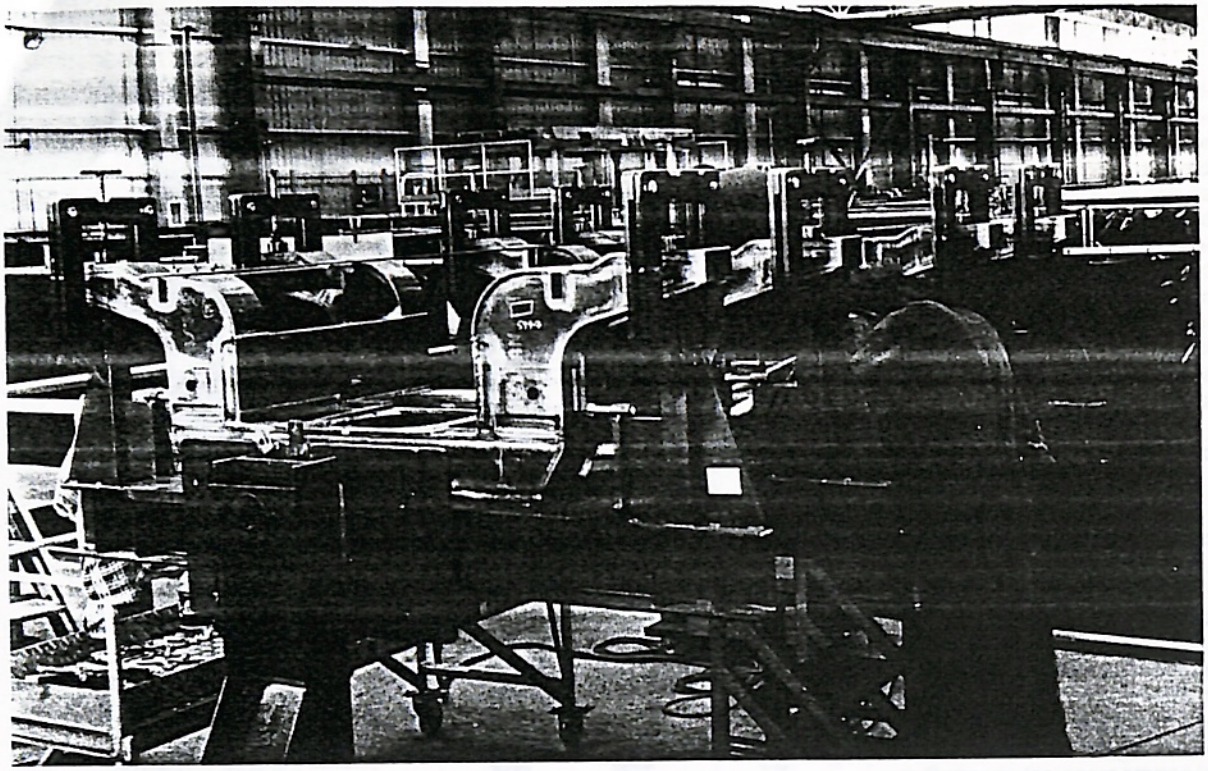


Sydney's Light Rail Cars

Construction of The Australian Variotram

By the time this article appears in print, it is expected that the first of Sydney's articulated light rail vehicles, the Variotram, will be approaching completion. They are being built for the Sydney Light Rail Company at the ADtranz factory in Dandenong, Victoria.

In *TA 11/94*, an overview of the design concept of the 100% low-floor ABB Variotram was published. This article updates that information insofar as the Sydney vehicles are concerned and adds some detail not covered before by *TA*. Since that article ADtranz has continued to develop the Variotram concept. A 70% low-floor variation is being built for OEG Mannheim and one 100% low-floor car with gearless hub motors is on order for DVG in Duisburg. There are also 20 metre-gauge cars for Helsinki. As noted from **Table 1**, the Chemnitz, Duisburg and Sydney 'modular' Variotrams in fact have very little in common.

The first Sydney LRVs were due to begin track testing in March 1997 and the system to be fully operational by mid-1997. As at early March, the first vehicle is due to arrive in Sydney to begin track testing by the end of April, and the system still is expected to be fully operational by mid-year.

