Mark IV Coaches for British Rail InterCity

GEC ALSTHOM

Mark IV Coaches for British Rail InterCity

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Based on a paper presented to the IEE Conference on Electrification at York, September 1989

1. Introduction

For the electrification of the East Coast Main Line from London to Leeds, Newcastle upon Tyne and Edinburgh, the Intercity Sector of British Rail has ordered 31 high speed passenger train sets. Each set comprises a Class 91 electric locomotive and a rake of nine vehicles. Eight of the vehicles are passenger-carrying and the ninth is a Driving Van Trailer (DVT) with a streamlined nose and driving cab at the outer end only.

The Class 91 locomotives are being manufactured under a contract between British Rail and GEC Transportation Ltd. The passenger vehicles are the subject of a separate contract, Metro-Cammell Ltd being the Main Contractor and these vehicles have been classified as Mk IV by British Rail.

The Class 91 locomotives and Mk IV train sets have been designed for daytime use on services operating at up to 225 km/h. The composition of the train sets was determined by an economic need to make maximum use of the Class 91 locomotives. The Mk IV vehicles are day coaches, but the locomotives will also be used at night hauling sleeping car and mail trains at speeds of up to 160 km/h.

The basis of the business specification produced by the Intercity Sector was a requirement for a fleet of vehicles offering a level of comfort for passengers during operation at 225 km/h and 6 degrees cant deficiency equivalent to the existing Mk III passenger rolling stock operating at 200 km/h and 4.25 degrees cant deficiency.

Improvements were also required in all areas of equipment and this paper sets out to cover the design approach adopted to provide a new generation of passenger vehicles.

2. Train Formation

The train formation is designed to permit push-pull operation of the sets with a Class 91 locomotive being marshalled at one end and the Driving Van Trailer at the other. In one direction the passenger coaches are hauled in a conventional manner; in the opposite direction the coaches are propelled at speeds up to the maximum of 225 km/h. Full driving controls are provided in the DVT which is equipped with a full width cab substantially identical to that of the locomotive. The remainder of the DVT is fitted out as a Train Conductor's Office and baggage compartment. Equipment cubicles house air-conditioning and electrical control equipment.

The passenger vehicles, whilst based on a common bodyshell, are equipped to provide the differing vehicle types and are marshalled into two standard train formations as follows:

STANDARD RAKE	PULLMAN RAKE
Tourist Open End	Tourist Open End
Tourist Open	Tourist Open
Tourist Open	Tourist Open Disabled
Tourist Open	Service Vehicle
Tourist Open Disabled	Pullman Open
Service	Pullman Open
Pullman Open	Service
Pullman Open	Pullman Open
Driving Van Trailer	Driving Van Trailer

Within the train formation, vehicles are coupled by Tightlock automatic couplers, whilst BR standard Buckeye couplers connect the Class 91 locomotive to the train. Vestibule buffers are employed with the Buckeye couplers to assist in absorbing buffing forces. Gangways between vehicles are to a new design fully sealed for improved environment, significant development testing having been undertaken by BREL in this design. Intercar electrical connections carrying power and control information are by plug and socket couplers.

3. Bodyshell Structure

The bodyshell of the Mk IV passenger vehicles and the Driving Van Trailers is of conventional construction based upon the lightweight shell developed by Metro-Cammell for the British Rail Class 156 Diesel Multiple Units of which some 228 have been constructed. The structure is a total monocoque, all-welded, carbon steel construction designed with the aid of finite element analysis to optimise strength, stiffness and weight.

The outer end of the Driving Van Trailers is a fabricated steel structure class with GRP panels to give a profile identical to that of the Class 91 locomotive. Following the Polmont derailment in 1984 which resulted from a push-pull train hitting a cow, the DVT is fitted with an obstacle deflector capable of withstanding a load of 600 kN. If this load is exceeded, the deflector begins to collapse through plastic deformation. The leading axle loads of the DVTs are additionally specified to be a minimum of 12 tonnes.

Pre-production shells for both the passenger coaches and the Driving Van Trailers were constructed for the purpose of conducting large scale strain gauge testing during which the full scope of static test loads were applied.

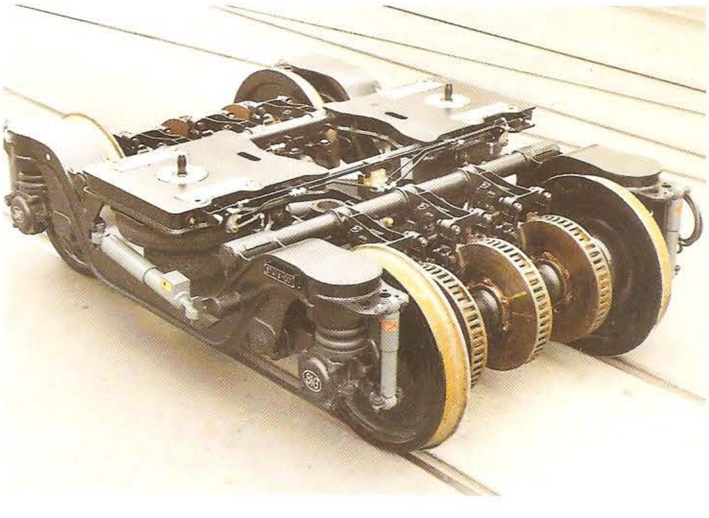
4. Interior Layout and Finish

Interior layouts were specified by British Rail as part of the comprehensive Procurement Specification. The responsibility for the translation of the Board's conceptual thinking into a manufacturable design and the selection of materials though was that of Metro-Cammell.

Three basic vehicle layouts exist with some minor variations. All use the same basic body shell; the service vehicles differing only in that the window apertures are reduced in the kitchen area.

