and manufacture are assigned as follows:

Comeng (Victoria):

1. Manufacture and assembly of complete bodyshell, except for equipment fitted by M.M.T.B.
2. Installation and cabling of all bodyshell electrical equipment.
3. Testing and commissioning of Comeng electrical equipment.

Comeng (N.S.W.):

1. Design of complete bodyshell, including design of sub-contracted fibreglass parts.
2. Design of auxiliary electrical circuits.
3. Initial estimation of costs and selection of equipment.
4. Design of cabling layout for entire tram.
5. Modification of Gothenburg bogie design (as supplied by ASEA) for the present contract.
6. Building welded bogie frames and supplying them and all other structural bogie parts to M.M.T.B.

M.M.T.B.:

1. Manufacture of fibreglass front end assemblies supplied to Comeng for fitting.
2. Manufacture of fibreglass assemblies for interior trim, fitted by M.M.T.B.
3. Design, manufacture and fitting of passenger seats, supplying and fitting of drivers and conductors seats.
4. Fitting of most of the handrails and staunchions (supplied by Comeng).
5. Supply, fitting and cabling of the Boselli flip-leaf destination equipment.
6. Assembly of bogie from parts supplied by Comeng (NSW) and ASEA and fitting bogies to tram body.
7. Supply and fitting of trolley poles and rope retrievers.

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ASEA:

1. Supply of traction electrical and mechanical equipment, comprising motors, gearboxes, flexible couplings, axles, wheels, chevron suspension elements, starting and braking resistor, brake discs and calipers, contactor boxes, tachogenerators.
2. Supply of control and auxiliary equipment comprising electronics and relays for traction control, circuit breaker frame, driver's controls, motor-alternator set and thyristor battery charger.
3. On-site commissioning of ASEA equipment after completion of work by M.M.T.B.

M.M.T.B. gave the benefit of its experience as a tramways operator, especially with the prototype 1041, where several modifications have been carried out to try new ideas in service.

ASEA has been able to draw on the experience of its parent company in Sweden as a manufacturer of traction equipment, especially with regard to the trams now running in Gothenburg.

Comeng (N.S.W.) is continuously occupied as a designer and manufacturer of passenger rolling stock and locomotives.

Comeng (Vic) as the main contractor had to co-ordinate all activities at the design stages and beyond, while preparing for the manufacture proper.

We will now describe the 'Z' class tram in detail.

All the features of 1041 listed above also apply here and indeed the superficial appearance is similar, although there is a host of differences both major and minor. We will not make further comparisons with 1041 as it has already been well described elsewhere.

The basic structure of the tram is almost entirely of roll-formed steel sections being either seam-welded by the MIG process, or spot-welded together. Although there is a distinct underframe, the full strength is not obtained until the body-shell is completely assembled, there being shear-panels on the inside of the walls below the window openings and large continuous gussetted shear members along the curved sides of the roof.

The exterior bodyside panels are of aluminium with swaged ribs. These panels are not structural and may be readily replaced if damaged. Interior trim is mainly of plastic laminate sheets held in by aluminium extrusions. Fibreglass is used for the skirting assemblies which conceal electrical cables and conduits and the seat bases, and also convey heated air throughout the passenger area. The distinctive tapered ends of the trams are large two piece fibreglass mouldings; the outer roof skin is also made up of fibreglass mouldings, partly for appearance but mainly for electrical safety reasons, there being no earthed metal accessible. All the windows are of armour-plate glaws, and, except for the windscreens, anti-sun tinted. The seating is steel-framed, foam-padded and covered with vinyl.

The bogie frames are of one-piece welded construction. The traction motors are fully-mounted on the bogie, driving the axles via resilient couplings and double-reduction gearboxes. A tacho-generator for wheelslip and speed control is mounted integral with each motor, and the motor drive shaft also carries a brake disc. The wheels are SAB resilient and the suspension elements are rubber chevron springs. Body weight is transferred to the bogie by side-bearer rollers and tractive effort is applied through the kingpins.

Traction Equipment

The driving circuit provides conventional resistor series-parallel acceleration control and dynamic braking. The traction motors are interconnected between bogies so that leading and trailing pairs are in permanent series. The equipment is contained in four underframe-mounted boxes: one containing the force-ventilate traction resistor; two containing the grouping, reversing and stepping contactors, and the fourth carrying the main line-switching contactors and the field shunting contactors, resistors and chokes, as well as some auxiliary equipment.

