The Multiple-Unit Train for the European High-Speed Network

ICE 3 for German Rail and Netherlands Railways

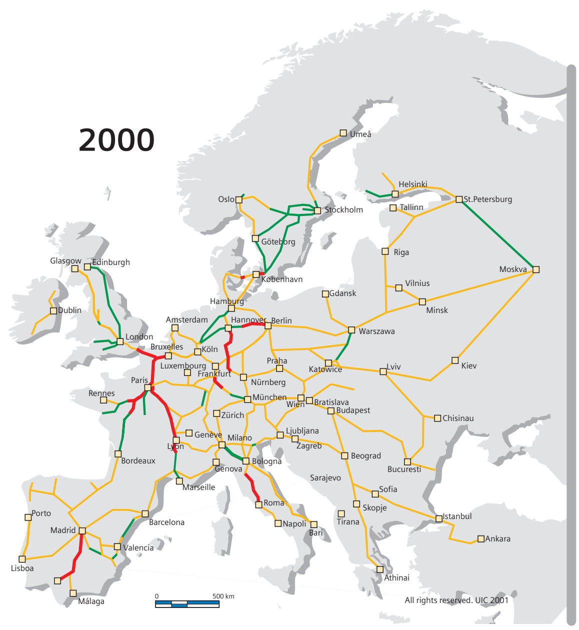
SIEMENS

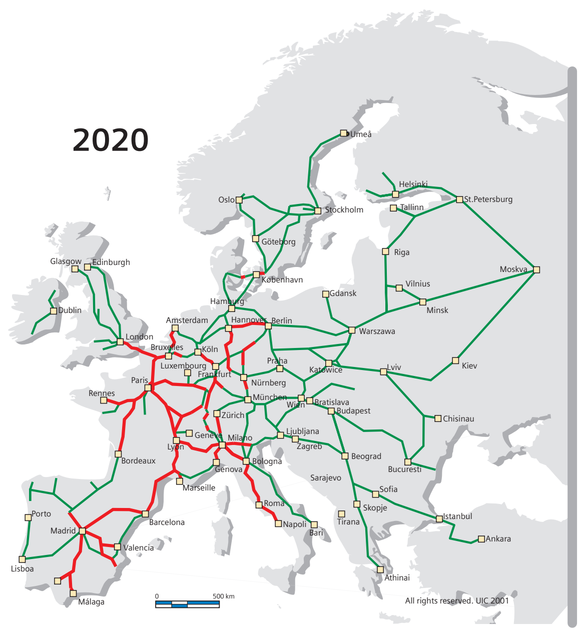
efficient rail solutions

Berlin – Amsterdam – Brussels – Paris – Bern

As Europe grows together, so too do Europe's railroads. You, the European railroad operators, are creating high-speed links between major cities all across Europe. Your passengers want to enjoy greater mobility but spend less time traveling. That's why we are there to help you achieve better efficiency with higher mileage and shorter travel times.

Development of Europe's rail network
The European high-speed routes
Europe's high-speed train routes continue to grow together at an ever increasing rate and eventually form a single compatible network. Not only the high-speed rail (HSR) network operated by German Rail will more than double in size over the next 20 years. Ever shorter travel times and higher travel comfort will entice more and more air passengers to make the switch to rail. Changing trains is history: today we can go straight into the heart of the European urban centers.





Europe's HSR network never stops growing (courtesy of: UIC 2001)

New high-speed line

Upgraded high-speed line

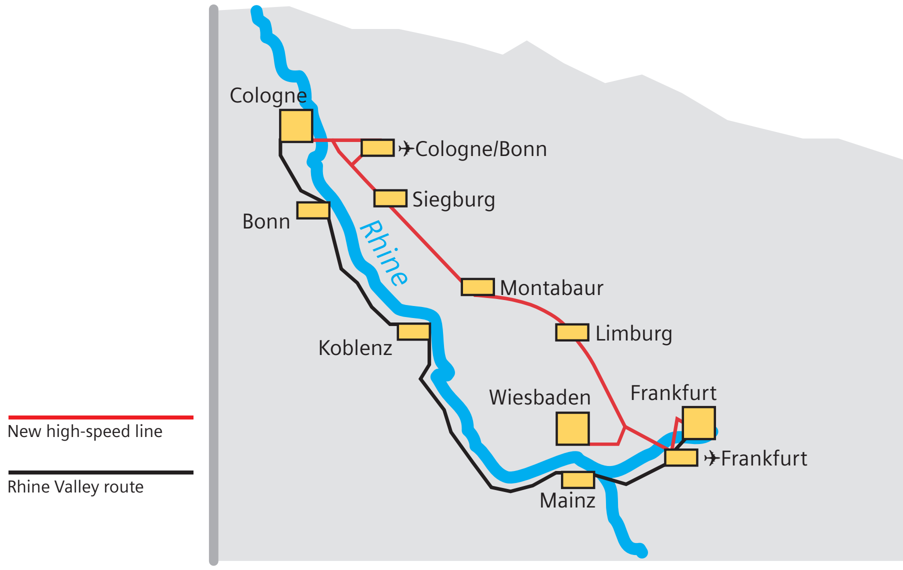
HSR network by 2020

– Madrid

This can only be achieved if high-speed trains are able to operate on all European high-speed lines. Present obstacles such as different rail infrastructures, traction power supply, and train protection systems must be eliminated. To this end, all European railroad operators and the railroad industry have drawn up a catalog of requirements that trains must meet for use in the European HSR network:

European trains for the high-speed rail network must

- not be more than 400 m long
- have a clearance envelope per UIC 505 – taking into account the special agreements between German Rail and the French National Railways SNCF
- be suitable for bi-directional operation
- have pressurized passenger compartments and driver's cabs
- have a maximum static axle load of 17 metric tons
- comply with platform heights of 760 mm and 550 mm
- have a cruising speed of at least 300 kph (186 mph)
- be able to run on all four European voltage systems: 15 kV / 16.7 Hz, 25 kV / 50 Hz, 1.5 kV, and 3 kV
- be equipped with the train protection and communications systems in use in the European network



Since the inauguration of the new high-speed Cologne-Rhine/Main route in 2002, travel time between Cologne and Frankfurt/Main has been cut by about one hour.

Fast. Faster. The ICE 3 for Europe.

The ICE® 3 has been designed respecting today's technical, economical, and ecological requirements. The costs per seat have been reduced with even more demanding performance requirements. The ICE 3 is the right solution for the European high-speed network – why not take a look for yourself?

The ICE 3 – a tried and trusted concept
The multiple-unit train concept of the ICE 3 is the right answer to high-speed transportation. The traction equipment and various systems modules are distributed underfloor along the length of the train. That leaves the entire interior free for passengers, which means more comfort and more capacity.

Another advantage is ICE 3's multiple system capability, allowing it to travel on all European voltage systems. All trains so far delivered are operating with huge success on the German Rail network and in bordering countries, proof of their leading position in high-speed travel. In Spain, 16 similar-design high-speed trainsets for the route between Madrid and Barcelona route are about to be put to the test.

Design variants	Operator	Delivery	Single-system train	Multi-system train
ICE 3 (series 1) 2 possible layouts – restaurant concept – bistro concept	German Rail	2000	37	13
ICE 3 (series 2) layout variant – bistro concept	German Rail	2004	13	–
ICE International identical in design to ICE 3 (series 1)	Netherlands Railways	2000	–	4

ICE 3 – just look at the technical advantages

- improved utilization of adhesion with more driven axles
- improved running comfort due to even weight distribution
- significant reduction in environmentally impact, for example, with air-cycle air conditioning, recyclable materials
- high operating speeds of up to 330 kph

ICE 3 – the economic alternative

- lower procurement and lifecycle costs at higher performance, which means a cut in cost per seat
- lower energy consumption per passenger kilometer due to energy recovery through regenerative breaking
- energy-saving braking system through a high share of regenerative brakes
- more seats for the same train length.

ICE 3 – a class of its own

International visitors heading for EXPO 2000 in Hanover were whisked to their destination on ICE 3. Traveling at 330 kph (205 mph), it now links up the major population centers Frankfurt/Main and Cologne. Multi-system trains operate on cross-border routes into the Netherlands, Belgium, France, and Switzerland.

The ICE 3 experience at Europe's train stations and at EXPO 2000.

Design. Comfort. Information. The ICE 3 for

An appealing esthetic design and a comfortable and smooth high-speed ride through Europe's countryside. The ICE 3 does not compromise on either. Thanks to the multiple-unit concept this train offers more room to passengers, and the lounge provides a fascinating view onto the line ahead. You can offer your passengers a relaxing journey and a new train travel experience on the European high-speed rail network.

Travel in an inviting ambience
The ICE 3 is the trendsetter in train design. In the lounge, passengers experience the full fascination of high-speed travel at first hand. An appealing interior design with a comfortable travel ambience sets new standards in rail travel. Characteristic features of the new ICE 3 include the curved walls of the basic layout giving a spacious overall impression of the passenger areas, and the open service point for better contact between the crew and passengers.

Placing the drive components underfloor provides space for a more appealing interior layout. That gives the passengers in the end-section viewing lounge a panoramic view over the driver's shoulder of the line ahead. Only a pane of glass separates the passengers from the driver, the glass partition can be darkened, if necessary.

You have the choice between two different layouts: the restaurant concept for even greater passenger comfort or the bistro concept without an onboard diner but with higher capacity. Even then, an attractive bistro provides an inviting place for passengers to relax and take refreshment. Every train has generously dimensioned 1st and 2nd class open saloons. In 1st class, compartments are also available. The combination of high-grade steel and wood integrates high-tech with coziness. At the same time, ergonomically designed seats offer first-class comfort. Depending on the layout, the train provides either a toddler compartment or multifunction compartment that could be used for meetings or other purposes. A wheelchair space and disabled persons' restroom, and garbage containers with waste segregation are standard on the ICE 3.