The Concept

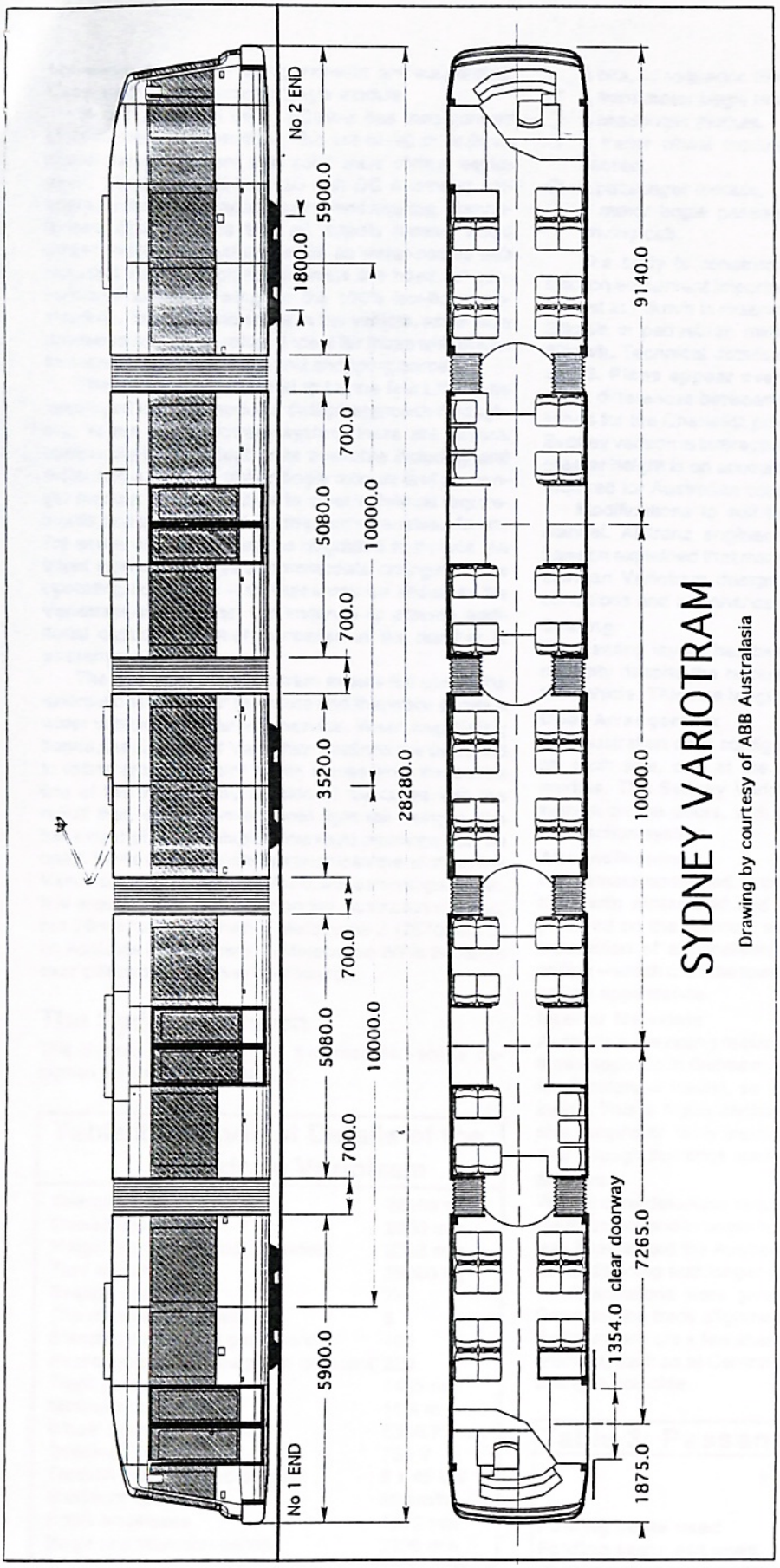
Operating in Germany as the Variotram, the Light Rail Vehicle (LRV) was an ABB concept which has been specifically redesigned to suit Australian conditions. Engineers had finalised the vehicle design and by September 1996 fabrication was well underway at the ADtranz factory (formerly ABB) in Dandenong, Victoria. (ADtranz was formed by the merger of the transportation activities of the electrical engineering group ABB and Daimler-Benz Transportation.)