5. Bogies

Two bogie designs were under review at the beginning of the design phase and after the letting of the main contract. One was a design from the then British Rail Engineering Limited (BREL) identified as the T4. The other was a design from the Swiss company of SIG and based on bogies supplied by them to a number of European railways. In the event, the Swiss design was selected.



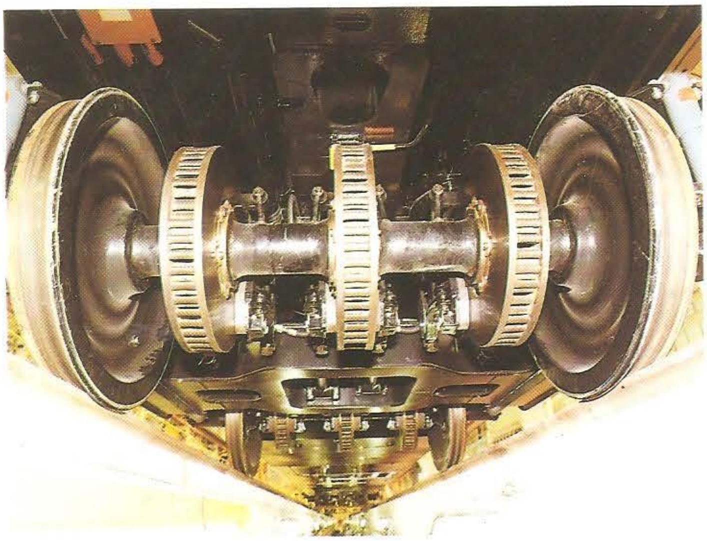
As noted in the introduction to this paper, the Intercity Sector's aspiration in the area of ride called for a level of lateral ride in a Mk IV vehicle operating at 225 km/h and at 6 degrees cant deficiency equivalent to that of an existing Mk III operating at 200 km/h and 4.25 degrees cant deficiency.

This business requirement is expressed in the BRB Procurement Specification in the form of a Lateral Ride Journey Average Figure defined as the arithmetic mean of the weighed rms acceleration evaluated at 10 second intervals over any 30 mile route section covered at the maximum permitted line speed for the vehicle. The maximum level is the worst 10 second value recorded. The track is specified within the Procurement Specification by means of representative track Power Spectral Densities.

Because of these stringent requirements, a significant amount of analytical and practical development work has been carried out during the design phase. This included pilot trials at up to 238 km/h (148.5 mile/h) on a section of the East Coast Main Line between Darlington and York.

The resultant design employs a fabricated steel bogie frame. Primary suspension utilises steel helical springs and hydraulic shock absorbers. Secondary suspension is by a combination of air suspension and a vertical rubber spring. Anti-roll bars are fitted together with vertical and lateral hydraulic shock absorbers. Yaw dampers mounted horizontally on each side of the bogie between the bogie frame and upper bogie bolster provide additional stability for high speed operation.

As a result of a whole life cost analysis, three ventilated discs each with its own pneumatic actuator are fitted to each axle to provide the required braking effort and provide maximum brake pad life.



6. Brake Control Equipment

Brake control throughout the train is a conventional two-pipe system employing a Brake Control Pipe and a Main Reservoir Pipe. Charging of the Brake Control Pipe to a nominal 5 bar maximum produces a full brake release. Reduction of this pressure to 3.5 bar produces a full service brake application. A complete loss of Brake Control Pipe pressure initiates an emergency brake application. Control of the Brake Control Pipe may be initiated by any of the following; Driver's brake or auxiliary controller, the Automatic Warning System (AWS) or the Driver's Safety Device (DSD). Application of any of these devices in the locomotive or DVT is communicated to the other via the TDM system. Passengers may initiate an emergency brake application by pulling one of the emergency handles situated within the saloon, toilet or by each external door.

A distributor valve on each vehicle responds to pressure variations in the brake pipe, providing an output pressure via a variable load valve to supply air to each of the six brake actuators mounted on each bogie.

To reduce the possibility of wheelslip at high speeds and to reduce the thermal input to the brake equipment, a two stage brake application is employed; a reduced brake application being made at speeds above 200 km/h.

Each vehicle is fitted with an electronic wheelslip detection equipment monitoring all axles. In the event of wheelslip, the brake actuator pressure on the affected axle is reduced by actuation of an electro-magnetic blowdown valve. Re-application of the brake application is on a pre-programmed basis. The wheelslip detection equipment also provides a 5 km/h speed signal to the power door control circuits to ensure that all doors are locked and disabled above that speed.

Compressed air is distributed down the train via the Main Reservoir Pipe charged at a nominal 7 bar.

The brake control equipment on each vehicle is modularised with all equipment, including air suspension and door air supply reservoirs mounted within a demountable steel frame locating within the vehicle underframe skirt. Isolating cocks and brake release handles are located at each skirt face or within a folding access door.

Parking brakes are located on the DVT only and are sufficient to hold the maximum rake on a 1 in 100 gradient. This brake is hydraulically actuated and applied and released electrically from either cab or driver's compartment or manually from within the guards area.

7. Auxiliary Power Supplies

Auxiliary power for coach lighting, air conditioning and heating, and emergency battery charging is derived from the electrical train supply (ETS) from the locomotive. The electric train supply is received by the rake from the locomotive (or shore supply) via two single pole ETS jumpers rated at 600 amps. This train supply is derived from a separate ETS winding on the main transformer of an electric locomotive or from an ETS alternator or generator on a diesel electric locomotive. It may, therefore be ac or dc and vary between 750-1050 volts with a bottom limit of 520V under emergency conditions.

Protection of this circuit is by means of a fuse or thermal overload on the locomotive and each ETS jumper carries the standard BRB interlock wire and auxiliary contact which must complete a loop circuit to permit the ETS supply contactors on the locomotive to close.

