CONSTRUCTION OF A FIXED LINK BETWEEN FRANCE AND THE UNITED KINGDOM

"THE CHANNEL TUNNEL"

A PRESENTATION TO THE
1992 CONFERENCE OF THE
INTERNATIONAL MACHINERY
INSURERS ASSOCIATION,
MUNICH, SEPTEMBER 1992

MAURICE BARDON - FRANCE

CLIVE FRASER-ANDREWS - UNITED KINGDOM

cf

THE CHANNEL TUNNEL

1 INTRODUCTION

At the 23rd IMIA Conference in 1990 and the 24th IMIA Conference in 1991, the French and British delegates reported on the Channel Tunnel project. The presentations in these previous years discussed the organisation of the project insurances and described the main features of the civil engineering construction and fixed equipment installations.

This paper completes the project description with information on the rolling stock being provided under the project contract and covered by the project insurances.

A brief discussion is included on the special underwriting considerations which have arisen in the later stages of the project and the paper is concluded with a commentary on the project insurance arrangements which have covered the construction of a fixed link between France and the United Kingdom - The Channel Tunnel.

cf

2 PROJECT PARTICULARS

Client	Eurotunnel (French-British Consortium)
Project Contractor	Trans-Manche Link (French-British Consortium)

Project Characteristics

running tunnel north: diameter 7.6m, length 50.473 km
running tunnel south: diameter 7.6m, length 50.449 km
service tunnel : diameter 4.8m, length 50.440 km
construction method : tunnel boring machines (11)

cross-over caverns : each 156m long, 18.1m wide, 10.5m high
construction methods: new Austrian tunnelling method (one cavern), tunnel boring machine and reinforced roof arch with excavation below.

terminals : Coquelles 750 ha, Folkestone 350 ha

rolling stock: detailed in Section 3

Project Programme

15.5.86	contract commencement date
28.2.88	tunnelling commenced
28.6.91	tunnelling completed
1991/93	installation of fixed equipment
1992/93	delivery of rolling stock
.9.93	start of commercial operation

Project Costs

1985 values £2,550 million, FF 25,500 million
1990 values £7,608 million, FF 76,080 million

cf

3 ROLLING STOCK

3.1 Railway Operation

The north running tunnel will normally carry traffic from England to France and the south running tunnel from France to England. The two undersea cross-overs provided between the running tunnels and the cross-overs at the two tunnel entrances enable single line working when necessary to avoid sections undergoing maintenance or for other reasons.

The tunnels will be used by the national railways of France (SNCF) and Britain (British Rail) for their international passenger and freight trains and by purpose built shuttle trains owned and operated by Eurotunnel between the two terminals. Eurotunnel will control all traffic travelling through the tunnels.

Figure 1 shows the loading gauges (the maximum cross-sectional profiles permitted) for the rolling stock running through the tunnels. Since the profiles of the shuttle vehicles exceed the national railways' loading gauges, the shuttle vehicles are essentially restricted to the Eurotunnel system.

The running time for a shuttle train will be about 35 minutes between terminals. With a three minute headway (time separation) between trains, the nominal capacity of each tunnel is 20 trains an hour. Eurotunnel expect to run up to ten trains an hour in each direction, with the remaining capacity being available to the national railways.

cf

3.2 Shuttle Trains

Eurotunnel's shuttle trains will convey road motor vehicles, their drivers and their passengers between the two terminals.

Road motor vehicles such as cars, vans, caravans, minibuses and coaches will be carried in tourist carrier wagons. A double deck type of carrier wagon will carry up to ten cars on the two decks, whilst caravans, coaches and cars with trailers will be carried in single deck carrier wagons.

Road motor vehicles in the category of heavy goods vehicles (H.G.V.) will be carried in the H.G.V. carrier wagons. These are single deck carrier wagons, each wagon carrying a solitary heavy goods vehicle.

The wagons will be formed into rakes, each rake comprising a set of semi-permanently coupled wagons which is uncoupled only if a particular wagon needs to be taken out of service.

There will be three types of rakes containing either 12 double deck tourist carrier wagons, or 12 single deck tourist carrier wagons, or 14 single deck H.G.V. carrier wagons.

Access to the carrier wagons will be provided by loading wagons which will enable the road vehicles to be driven from the terminal platform and turned on to the end carrier wagon of the rake. For the three types of carrier wagons there are three corresponding types of loading wagons, one type having an upper and lower ramp to provide access to both levels of the double deck carrier wagons. When loading, the vehicles are driven along the rake of wagons until reaching the foremost space available.

On arrival at the destination, the vehicles will be unloaded by being driven forward on to another loading wagon and thence turning out on to the platform.

Each shuttle train will comprise two rakes complete with their loading wagons and an electric locomotive at each end. Hence, each tourist shuttle train formation will be:

locomotive		
loading wagon	)	
12 carrier wagons	)	rake
loading wagon	)	
loading wagon	)	
12 carrier wagons	)	rake
loading wagon	)	
locomotive		

Each H.G.V. shuttle train will have a similar formation, except that there will be an amenity coach in which the heavy goods vehicles' drivers may travel if they wish. The amenity coach will be positioned directly behind the leading locomotive. Hence, each H.G.V. shuttle train formation will be:

locomotive		
amenity coach		
loading wagon	)	
14 carrier wagons	)	rake
loading wagon	)	
loading wagon	)	
14 carrier wagons	)	
loading wagon	)	rake
locomotive		

cf

3.3 Eurotunnel Fleet

The rolling stock being supplied to Eurotunnel as part of the project consists of:

38 electric locomotives
108 tourist single deck carrier wagons
108 tourist double deck carrier wagons
228 H.G.V. carrier wagons
18 tourist single deck loading wagons
18 tourist double deck loading wagons
33 H.G.V. loading wagons
9 amenity wagons
5 diesel locomotives
24 service tunnel vehicles

Illustrations and some details of these vehicles are given in Figure 2 and the subsequent figures.