The Variotram is a distinctive concept among LRVs, being low-floor throughout, multi-articulated and running on unconventional bogies or trucks to which short passenger compartments are directly fitted, and from which longer

TOP: Extensive use was made of jigs in the fabrication and assembly of the Variotrams at the ADtranz plant in Dandenong, Victoria. This photo shows the jigs used for the bogies; the U shape of the bogie frame is actually the passenger walkway between the axle-less wheels. - ADtranz

Table 1: Variations in the Variotram

City	Chemnitz	OEG	Sydney
Type	uni-directional	bi-directional	bi-directional
Length mm	31380	32200	28280
Width mm	2650	2500	2650
End module mm	5640	5640	5900
Intermediate module mm	7250	7250	5080
Centre module	2800	3600	3520
Power kW	8x45	4x95	8x45



Safety Working

The Sydney cars are being fitted with full automatic train protection (ATP) which applies for both on-street and reserved track operation. This will ensure that trams stop at stations and do not exceed speed limits. Beacons placed in the track send signals to the cars to firstly warn the driver of the need to stop, then if this is ignored, applies brakes in two progressive stages, the latter being a full emergency brake application.

Priority will be given at road traffic lights.

Miscellaneous

Larger roof drains are fitted to cope with Sydney's heavy rain.

Clearly the Variotram concept is continuing to undergo development. ADtranz in Melbourne has taken advantage of experience with the German cars, and any Australian enhancements are being fed back to Germany for incorporation in other contracts where appropriate.

Bogie and Drive

Each Variotram module is an independently functioning unit with bogies designed for a 100% low-floor level of 35cm above rail. At access points, the floor dips slightly to 29cm. There are no raised floor sections inside the vehicle, and the wide articulation areas between the modules offer no obstruction to passengers walking from one end to the other.

The Variotram's bogie design is the key to low-floor technology. When travelling through a curve the traditional bogie frame rotates about its vertical axis with the wheelsets mounted on axles. The rotational movement between the car body and bogie, plus the system of wheelsets, require considerable space so that a high floor level is necessary.

Track guidance is provided in the torsionally flexible bogie frame by having each wheel suspended in a wheel support unit. The entire wheel support unit pivots about a fixed point in the bogie frame and is supported by primary springs and parallel vibration dampers. Secondary suspension is by helicoil springs

non-wheel passenger compartments are suspended. Cabs are part of the motor bogie module.

In designing the LRV, ADtranz has incorporated state-of-the-art technology. The use of AC drive three phase traction motors and solid state control equipment, powered from the 750 volt DC overhead catenary, gives quicker acceleration and braking. Computerised logic ensures that all wheels receive equal power. Advanced features such as water-cooled hub mounted traction motors eliminate the need for conventional axles, allowing for the 100% low-floor construction. There are no steps in the vehicle, while wide doorways and aisles make it ideal for those with prams and strollers, wheelchairs and shopping parcels.

The Variotram is claimed to be the first LRV to be developed using a modular design approach throughout. Within the Variotram system there are several completely independent units available including end motor bogie module, trailer bogie module and passenger module, which combine to meet individual requirements and are fully and permanently variable. An entire series of vehicles can be upgraded to include the latest technology or to accommodate changes in the operating conditions – modules can be added to the Variotram at any time, for instance to provide additional capacity to meet increases in the number of passengers.

The design of the Variotram makes full use of the kinematic envelope of the route and therefore allows a wider vehicle to be put into service. When negotiating bends, the articulated Variotram sections are designed to rotate around a point which moves from the centre line of the track to the outside of the curve with the result that, unlike conventional light rail designs, the full extent of the available kinematic envelope can be used. While ABB publicity emphasises the width of the Variotram, that is valid only for European comparisons. It is around 150mm wider than the Australian city bus, but 20mm narrower than a Melbourne Z (2670mm) or an Adelaide H (2800mm). A Melbourne W7 is 2438mm over pillars or 2743 over footboards.

The Sydney Version

The Sydney Variotram is a five module vehicle designed for two-way operation.