A static converter on each coach and DVT converts the ETS to a 26 kVA, 415 V ac, 50 Hz, 3 phase and neutral supply and a 7 kW, 110V dc supply which also float-charges the vehicle battery. Full short-circuit and overload protection is provided together with a thermal limit calculated by its own microprocessor control unit, which also regulates the load shedding of the battery loads on converter shut-down or failure.

On the service vehicles only, a second static converter provides 33 kVA single phase, 240 Vac 50 Hz supply with a high quality sine-waveform dedicated for the catering equipment. If this supply should fail, a changeover and isolation switch in the kitchen can switch a limited amount of catering facilities to the 3-phase converter.

Both static converter types are supplied by ACEC of Belgium now part of the GEC Alsthom group and incorporate the latest GTO and microprocessor technology. They start automatically on connection of the ETS supply and do not require any secondary supply for starting.

8. Train Control

A time division multiplexing (TDM) system is employed to transmit control and monitoring signals for the locomotive traction system from one end of the train to the other.

The system gives remote control of traction power and train brakes to locomotives equipped with appropriate TDM equipment from the Driving Van Trailers. Whilst braking control is required at all times, traction control is only required when controlling a remote locomotive. Any monitored faults or control malfunctions are displayed to the driver on a "Cab Display Unit".

The system uses cores 1 and 2 of the standard UIC 12-core communications cable installed throughout the train to communicate in a serial manner employing frequency shift keying techniques. The master unit monitors the driver control highway and its own local inputs, and communicates its control requests to all units whilst reporting its own status to the driver. The Master TDM polls each outstation giving a control/refresh update and in return receives status report from each outstation.

High level priority control commands are given in a broadcast message, requiring immediate implementation with no reply response. The correct implementation is then checked on normal polled update.

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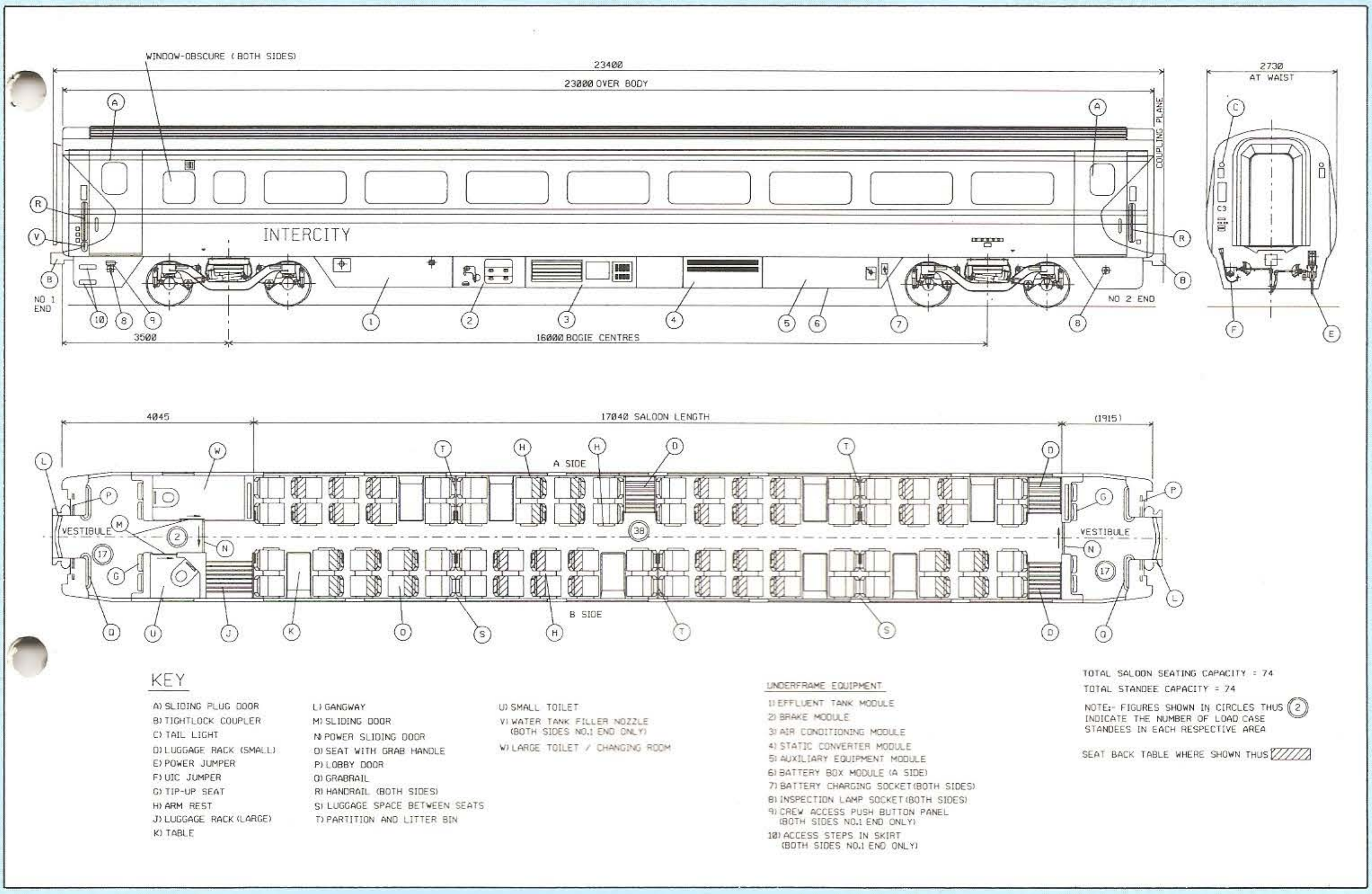


There are three Standard Class vehicles with detailed differences. They are designated Tourist Open (TO), Tourist Open End (TOE), which is marshalled next to the locomotive, and Tourist Open Disabled (TOD).