The current contract price for the rolling stock stands at £585 million (FF 5850 million).

3.4 Programme

At the inception of the project in 1986, milestone dates were set for the attainment of the key tasks for the tunnelling and for the rolling stock.

All participants in the project are justifiably proud of attaining the final tunnelling milestone date three days in advance of the programmed date set five years previously. However, the rolling stock has been delayed as the following table shows.

	Original Plan	Current Forecast
Breakthrough of final tunnel	01.07.91	achieved 28.06.91
First train for testing	15.03.92	07.08.92 without tourist wagons and electric locomotives
Start commissioning of entire system	15.11.92	20.03.93
Start commercial operation	15.05.93	09.93
Completion of project	15.05.93	.94

cf

3.5 Testing & Commissioning

All rolling stock is tested at the manufacturers' works, the first of each kind being subjected to the customary type testing of a more extensive nature than for the subsequent deliveries. For example the first two electric locomotives will be subjected to extensive proving tests on a test track circuit on Czechoslovakia before delivery to site. Also, the prototype service tunnel vehicle has been subjected to an endurance test of 15,000 km running, which was completed in 1991.

After the fixed equipment installed at site has been functionally tested and provisionally accepted, the power, signalling and other equipment is successively integrated as the quantity of rolling stock increases at site until available in sufficient numbers to enable testing to be carried out under operational conditions. It is at this stage that the final commissioning of the system, incorporating its rolling stock, can take place at peak traffic flow conditions.

However, delays in rolling stock deliveries are now inevitable and this will give rise to some unintended complications affecting the testing, commissioning and acceptance of the rolling stock as part of the integrated system.

The first items of rolling stock to be delivered to site are the diesel locomotives being delivered in mid-1992.

Current expectations are for the first electric locomotive to be delivered in Autumn 1992 with subsequent deliveries of electric locomotives and carrier wagons in sufficient numbers to enable first train testing to take place in the north running tunnel early in 1993. Thereafter rolling stock deliveries will continue well into 1994.

Furthermore, it may be necessary for the contractors to carry out enhancements to the rolling stock after its entry into commercial service, in order to meet the retrospective requirements of the regulatory authorities responsible for safety. These enhancements will include a change in the design of the tourist vehicle carrier wagons in order to accommodate pass doors at each end 100mm wider than the original design. Also, there have been protracted discussions on the possible need for retrospective modifications on the H.G.V. carrier wagons, with a view to making them fully enclosed and fitted with associated additional internal equipment.

cf

4 SPECIAL UNDERWRITING CONSIDERATIONS

Items of rolling stock are not usually covered by the project policy until they are delivered to site, after which the project policy provides cover for the items of rolling stock up to the time they individually enter commercial service.

However, the policy has always provided cover on a wide territorial basis provided the location concerned is allocated for use by the contractor, TML. Such is the case for the test track circuit in Czechoslovakia on which the first two electric locomotives are undergoing extensive proving tests before delivery to site.

As a result of the delays in rolling stock deliveries, the commercial services will start before sufficient rolling stock is available to enable the final commissioning of the system at peak traffic flow conditions. This may affect:

- the commissioning of the fixed equipment systems at the peak traffic flow conditions

- the commissioning of the project rolling stock running in conjunction with provisionally accepted fixed equipment

- the commercial running of the project rolling stock in conjunction with provisionally accepted fixed equipment

- the commercial running of rolling stock owned by SNCF and British Rail in conjunction with provisionally accepted fixed equipment.

The issues emerging from these situations, and the aspects to be covered by the project policy and the future annual operating policies, are all under active discussion by the parties to these policies.

cf

It seems likely that the Insurers may be accepting an increase in the level of risk during the contractual maintenance period, arising from the retrospective enhancements to the project rolling stock carried out by the contractors after the rolling stock has entered commercial service. The implications of this situation are also under active review.

In view of the delays in rolling stock deliveries, it should be noted that the delay in completion cover is restricted to revenue losses only as a consequence of damage at site. The terms of the delay in completion cover are:

Delay in completion is indemnified only if all the following circumstances apply:

- damage occurs which is indemnifiable under Section 2 of the Policy

- there is delay in full commercial operation of the project as a direct result of such occurrences

- considering each occurrence individually, the repair of the damage causes a delay exceeding 14 days, beyond which the additional period contributes to an aggregate figure

- the aggregate figure exceeds 90 days, beyond which the indemnity is calculated.

At the finish of the excavation phase of the tunnels (28th June 1991) not a single day of delay had been assigned to the aggregate figure.

5 CONCLUSIONS

The 28th June 1991 marked the completion of the two rail tunnels and the service tunnel constituting the works which henceforth link the British Isles to the Continent, and vice versa.

The Insurers who were involved in the insurance programme set up for this important project have not suffered any significant loss in relation to the civil engineering works themselves; 150km of tunnel have been bored under the Channel without any modification of the techniques originally envisaged. It is not by chance that such a result has been achieved for a type of works which often has unpleasant surprises in store, for Insurers as well.

During the first presentation made to members of IMIA at Toronto it was said that the earlier attempts to bore a tunnel under the Channel dated from the end of the last century and became more fruitful with the passage of the years up to the start of work at site in 1987. Consequently, almost complete information on the ground conditions was available, and the designers had a solid basis for the formulation of their plans.