Of most interest is the method of control. The system used is ASEA's Tramiac, developed from the equipment supplied to Gothenburg Tramways. This electric system continuously monitors the drivers control, motor speed and current and drives the traction circuits to give the desired performance. The driver has three pedals to control the movement of the tram: accelerator, brake and safety pedal. The safety pedal must be held down in the mid position to start the tram and all the time the tram is moving, or else emergency braking will immediately be applied. As to the other two pedals, the driver uses them more or less as in a car with automatic transmission.

The electronic equipment is contained in two cubicles situated beside the driver at each end of the tram. One cubicle contains the electronics proper and the other contains relays for interfacing and for interlocking and auxiliary purposes connected with the traction equipment. Both the electrics and relay racks are in modular form using ASEA's Combiflex system.

The general mode of operation is as follows. The accelerator or brake pedal is depressed, operating a miniature camshaft through which microswitches apply to the electronics a reference voltage corresponding to the desired acceleration or braking rate; then the traction circuit is arranged automatically until the feedback from the tachogenerators and current-monitors indicates that the correct condition is reached. If wheelslip is detected, notching is temporarily halted, or in severe cases reversed, until the condition clears. The main braking mode is dynamic; at low speeds as the dynamic fades, the disc brakes take over to halt the tram and to act as a parking brake. If the dynamic brake should fail, the disc brakes will take over at any speed. Emergency braking consists of full dynamic brake plus the track brakes, and sand will be automatically applied to the rails. While the traction resistor is force-ventilated, its thermal capacity is adequate for one stop fully loaded without any ventilation (at 27t from 75km/h = 5.8MJ). The dynamic braking current is initiated by a small alkaline battery connected across two motor fields and which is recharged during the later stages of braking. The disc brakes are hydraulically operated (no compressed air on the tram); braking is applied by springs and released by hydraulic pressure, the pressure being controlled from the tramiac via an electro-hydraulic valve. The system is failsafe against loss of hydraulic pressure. The disc brakes may be released either mechanically or by means of an integral hand pump.

<u>Auxiliary Equipment</u>

The tram has a nominal 24V battery supply on board for the operation of relays, contactors, track brakes and the pump supplying the hydraulic braking circuit. A motor-alternator set mounted on the underframe has two integral fans - one to force-cool the traction motors and to supply positive air pressure to the equipment cases, and the other to force-cool the traction resistor. The heated air from the resistor may be used to heat the tram interior. The alternator three phase 20V output charges the 165Ah battery to 27.5V via a thyristor bridge, and via a transformer feeds the ceiling ventilation fans.

The drivers control panel contains the following:

1. Forward/Reverse switch. In addition to controlling the direction of travel of the tram, this switch controls most of the auxiliary equipment so that the controls are deadened at the non-driving end to prevent possible unauthorised use. The switch is electrically interlocked with the one at the other end of the tram so that one cannot be used unless the other is off and neither can be moved while the tram is moving.

2. Battery switch. Disconnects the battery, thereby deadening most of the 24V circuits. Also cuts off the motor-alternator and the battery charger.

3. Lighting switch. One switch controls all lights - 600V fluorescent lights in the passenger area and in the destination equipment; the headlights and tail lights (if the tram reverses, so do these lights); and the lights over the stepwells. If the lighting is switched on, each stepwell light is lit when the appropriate door is opened. In addition they provide emergency interior lighting if the 600V supply fails.
   As a further refinement, the stop lights at both ends are illuminated at night to act as markers when both F/R switches are off, as happens while the driver is changing ends, when the normal head and tail lights would extinguish.

4. Windscreen wiper switch. Wipers are two-speed, self-parking, two arms per windscreen and pivoted at the top.

5. Windscreen washer switch. Electric pump takes water from 1-gallon container; equipment duplicated both ends.

6. Drivers heater demister switch. Equipment duplicated at both ends, comprises blower fan, 600V 2.4kW heater, outlets to windscreen and drivers knee space.

7. Switches to control the doors. There are four doors. On the left-hand side for a given direction of travel, the door at the front is the entrance and the exit is half way back. All four doors are controllable from each end, but the switches are arranged for convenient operation in the most common modes. The doors are interlocked with the traction equipment so that the tram cannot be driven with the

doors open and so that the doors cannot be opened once the tram is moving. A sealed override switch overcomes both these features if operated, and an indicator light shows if the doors are open or if the interlocks have not been satisfied. The doors themselves are driven by crank rods from a reversible geared motor. They are constructed of aluminium extrusions and have pneumatic safety edges.

The exit doors have some refinements: The driver can set them to 'unlock'; in this case the passenger can press a button to open the door which stays open while he stands on the tread mat and closes automatically when he steps off. Pulling the 'next stop' cord will also open the door in this condition. Furthermore, if the cord is pulled in the usual way while the tram is moving and the driver presets the door to unlock, the exit will automatically open for the first cycle as the tram comes to rest. Lastly a memory relay in the exit retains the unlock feature while the driver changes ends.