Tourist Open — TO

There are 74 seats arranged 2+2 on each side of a central aisle. One of the aims of the Mk4 interior has been to avoid the "narrow-bodied airliner' look of a long thin tube. Thus the seating is a mix of eight facing pairs across tables interspersed with unidirectional airline-style seating with drop-down seat-back tables.

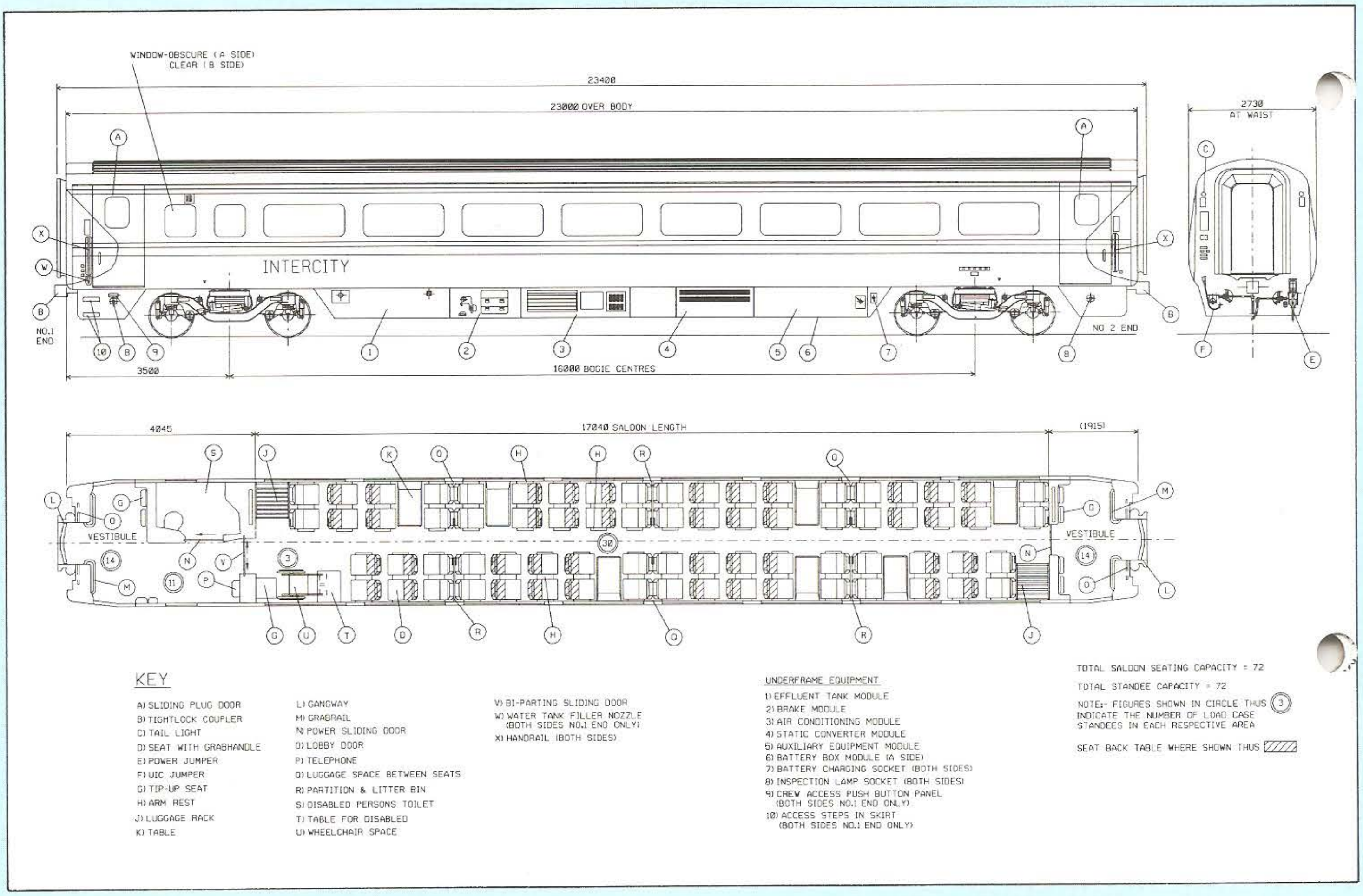
Several features help break-up the visual effect of the open saloon. For example, there are different combinations of facing-pairs and unidirectional seating on each side of the aisle. Full-height smoked glass partitions further disguise the length as does the change in seat fabric colour between smoking and non-smoking areas.

A conventional full-height shelved luggage rack at one end of the saloon is supplemented by three 'luggage stacks', one in the centre of the vehicle between seats and two at the other end. These stacks also contribute to breaking up the interior. There are also overhead luggage racks.

Ingenious layout work places each row of seats on both sides beside a window, despite the use of a common body shell for both Tourist and Pullman coaches.

Two toilets are installed at one end of the vehicle on opposite sides of the vestibule. One of the toilets is larger than on previous BR vehicles and this extra space has been used to provide additional features. Most welcome will be the fold-down baby-changing table. There is also a warm-air hand dryer in addition to paper towels.

In the small toilet there is just the usual wc and wash-basin. All wash basins are supplied with a timed flow of water at a constant temperature.



Tourist Open (Disabled) — TOD

In the vehicle for disabled travellers, which will always be located next to the catering vehicle, the two seats backing onto the bulkhead, plus the table, of a facing pair at one end are removed to provide space for a wheel-chair, reducing capacity to 72 seats. A drop-down table is provided in the wheel-chair space and there is also call for aid button. A tip-up 'courier seat' on the bulkhead can be used when the wheelchair space is empty.