It may also be said that when Eurotunnel had to decide between several possible alternatives, the availability of records identifying or indicating the existence of problems allowed them to take the decision which, in technical terms, has been proved to be correct. It is no less evident that the Insurers whose task it was to assess the risks have benefited from this situation.

cf

The complementary and final account which is now presented on the occasion of this 25th IMIA Conference at Munich relates essentially to the railway rolling stock. It can be seen that unlike the situation with the civil engineering works, Eurotunnel and the constructors of the railway rolling stock are having to work on the basis of an evolving specification and under time constraints.

As for the reasons for this, there is nothing to be gained by creating an issue over the time factor. Eurotunnel is a company quoted on the Stock Exchange and it is imperative for the Eurotunnel management that commercial operations commence as near as possible to the date announced to the shareholders and to the banks. The evolving nature of the specification is due to the regulatory authorities which are responsible for the approval of equipment and procedures progressively imposing or advising constraints which require the constructors to modify the equipment and procedures. It is not for the Insurers to pass judgement on the situation; they can only note the situation and draw from it the relevant lessons.

It has been seen that the quality of the civil engineering works information which Eurotunnel had available when its management had to choose between the various strategies was a direct consequence of the protracted period of time beforehand, during which a considerable volume of reliable information accrued. The designers were able to produce detailed plans under the most favourable conditions.

cf

For the rolling stock, the situation is therefore not at all the same. However this should not necessarily give rise to concern.

The safety issue which is the cause of the delays is an unquestionable necessity and, at the same time, a measure of the value placed upon the technical considerations which are to be employed. Above all, it permits the Insurers to take account of the impact of the modifications in relation to the initial objectives which were considered when the risk was underwritten.

The Insurers should not therefore find themselves faced with a risk which is not up to the standard they are entitled to expect. If demonstration were needed, this case shows the importance of the availability of the most up to date information and the subsequent need to follow the stages of development in order anticipate any variation.

This analysis will no doubt appear rather simplistic, but faced with the continual decline of the results in this insurance market generally, the intention was to draw, in a few sentences, the lessons which can be learned from a major project which has avoided featuring among those cases suffering the biggest losses of recent years.

cf

Furthermore, the question arises for members of an association such as IMIA whether to go beyond pure technical and statistical considerations, and to concern themselves with the increasing influence, in terms of impact, of:

> other factors (financial, social, political) likely to affect technical and statistical considerations;
>
> and to perfect means of working with our partners, the industrialists, during the design phase of their major projects. More generally, on what should be done to accelerate the improvement of the results in this insurance market generally, starting from the principle that control would be better by taking action on loss prevention, and not just on premiums levels.

In conclusion, and above and beyond these few comments, it is hoped that the members of IMIA have been enabled to share the satisfaction which the French and British delegates have derived from their close involvement in an achievement which will mark the end of the 20th Century at a European level.