The complication of the door operation is desired to speed up passenger transfer and to prevent unauthorised entry via the exits (thus avoiding the seated conductor).

A keyswitch beside each entrance door on the outside allows the driver to operate the door when garaging the tram.

8. Push buttons for: line-breaker reset and sanding valves.

9. Push buttons to override the normal disc brake operation, in which the dis-s only operate to bring the tram to rest and to act as a parking brake. The application button is used to delay release of the brake as in hill-starts where the tram might roll backwards before motor torque is built up. The release button is used to allow the tram to roll freely downhill as in moving short distances in heavy traffic.

10. Push button for the alarm gong. This single-stroke gong also sounds once automatically in emergency braking.

11. Push button for points-changing. In the existing Melbourne system on the old trams, the driver either coasts to a point or drives through on first notch; the street equipment detects the current taken from the overhead and operates the

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points accordingly. With these new trams, the driver has no way of setting a particular notch and could consequently blow the fuse of the point machine by drawing too much traction current. Therefore the tram coasts through all points, and if the driver wishes to turn, he presses this button which connects a resistor load of 50A to the 600V line, thereby operating the street equipment.

12. Three illuminated push buttons - left, right and cancel - to control the electronic direction indicator flasher unit. The turn buttons flash appropriately and a click is heard while the unit operates and additionally if a globe should fail, red lights in the cancel button flash in sympathy, indicating at which end is the failed globe.

13. Switch to operate public address system. The driver can select Internal and speak to passengers via ceiling speakers, or External to address intending passengers via a horn speaker situated under the skirt at the driving end. The microphone is attached to the bulkhead above the drivers head.

14. Battery voltmeter.

15. Speedometer, calibrated in km/h, fed from the wheelslip tachogenerators.

16. Alarm indicator unit. One of the eight windows lights up for each of the following conditions:

    Loss of 600V
    Line breaker tripped
    Disc brake operating
    Loss of battery charge
    Wheelslip
    Track brake operating
    Next stop cord pulled
    Door override operated

In addition the disc brake, trackbrake and wheelslip conditions operate a buzzer in the drivers desk and when the next stop cord is pulled, in addition to the driver's indicator, an illuminated "Next Stop" sign lights on each bulkhead (so that passengers can see someone has pulled the cord) and a buzzer sounds for one second. The illuminated sign remains on until the tram door is opened.

17. Lamp test button. Drives a changeover relay to energise all the globes in the alarm indicator and the Door Open Light.

Conductors Controls

The conductor has controls on his desk for the following:

1. Public address system. A duplicate of the facilities available to the driver, using the same amplifier.

2. Electrically operated ticket machine.

3. Seat-lock solenoids. The three seats between the conductor and the entrance door tip-up like cinema seats and these solenoids lock the seats in the up position to create more standing room in crowded conditions.

In addition, the conductor can reach the next stop cord from his seat by which he has a limited amount of control over the exit door, i.e. if the door is unlocked, he can reopen the door with the cord, if for instance he sees anyone in difficulties, encumbered by parcels etc.

Other Features

1. In addition to his heater demister, the driver has a fresh air duct with a control shutter to his kneespace fed from a scoop behind the bumper bar.

2. Each end of the tram is fitted with a spring loaded lifeguard; if someone were to fall in front of the tram, they would hit the trigger gate releasing the cradle which drops on to the rails, preventing injury from the tram wheels. The lifeguard is reset by a lever in the drivers cab.

3. Ventilation system

The motor generator set, as mentioned before, has a centrifugal fan on each end. One fan draws outside air via a bodyside grille and blows it down a central duct on the underframe for ventilation of the traction motors and the contactor boxes. The duct incidentally is one of the major underframe longitudinal members.

The other fan draws air from the interior of the tram via a grille in an exit stepwell, through the traction resistor and so to a large gate valve where the heated air is either dumped overboard or returned to the tram interior via the fibreglass skirtings to emerge from under some of the seats. A thermostat at the exit of the resistor box interlocks with the traction equipment. Four adjustable thermostats in the air intake control the passenger heating and ventilation system. Two of them control the dump valve which is driven hydraulically from a bleed-off from the braking system. The valve can be set to three positions corresponding to - no heat, half-heat and full-heat. The other two thermostats control the ceiling fans for off, half speed and full speed. There are six fans arranged in line down the centre of the ceiling; they draw air from under the cowling on top of the roof and blow it into the tram.