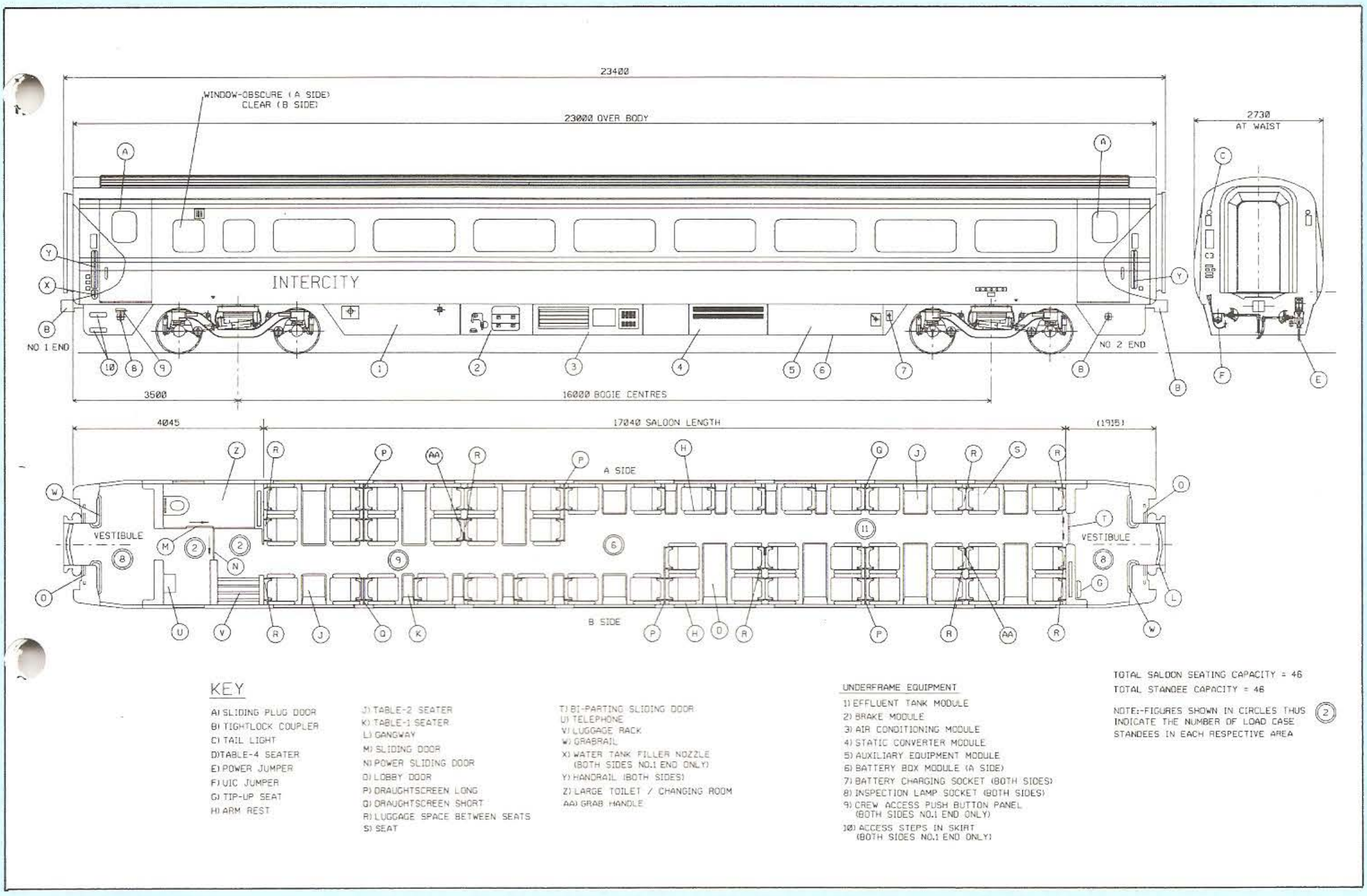
Once again, all seats are beside windows, but luggage storage is reduced to two stacks, one at each end.

On one side of the vestibule adjacent to the wheelchair space is the vehicle's single toilet. This is the latest version of British Rail's toilet specially designed for use by the disabled.

Features include an even larger push-button operated powered sliding door than on previous versions, plus the usual hand rails, special wc, and call for aid button. Also fitted are the fold down changing table and warm air hand dryer of the TO/TOE large toilet.

Opposite the disabled toilet is the telephone booth for Standard class travellers.

Extra space for luggage storage is provided between seats.



Pullman Open (PO)