cf

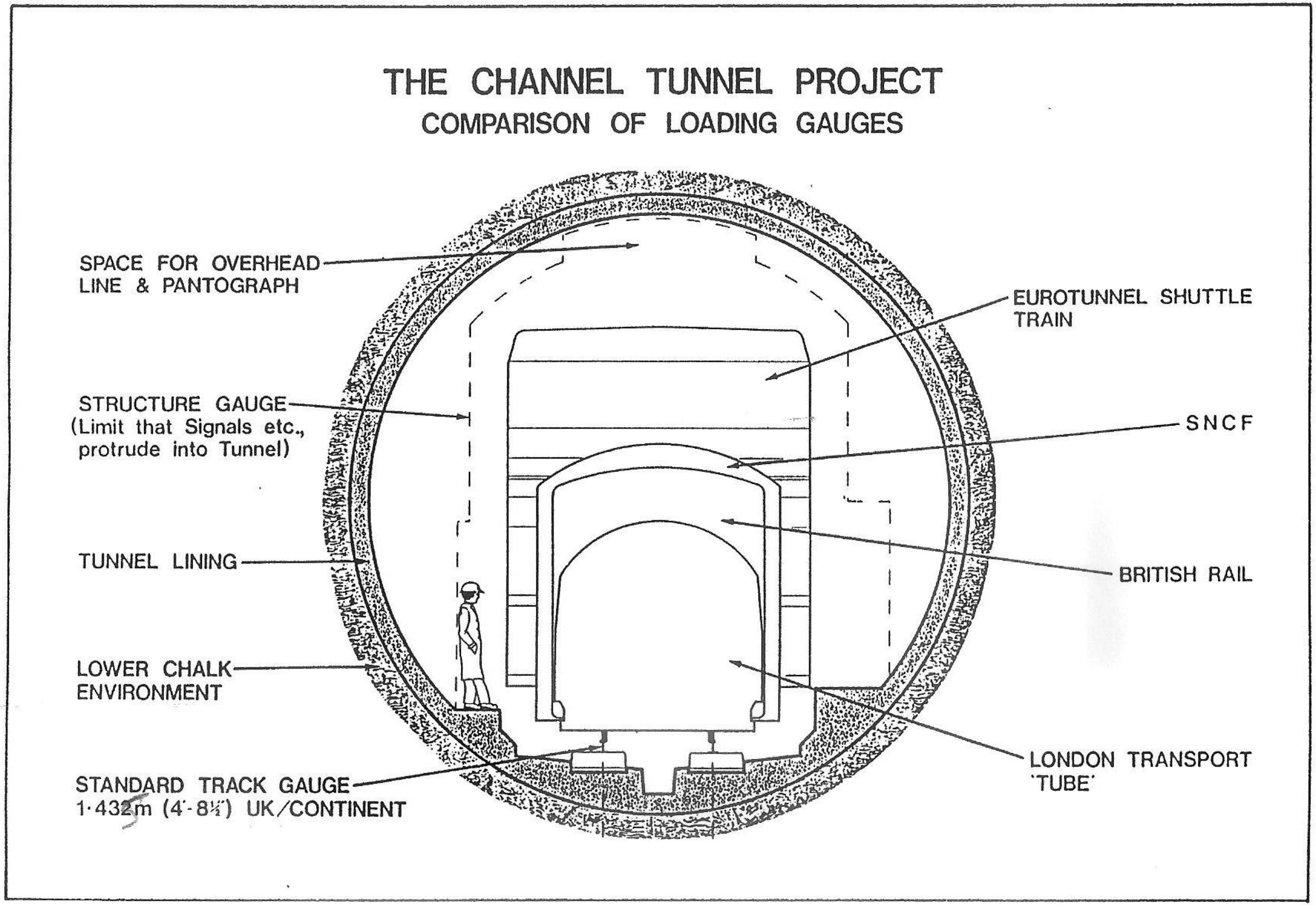
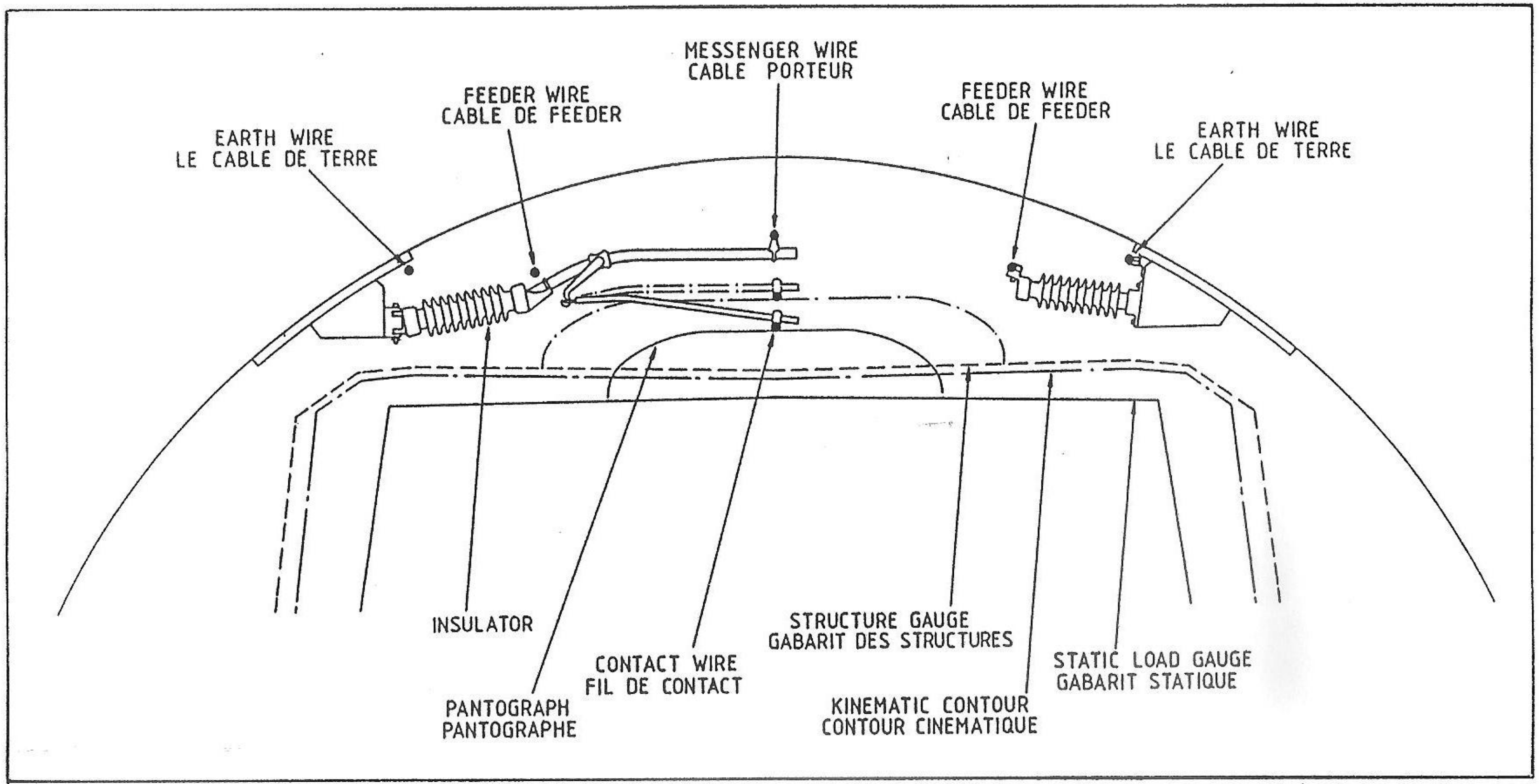


FIGURE 1 LOADING GAUGES

FIGURE 2 CATENARY–PANTOGRAPH ARRANGEMENT



General arrangement of catenary in the tunnels

FIGURE 3 SHUTTLE LOCO PARTICULARS

LOCOMOTIVE TECHNICAL DATA

1. GENERAL

Supply	Single phase 25 kv 50 Hz overhead contact wire.
Operating voltage range	27.5 kv - 17.5 kv
Wheel arrangement	Bo-Bo-Bo (6 axle)
Track gauge	1435 mm
Traction power at rail	5600 kW
- speed range	60 to 160 km/h
Maximum Tractive Effort	400 kN
- speed range	0 to 20 km/h
Maximum operating speed	160 km/h
Maximum design speed	176 km/h
Locomotive Weight	130 tonnes
Structure gauge	To UIC 505-1
Overall length	20.4 metres
Height with pantograph lowered	4100 mm
Width	3000mm

2. BODY

Single ended locomotive with a streamlined front end (driving end) and a full width gangway at the shuttle end. A secondary cab with reduced driver controls is provided at the shuttle end to facilitate shunting and emergency duties.