The modes of operation, together with the present temperature settings are as follows:

Below 60°F	Full heat, no fans
60 - 65°F	Half heat, no fans
65 - 75°F	No heat, no fans
75 - 85°F	No heat, half speed fans
Above 85°F	No heat, full speed fans

A control switch, accessible to the driver, selects either automatic operation by the thermostats or continuous operation in any of the above five modes.

4. Destination equipment. This is of the familiar flip-leaf type as used at airports and in digital clocks. There are three indicator units at each end of the tram: The destination in the front canopy above the windscreen; another destination in the side by the entrance door; the three-figure route number set diagonally on the roof above the entrance door. All six units are controlled from the No. 1 end drivers cab; the driver sets the desired destination and route number on thumbwheels and presses "Go" buttons. Illumination at night is provided for the side destinations by a small 24V inverters and fluorescent tubes, and for the others by 600V tubes in conjunction with the saloon lighting. (2 tubes and ballast resistor in series across the 600V supply).

5. Colour scheme. Roof: Oriental gold, a sort of greenish khaki colour chosen for appearance.sake to match the colour of the debris of copper oxides etc. which fall from the overhead.

Window level: Cream.

Waist level: Marigold, a prominent orange colour chosen for visibility.

Skirt level and bogies: Cocoa brown, a retiring colour to conceal the bogies and emphasis the clean lines of the tram.

Safety Features

It is appropriate to emphasise these as many criticisms of existing trams are made on grounds of safety.

1. Drivers safety pedal must be held at mid-stroke while the tram is moving. Over-depression or release results in immediate application of emergency braking.

2. Three braking systems - dynamic, disc and track. If the dynamic fails, the disc brakes automatically take over. If there is loss of pressure in the hydraulic system, due to faults or accidental damage, the disc brakes will be applied full on. There is more braking capacity than normal wheel-rail adhesion can use, which is why only dynamic and track brakes are used in emergency. The wheelslip detection and correction system operates during braking (as well as acceleration), thereby allowing more effective braking, since slipping friction is less than rolling friction. The disc brakes and track brakes are supplied from the main battery; the dynamic brake has its own existing battery and is they self-sustaining; therefore loss of 600V (as when the trolley pole dewires) would not cause loss of braking. Loss of 24V as explained above would result in permanent application of disc brakes.

3. Good running lights - two sealed beam headlights in permanent 'did' at the driving end, and two large diameter tail lights at the rear end. High level of interior lighting also makes the tram extremely visible at night. Stoplights are provided and flashing turn indicators, visible from all directions.

4. The distinctive colour scheme especially the orange band from the solebar to the window level is very eyecatching in daytime.

5. The warning gong of the same single stroke type and note as on existing trams has been retained because of Melbourne's familiarity with the sound.

6. The doors and their interlocking with the traction equipment prevent accidents caused by passengers trying to board or leave moving trams. The safety edges prevent people being trapped in the doors.

7. The lifeguard as fitted to existing trams has been retained to prevent injury to persons falling in front of a moving tram.

8. The driver has an external rear vision mirror so that he can readily view passengers leaving the exit door.

9. For electrical safety, the roof skin is all-insulated. A lightning arrestor is provided. On the underframe, a knife-switch isolator is provided which breaks the trolley pole supply prior to any of the main or auxiliary circuits.

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Data

Overall length	16560mm	
" height	3537mm	top of number box
" width	2670mm	
Floor height above rail	850mm	
Bogie centres	8500mm	
Bogie wheelbase	1796mm	
Track gauge (standard)	1435mm	
Tare weight (approx.)	19t	
Weight each bogie (approx.)	4t	
Total fully loaded weight (approx.)	27t	
Passenger capacity, seated	~~48~~	58
" " , standing	77	70
Total	125	128
Supply voltage, nominal	600V	
Total continuous rating of motors	208kW	
Wheel dia, new	680mm	
" " , condemning	630mm	
Tram speed max., level track	72km/h	
Motor speed at 72km/h	4091 rev/min.	
" " , max. continuous	5000 rev/min.	
Acceleration, max.	1.8 m/s^2	
" , average 0–72km/h	0.7 m/s^2	
Deceleration, max. emergency	3.66m/s^2	
" , average 72–0 km/h	1.5 m/s^2	
" , max. dynamic only	1.6 m/s^2	
" , " disc only	1.6 m/s^2	
Jerk rate, less than	2.1 m/s^3	
No. of accelerating steps	41	

Motor-alternator

Motor: compound winding, 4 poles, 600V, 6.4kW

Alternator: 3-phase synchronous, Y-connection, 24V, 60A, 2.5kVA

Nominal speed 1700 rev/min. = 56.7Hz

Battery charging current, max. 65–75A

" voltage, fully charged 27.5V