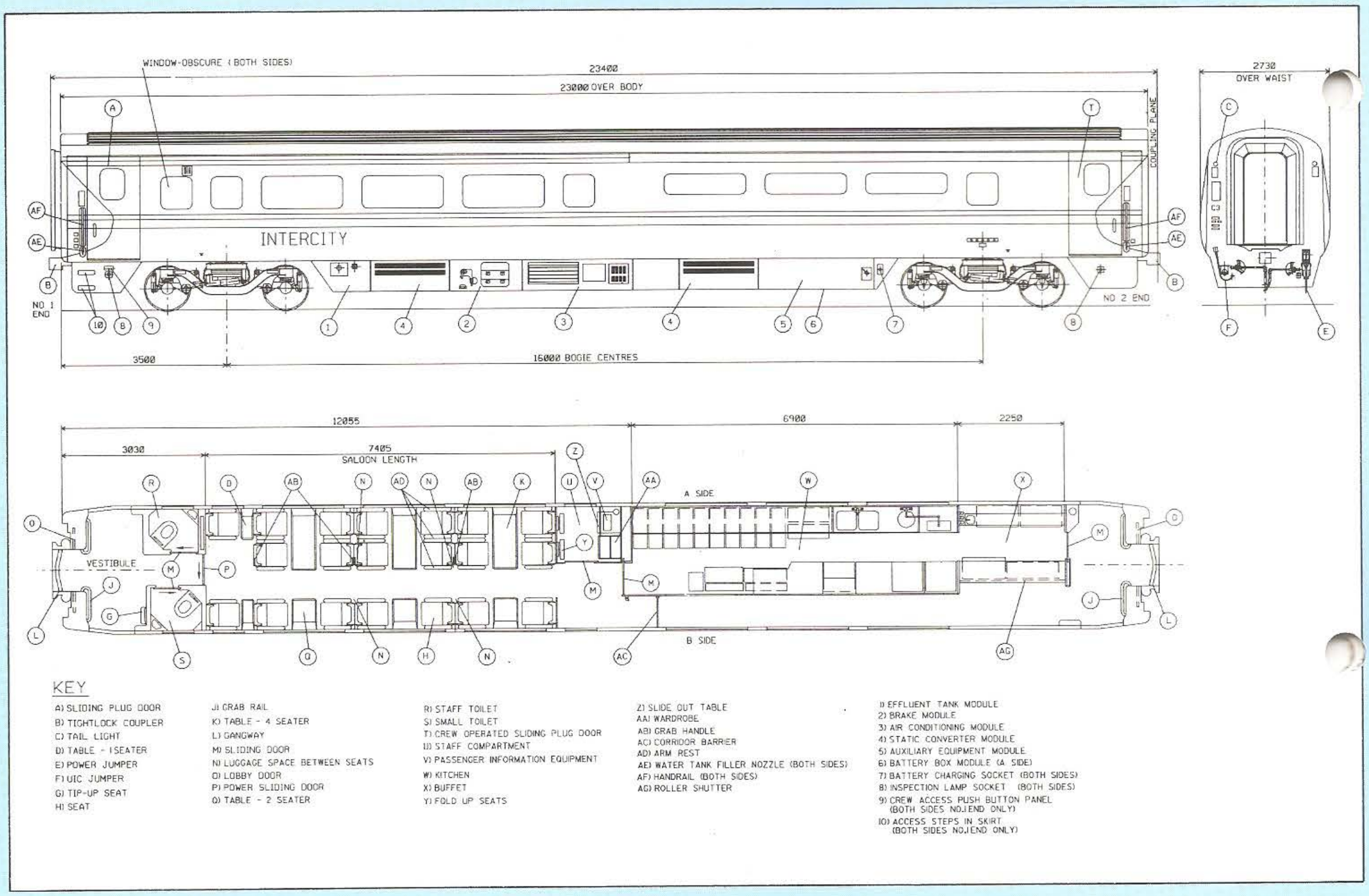
Here too, the length of the vehicle has been disguised by variations in seating layout and full-height smoked glass screens. In the middle of the vehicle, the 1+2 seating arrangement changes to 2+1 so that the aisle has a dog-leg, or chicane.

There are 46 reclining seats, of which eight are face to back. All seats have tables. At one end, the glass screens create an enclosed block of six seats, rather like the 'coupe' in old Pullman cars.

Diffused ceiling lighting and indirect light spilling downwards from the coves of the ceiling create a restful atmosphere. There are also individually switchable spot lights in the luggage rack above each seat.

Each car has a single large-pattern toilet opening off the vestibule. Opposite the toilet in each vestibule is a telephone booth.

The chicane is clearly seen here.



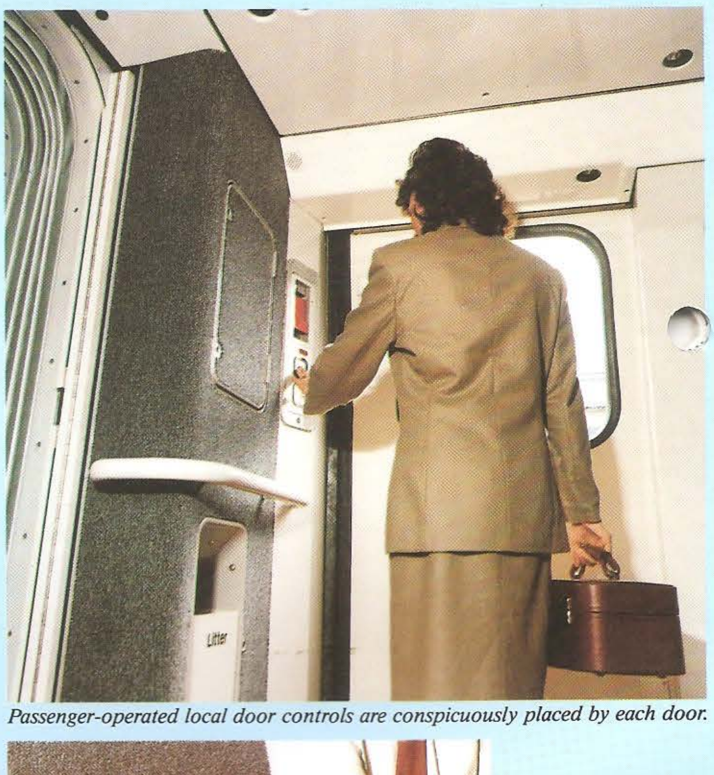
Service Vehicle (SV)

This has the kitchen and buffet bar plus a 20 seat dining area with the same seating and lighting as the Pullman car.

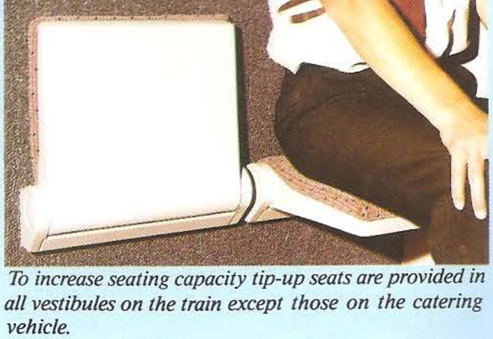
Careful thought on space utilisation has packed a considerable amount into the available space. The catering staff have their own compartment and there is storage space for the catering service trolleys. There are also separate small-pattern toilets for staff and passengers at one end.

Colour schemes

In both classes, greys dominate, enlivened in the Tourist vehicles with red seat trim. Pullman interiors are various shades of grey, plus black, with chrome trim on the seats. There will be ornamental structures in the corners of each "chicane."