Locomotive body is a fully welded monocoque structure provided with removable roof section.

3. BOGIES

Three two-axle bogies with outer bogie centres of 12 metres.

4. TRACTION POWER CONVERTOR

Three fully independent 3-phase ac-convertors each supplying a bogie-pair of traction motors.

The convertors use Gate Turn-Off Thyristors (GTO's) and comprise:

- 4 Quadrant line side convertor
- DC link
- 3-phase load inverter

Modularly constructed with convertor components cooled by oil immersion.

Tractor control by microprocessor.

5. TRACTION MOTORS

- Three-phase asynchronous squirrel cage induction motor.
- Continuous rating: 950 kW
- Bogie frame mounted.

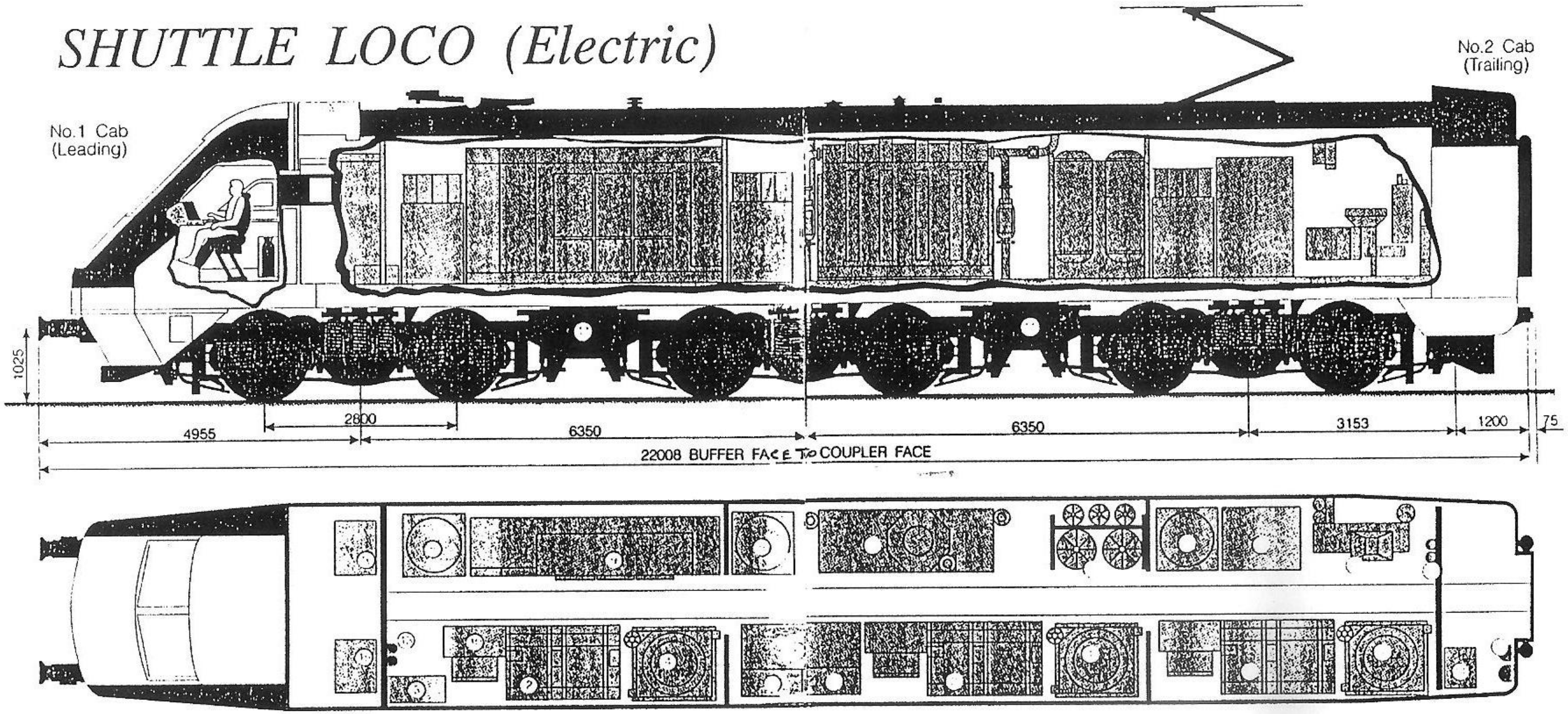
6. AUXILLARY SUPPLIES

- 380 Volt 3-phase supplied for locomotive auxiliary machines derived from fully independent three-phase convertors.
- 1500 vdc for shuttle train services.
- 110 vdc for locomotive control circuits.