Table 2: Technical Details of the Sydney Variotram

Overall length	28280 mm
Overall width	2650 mm
Height (pantograph not included)	3388 mm
Tare weight	36000 kg
Seating capacity	74
(Tip-up seats included)	6
Standing capacity (4 persons/m^2)	103
Passengers (total; see panel adjacent)	223
Track gauge	1435 mm
Minimum curve radius	16.4 m
Wheel diameter (new/worn)	630/570 mm
Overhead line voltage	750 V
Traction motors (rated output)	8 x 45 kW
Maximum speed	80 km/h
Bogie wheelbase	1800 mm
Bogie to articulation centre	2100 mm

It has, in sequence from the front:

- a front motor bogie module incorporating the cab,
- a passenger module,
- a trailer wheel module incorporating a short passenger section,
- a passenger module,
- a motor bogie passenger module incorporating the rear driving cab.

The body is constructed of welded stainless steel, with traction equipment imported from Germany. Operating speeds are set at 70km/h in reserved track, road speeds on-street, and 20km/h in pedestrian malls, but the vehicles are capable of 80km/h. Technical details of the Sydney LRV are in **Tables 2 and 3. Plans appear overleaf.** It will be noted that there are some differences between these specifications and those published for the Chemnitz prototype (***TA 11/94***). In particular, the Sydney version is bidirectional and has doors on each side. The greater height is on account of the rooftop airconditioning units required for Australian conditions.

Modifications to suit the Australian conditions were substantial. ADtranz engineering manager at Dandenong, Neal Lawson explained that many changes were made to the original German Variotram design to adapt the vehicle to Australian conditions and to enhance the design.

Seating

The seating layout has been changed to increase the seated capacity despite the necessity to have doors on both sides of the vehicle. This has lengthened the passenger modules.

Door Arrangement

The Australian door configuration provides three double doors on each side, one at the front and one on each passenger module. The Sydney Variotram features an enhanced safety system on the doors, with obstacle detection interlocked with the traction system.

Airconditioning

Full climate controlled airconditioning is required in Sydney to cope with winter cold and humid summer heat. This was not provided on the German vehicle which only has heating. The installation of airconditioning ducts required changes to the ceiling – which is a little lower – hence there was a change to the ceiling appearance.

Interior Materials

Australia's fire rating requirements are significantly higher than those applying in Germany (in fact nearly as stringent as those for Eurotunnel trains), so different materials have been used inside. This is highly desirable as the Sydney route has extensive lengths of fairly inaccessible track, tunnels and right-of-way through buildings such as the Casino.