Passenger-operated local door controls are conspicuously placed by each door.



To increase seating capacity tip-up seats are provided in all vestibules on the train except those on the catering vehicle.

9. Coach Control

A frequency division multiplexing (FDM) system is similarly utilised to transmit control and monitoring information related to coach equipment including doors closed confirmation. The information is transmitted over two cores of the UIC 12-core cable.

10. Air-Conditioning

The air conditioning equipment has been sourced from two suppliers, Temperature Limited and Ebac Limited. Each supplier supplies a range of equipment interchangeable with that of the other and the description which follows is representative of both.

10.1 Coach Equipment

The passenger saloon areas and also the non-service areas on the service vehicle are provided with conditioned air from a self-contained, fully automatic module mounted beneath the vehicle underframe.

Two separate air distribution supply ducting systems are provided within each vehicle, each fed from separate outlets on the underframe module. One system feeds the floor level coving grilles and is employed during the heating cycle only. A pneumatically operated flap shuts off the air flow during other operating modes.

The other system feeds a ceiling duct running centrally along the full length of the saloon from which the air is evenly discharged. In the case of the service vehicle, this duct runs along the side corridor area.

A third duct system extracts air via the centre floor level coving grilles on both sides of the vehicle and returns it to the module. Some of the extract air is returned to atmosphere, some is mixed with fresh air and recycled.

Typical airflows are as follows:

fresh air intake 1100 m^3/h at face at module

fresh air filter scavenge 100 m^3/h to atmosphere

total recirculating air 4000 m^3/h through ventilation fan

exhaust air 900 m^3/h to atmosphere

In the event of a brake application exceeding 50% of the maximum a signal is sent to the air conditioning control from the brake system module. On receipt of this signal, a pneumatically controlled damper shuts off the fresh air intake grill and the exhaust and filter scavenge fan motors are de-energised. This eliminates the ingress of brake pad smell and dust during heavy braking.

The fresh air intake incorporates a cyclone type pre-filler with scavenge fan to dump dirty air. This is provided to prolong periods between changeout of the recirculated air panel filters by considerably reducing exterior dirt ingress.

Both suppliers' modules employ the same basic design concept utilising a conventional vapour-compression cycle refrigeration circuit. A reverse cycle circuit is incorporated to provide both cooling and heating functions. Performance output control is achieved by unloading the compressor by $1/3$ or $2/3$ using electrically operated unloading valves.

Electric heat banks are connected to the 415V, 3-phase supply. These are energised in the pre-heat and de-frost modes and act as a back-up heating source in the event of a refrigeration circuit failure.

To provide flexible and efficient control of the vehicle interior environment each module incorporates a microprocessor which has been specially developed for this application. Various sensors built into the refrigeration circuit, and at key points in the air paths, detect changes in temperature and pressure and provide the microprocessor with the necessary monitoring information. Besides providing the automatic control facility, the microprocessor can also detect faults, display error codes and stores data relating to operational and fault conditions. By means of a portable micro-computer (eg. Husky etc) interrogation of the system parameters for fault diagnosis purposes is possible.

415v ac 3 phase and 110v dc supplies are taken from the vehicle static inverter. The compressor and fan motors are 3 phase type except the main ventilation fan which is 110v dc. In the event of loss of ETS or static inverter fault the motor will continue to operate from the 96v battery supply for a period of 50 mins to provide emergency ventilation.

10.2 DVT Equipment

The driving cab and the guard's compartment are both fully air-conditioned. Separate HVAC units, located within the van space at either end, supply the crew areas through local duct systems. Flexible ducts between the units and vehicle bodyside louvres are provided for drawing in condenser air and fresh air, and exhausting the condenser air. Conditioned air is discharged into the cab through the perforated ceiling panels which provide the necessary diffusion. Air is returned to the unit via the cab vestibule through a grille in the van partition.

In the guard's compartment conditioned air is discharged through the supply-air grille at ceiling level on the van partition. The return-air grille is located on the same partition at floor level.

The HVAC units are fully packaged. The hermetic refrigeration circuit utilises the conventional vapour-compression cycle in conjunction with a semi-hermetic compressor (air cooled). Maximum cooling duty is just under 3kW at 28°C/45% RH outside ambient to maintain 21°C/50% RH interior ambient. Two-stage electric heating is provided, the elements being arranged in banks running off the 415v 3-phase supply. Maximum heat output is 4.5kW for the −10°C outside ambient design conditions. Delivered airflow is approx 800 m^3/hr including 120 m^3/hr of filtered fresh air, approx 100 m^3/hr is dumped from the unit by an exhaust fan into the van area.

The switches on both the driver's and guard's control consoles are provided for manual control of the associated unit. One switch allows selection of the heating, cooling or vent only modes whilst the other is for max or min settings of heating or cooling.

Units are supplied with 415v 3 phase for powering the compressor and fan motors, and 110v dc for the control circuits. Both supplies are fed from the static converter; no emergency operation is available.

Additionally the driver is provided with a heated footplate controlled from a separate switch on the control console. Two low temperature, composite element heater pads powered from the 110v dc supply, and rated at approx 22kW each, are located under the footplate. The rating of the elements is such that the surface temperature is limited to a maximum of 50°C.

The van area is heated by four fully recirculatory fan heaters located above each exterior doorway at ceiling level. The fans run continuously and the heating elements are thermostatically controlled to achieve at last 15°C within the van. A separate overheat thermostat protects the unit in the event of a major fault by cutting-out the electrical supply. Power supply is 240v single phase from the static converter, and rating is 1.5 kW.

The No. 2 end vestibule is heated by one heater unit identical to the van heaters but fitted with an air distribution cowl. The unit is located within the ceiling space and discharges air through the perforated ceiling panel.