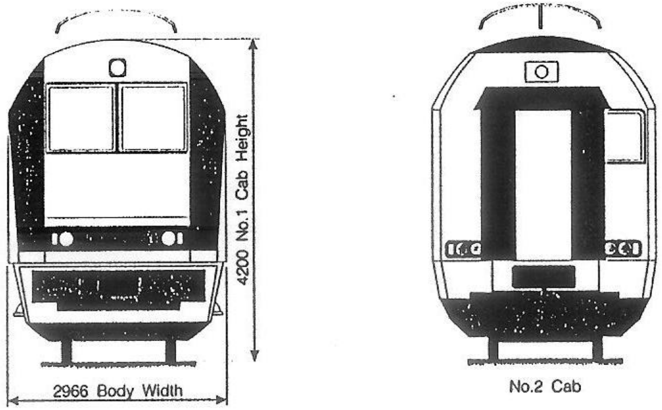
7. BRAKING SYSTEM

Either rheostatic or regenerative braking fully blended with locomotive friction (tread) brake. The locomotive is provided with an independent air brake, an automatic air brake system complying with the requirements of UIC 540 and an electropneumatic air brake control system complying with UIC 541-5.

SHUTTLE LOCO (Electric)



SERVICE SPEED	160 KM/H
POWER	5.76 MW (CONTINUOUS)
	25 KV
WEIGHT	132 TONNES
MAX. TRACTIVE EFFORT	400 KN PER LOCOMOTIVE
MAX. LOAD/WHEEL	12 TONNES
MAX. LOAD/AXLE	22.5 TONNES
MIN. CURVE RADIUS	100 M (LOCOMOTIVE ONLY)
	246 M (COUPLED)
WHEEL DIAMETER	1250 MM
TRACK GAUGE	1435 MM



Key:

(1) TRANSFORMER
(2) TRACTION CONVERTER
(3) RESONANT CAPACITORS
(4) OIL COOLING HEAT EXCHANGERS
(5) TRACTION MOTOR BLOWERS
(6) BRAKE CONTROL PANEL
(7) COMPRESSOR
(8) AIR RESERVOIR
(9) AUXILIARY CONVERTER (380v / 50Hz)
(10) BATTERY CHARGER
(11) BATTERY RACKS
(12) TRAIN RECTIFIER (1500v DC)
(13) HALON BOTTLES (FIRE PROTECTION)
(14) RADIO COMMUNICATION CUBICLE
(15) AUTOMATIC TRAIN PROTECTION
(16) LOCOMOTIVE CONTROL ELECTRONICS AND FIRE PROTECTION
(17) PANTOGRAPHS
(18) HIGH VOLTAGE ROOF EQUIPMENT
(19) HEATING, VENTILATION, AIR CONDITIONING EQUIPMENT