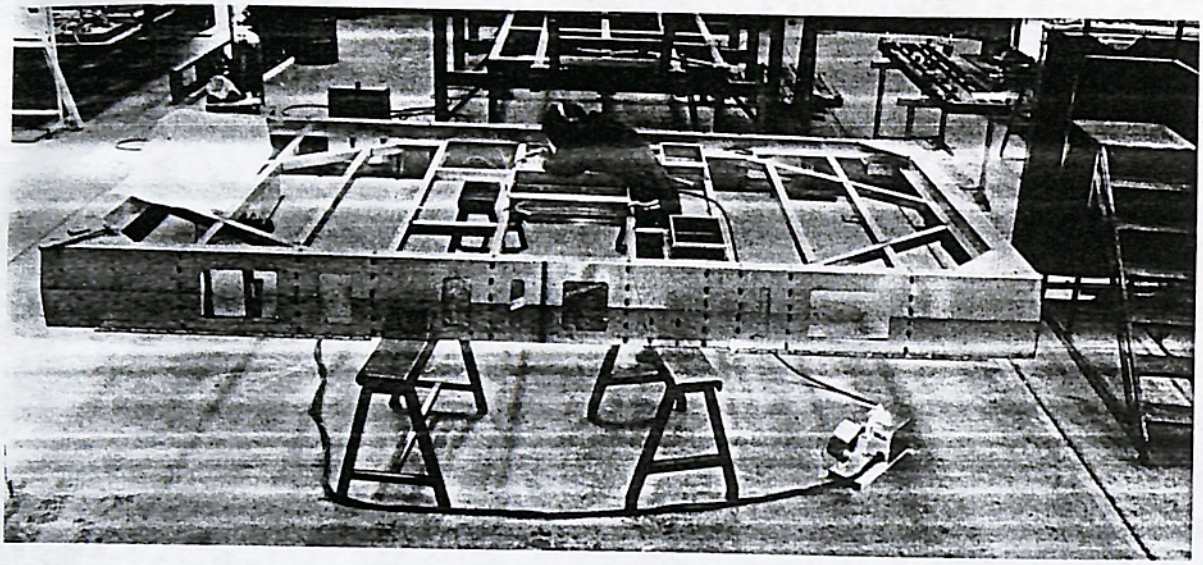
Structure

Weight considerations required that some changes be made to the structure and in bogie fabrication. The basic German design was heavier, but the Australian vehicle has the added weight of airconditioning and longer passenger modules.

Articulations were given an extra degree of flexibility; in Germany the track alignment is generally very flat, whereas in Sydney there are a few sharp curves and significant changes in gradient, such as at Central Station, where curves and gradient changes coincide.

Table 3: Passenger Capacities

	SEATED	STANDING (at 6/m^2)	TOTAL
Folding seats used	74	143	217
Folding seats not used	68	155	223



ABOVE: Welding the roof of a passenger module. - ADtranz

with progressive characteristics located between bogie frame and car body and provided with additional vertical and horizontal vibration dampers. The central location of the secondary springs, in much the same way as with a conventional bogie, has the effect of reducing impact forces by half.

Longitudinal forces are transmitted from the bogie to the car body via two traction rods. Movement in the transverse direction is limited by means of progressive rubber stops.

Resilient wheels reduce vibrations back into the passenger modules and also reduce the ground-borne vibration. All suspension and damping elements have been designed to eliminate wear and tear, so as to reduce maintenance costs.

Variotram is fitted with gearless hub motors, which have eliminated the need for axles between the wheels. With the Variotram's hub motor drive system, the wheels are resiliently mounted onto the motor hubs and free-wheeling trailer bogie hubs. The motor bearings are designed to transmit the wheel loads and lateral forces between wheel and rail. In the case of the trailer unit, the wheel is fitted with two tapered roller bearings mounted directly onto the stub axle of the wheel support unit.

The service brake is electrodynamic, applied to the drive wheels, with the three phase drive system providing excellent braking performance down to a virtual standstill. Two of the traction motors in each bogie are also fitted with disc brakes operated by spring loaded cylinders and used as a low speed service brake and also as a mechanical emergency brake and as a parking brake. Hydraulic disc brakes are provided for the non-driven wheels. Electromagnetic track brakes are provided for both the powered and the trailer bogie modules.

The traction motor is a three-phase induction motor with an external rotor to provide direct drive to the wheel. The two end plates of the hub motor accommodate the grease lubricated, cylindrical roller bearings and are bolted onto the ends of the casing tube. The squirrel-cage winding is laid in slots provided for it on the inside of the tube, with the wheel rim fitted onto the outside. The stator is mounted on the stationary axle and supports the impact-resistant winding. The traction motor and traction inverter are all cooled by an integrated system using domestic tap water, plus coolant.

Each powered bogie with its four traction motors is allocated a traction inverter unit which incorporates two transistor inverter modules, each of which is designed for parallel connection of two traction motors. The cooling system for the inverters, as with the traction motors, is based on domestic water with anti-freeze.

The three-phase auxiliary systems for the ventilation system and the cooling water circulation system of the traction unit are connected to a static converter in each of the powered bogies, which takes its power from the overhead line.

Having two motor bogie modules the Sydney LRV is equipped with two independent traction converters powered from the same source, which increases its operational reliability. There is a separate traction inverter for the auxiliary equipment, including the airconditioning, lighting, horn, onboard computer, etc.

Operations

The Sydney Variotram is designed for single person operation and services are expected to operate 18 hours per day at 5.5 minutes peak frequency and 11 minute frequency at other times. For this level of service, six vehicles will be required, leaving one spare.

Tickets will be magnetic swipe cards validated by machines at each stopping point.

Should the City and Leichhardt extensions proceed, at least 15 additional Variotrams would be required ■