11. Communications

Audio communication equipment fitted falls into four categories: Radio, Crew Communications, PA and the Auto Announcer.

11.1 Radio

Each DVT cab is fitted with a VHF Band III radio to BRB specification 1609. This radio works within the BRB National Radio Network and allows the driver to contact any telephone extension within the BRB ETS system. Direct lines from fixed stations enable the driver to speak directly to the Electric Control Rooms and to the Train Control Operator, all via his in-cab radio. One train may be patched through to speak to another train but only under the control of the Train Control Operator. All these functions can be achieved automatically without operator intervention.

Provision is also made within the DVT for subsequent fitting of a Driver Only UHF radio.

11.2 Crew Communications

Crew Communications is achieved by an FM Crew Communications system which operates at a carrier frequency of 110 kHz along cores 1 and 2 of the train communication cable which is to UIC 568. Cores 1 and 2 also carry Public Address and TDM, hence the need for an FM system to ensure simultaneous operation can take place. Combined Crew Communication and Public Address handsets are located in each coach in the No. 1 end vestibule. In addition handsets are provided in the kitchen area of the service vehicle and in the cab and guards compartment of the DVT. The drivers handset can access the Crew Communications system only, not the Public Address whilst that in the kitchen can only access the Public Address not the Crew Communications.

11.3 Public Address

The public address system is a base band system working in the range 0-6 kHz on cores 1 and 2 of the UIC cable. Public Address announcements can be made by the Train Guard from any handset or by the catering staff from the kitchen handset. PA and Crew Communications electronics are provided by a combined unit which is mounted in the vehicle electronics cubicle.

11.4 Auto Announcer Unit

Each Service Vehicle contains an auto announcer which is fitted in the staff compartment adjacent to the kitchen. The auto announcer contains 8 standard operational messages for general passenger information together with a comprehensive list of catering announcements. Messages are selected by the Guard or Catering Staff by means of a keypad on the front of the unit. Messages may be stored for timed issued and may be monitored before general broadcast to the train.

The auto announcer also incorporates 3 permanent emergency/operational messages, namely:

(a) Passenger Emergency
(b) Disabled Passenger Call for Aid
(c) Guards Attention — Contact Driver

Emergency messages are triggered by the FDM and override any other speech transmission taking place via the PA. These messages cannot be accessed from the keypad. All messages are digitally stored in EEPROM.

12. Doors and Door Control Circuits

Each passenger vehicle is equipped with a Kiekert air-operated sliding-plug door at each corner.

These doors can be remotely controlled from the DVT or any coach. At each side of the No 2 end vestibule of the DVT and the No. 1 end vestibule of coaches there are guard's door control panels. Each is under a cover accessible by a square key, and each panel must be released by the use of a high security key in a three position keyswitch. Drivers also have remote door controls in the vestibules of the driving cabs of the DVT and the Class 91.

These pushbuttons pass signals to the door controls at each coach; unlock A-side, unlock B-side and close and lock signals being transmitted via cores 5, 6, 7 and of the communications cable and doors open being transmitted via the FDM system. Control relays on each coach and an electronic control unit for each door interpret these signals, together with speed signals derived from the WSP equipment which interlock and prevent door opening when the train is moving.

The operating mechanism for the sliding-plug door can be seen on this view.

Local controls for passenger operation.

Once train doors on a side of the train are unlocked by the guard, local open and close pushbuttons are enabled and illuminated at each door on that side. Doors can now be opened or closed locally by passengers or all opened by the guard or driver. An audible alarm sounds prior to closure at each door, and a safety edge detects obstructions at each door and re-opens it automatically.

The guard or driver can remotely close and lock all doors. Once the command is made, all doors close and the local passenger controls are disabled. Any door failing to close and lock is detected by the FDM systems and prevents the train from moving above 5 km/h. A blue lamp flashing at the guards or drivers panel denotes an open door, and a steady lamp shows all doors have closed. A "right away" signal to the Driver cannot be signalled until all doors are closed.

A speed signal at 5 km/h derived from the WSP equipment ensures all doors are forced closed when the train is moving and applies emergency brake if any door opens at speed. It also prevents a door emergency handle from unlocking the door until the train is below 5 km/h.

13. Reliability Safety and Systems Integration

The design process of these vehicles with their additional features, such as power-operated doors, required the application of techniques now becoming common in the railway industry.

This included the use of Failure Mode Effects and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA) to such areas as:

Door Control Circuits
Wheelslip Protection Circuits
Train Control (TDM)

The results of these studies were incorproated into the design as appropriate.

14. Conclusion

The modern passenger train formation is a complex system employing a wide range of equipment together with an equally wide range of control and monitoring systems. The complexity and sophistication of these systems will inevitably grow. Within the design of the vehicles described above, consideration was given to the incorporation of visual passenger information displays. These were ruled out on cost grounds and not because the technology was not available.

APPENDIX A

Vehicle Overall Dimensions

		PASSENGER VEHICLES	DVT
Length (over body)	(m)	23	18.03
Width (over body)	(m)	2.73	2.73
Height (rail to roof)	(m)	3.79	3.79
Bogie Pivot Centres	(m)	16	10.9
Bogie Wheelbase	(m)	2.5	2.5
Vehicle weight tare + full supplies (tonnes)		39.9-43.5	42.2
Vehicle crush (tonnes)		45.4-54.2	50.2

APPENDIX B

Principal Suppliers

Main Contractor	Metro-Cammell Ltd
Bodyshells	BREL BREDA
Interior Finish	AMT
Bogies	SIG
Gangways	BREL
Doors	Kiekert
Brake Control	Westinghouse
HVAC	Ebac Temperature
Converters	ACEC
Disc-Brakes	Knorr Lucas Girling
WSP	Faiveley
FDM	ABB
TDM	Plessey

Both externally and internally the DVT (Driving Van Trailer) seen here is very similar to the Class 91 locomotive.

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