FIGURE 4 SHUTTLE LOCO LAYOUT

FIGURE 5 SHUTTLE LOCO CAB

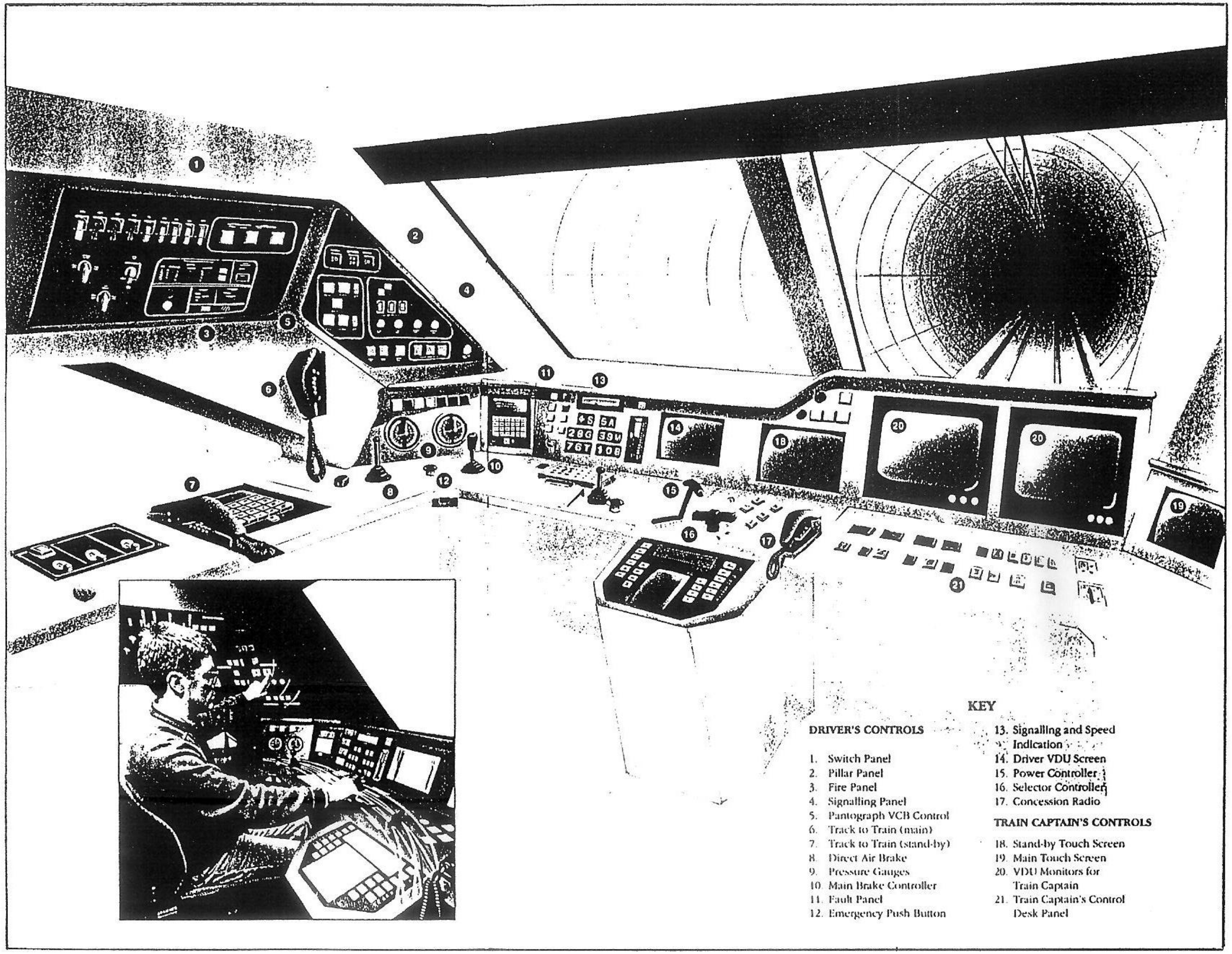


FIGURE 6 WAGON PARTICULARS & HGV WAGONS

TECHNICAL SUMMARY OF WAGONS

	Tare weight	Length	Width	Height
Double Deck Carrier	60 t	26m	4.1m	5.6m
Double Deck Loader	64 t	28m	4.1m	5.6m
Single Deck Carrier	56 t	26m	4.1m	5.6m
Single Deck Loader	61 t	*	4.1m	5.6m
HGV Carrier	40 t	C23m	4.1m	5.6m
HGV Loader	63 t	C28m	4.1m	5.6m

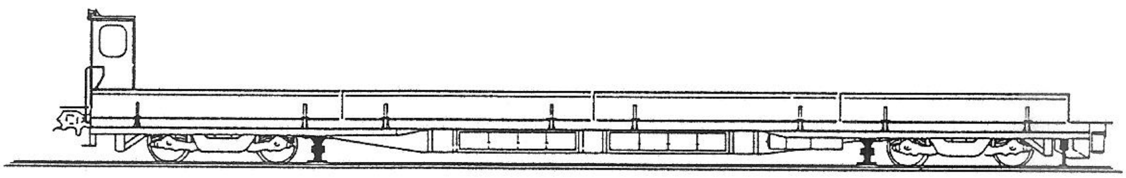
* Still under discussion

BOGIE
Wheel diameter 850mm
Maximum axle load 22 t
Wheel base 2.6 m
Wagon ride index 2.3 to 2.5 Sperling
Friction brakes: axle mounted discs

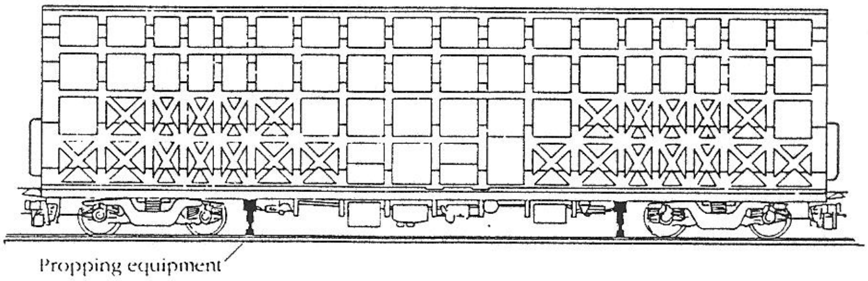
BRAKE EQUIPMENT
Automatic air brake to UIC 540 with electropneumatic control to UIC541-5.

Wheelslide protection equipment to UIC541-05.

Variable load control on the carrying wagons.



HGV Loader



HGV Carrier

FIGURE 7 SINGLE & DOUBLE DECK TOURIST WAGONS

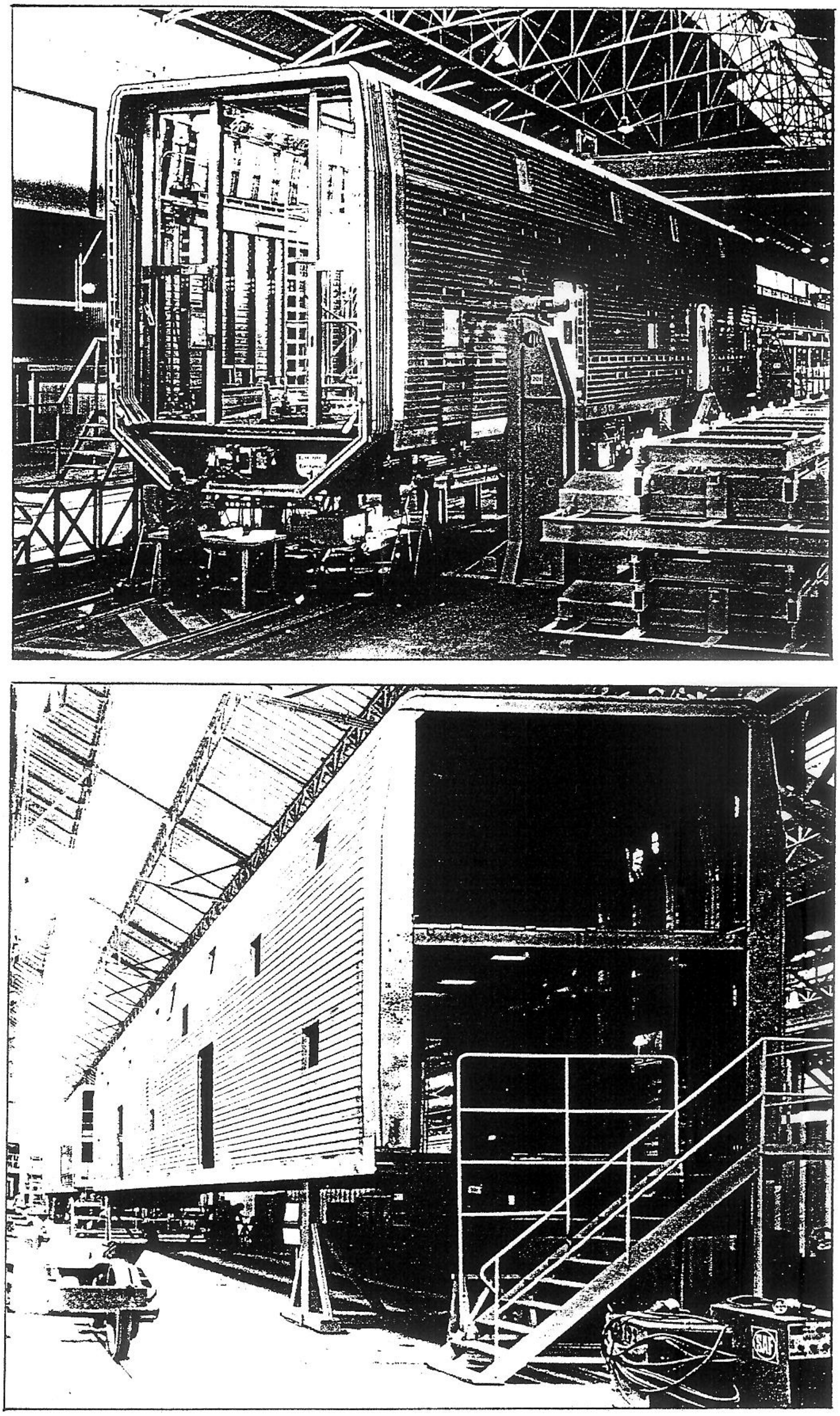
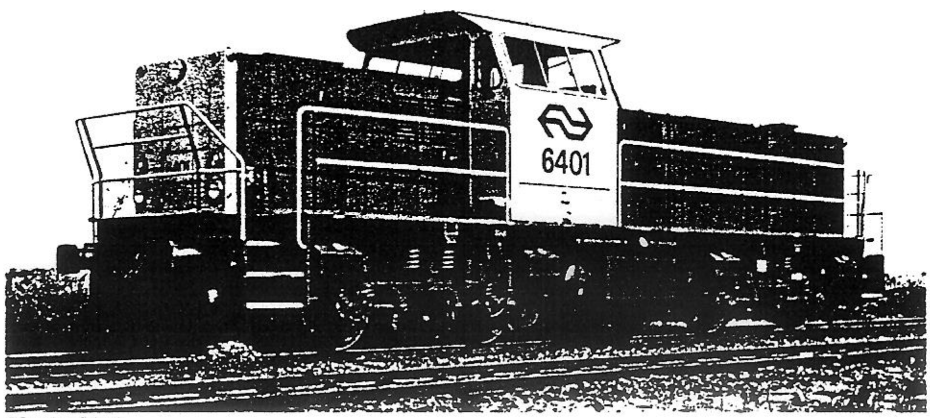
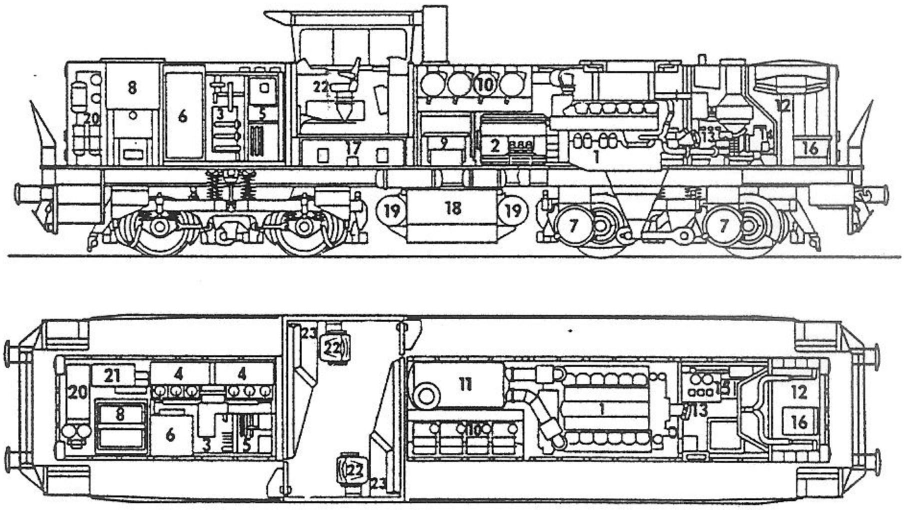


FIGURE 8 DIESEL LOCOMOTIVE



The DE6400



1. *Main Diesel Motor*
2. *Main Generator*
3. *Electronic Control Cabinet*
4. *Voltage Inverters*
5. *Electro-Mechanical Control Cabinet*
6. *Computer Electronic Control Cabinet*
7. *Traction Motor*
8. *Dynamic Brake Stack*
9. *Traction Motor Blower*
10. *Inlet Air Filters*
11. *Silencer*
12. *Radiator*
13. *Hydrostatic Pump*
14. *Air Compressor*
15. *Auxiliary Diesel Engine*
16. *Auxiliary Batteries*
17. *Main Batteries*
18. *Fuel Tank*
19. *Air Reservoir*
20. *Brake Panel*
21. *Automatic Train Protection Equipment*
22. *Driver's Seat*
23. *Driver's Console*

FIGURE 9 SERVICE TUNNEL TRANSPORTATION VEHICLE