Well informed while you travel
The ICE 3 passenger can get information anywhere and everywhere. The passenger information system (PIS) provides

- The following communication functions: Service and call points and paging for passengers in 1st class, multipurpose/toddler compartment, and at the wheelchair place, as well as crew-to-crew communication.

View into the ultra-modern cockpit

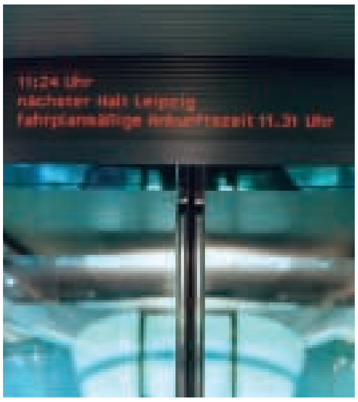
your passengers.

- Improved private communication with additional D and E network repeaters for cell phone use in selected train sections. The repeaters already meet the future UMTS standard.
- All passengers have access to six stereo radio channels, the 1st class area of the restaurant concept also provides two video channels.
- Information for passengers through:
  - PA system announcements,
  - train-route displays outside and inside, the entrance vestibules displays also show the car number, route with departure and destination stations, train type, name and number
  - information displays in the open-plan passenger areas,
  - electronic seat reservation displays updated after every stop at a station.

Smart solutions for the environment

- Noise protection. Whenever the ICE 3 draws into a station the ventilation system is automatically turned down to reduce the noise level for the passengers. The vehicle head with its smooth surface and flush windows, doors, and flat underfloor throughout optimizes the ICE 3 aero-acoustically.
- Intelligent use of materials. The air conditioning system of the ICE 3 uses air as a cooling medium to reduce emissions and protect our natural resources.
- Disposal: Natural, non-composite materials (leather, glass, wood instead of PVC and laminated sheets) eliminate problematic waste. The separable seat covers are stretched across foam upholstery, making recycling easier by cutting out composite materials.
- Energy recovery by regenerative braking saves power.

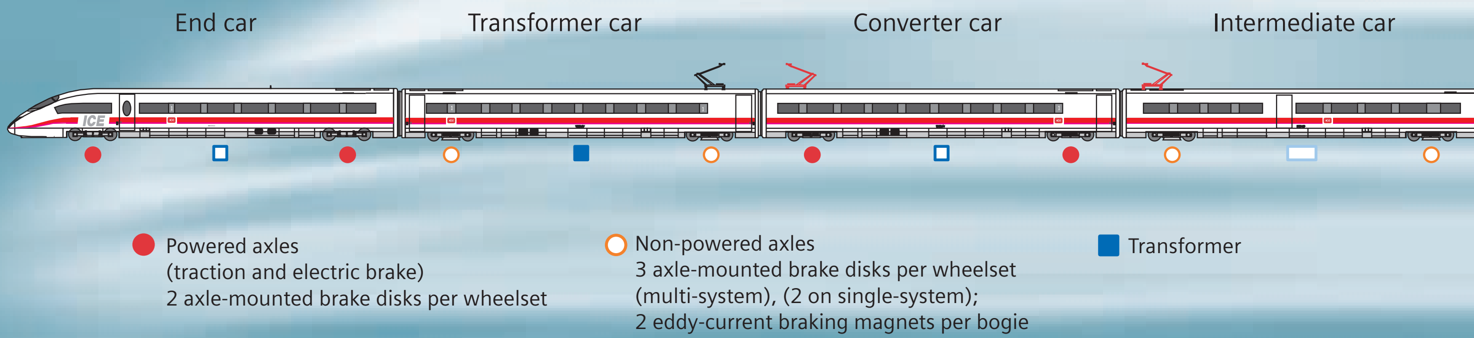
Comfort with a capital C



Well-informed onboard, too

Luxury in the restaurant concept

The modern bistro/galley area



ICE 3 technology – The multiple-unit train concept

The vehicle concept
Like its predecessor the ICE 2, the ICE 3 can be extended by coupling two half-trains together. The ICE 3 multiple-unit (or half-train) comprises eight cars. Depending on requirements, two half-trains can be combined to form an extended trainset with a maximum length of 400 m, or simply operated as two 200-m-long half-trains.

The eight-car half-train consists of four driven and four non-driven cars. Four cars form one electrical unit (end car, transformer car, converter car, and intermediate car). Thanks to the distributed traction configuration with 50% of the axles being driven, the train can climb grades of up to 4% while keeping axle loads down to only 17 metric tons.

Traction equipment
The traction equipment of the ICE 3 is configured

- as a single-system train
  - with 15 kV / 16.7 Hz for use on German Rail networks and
- as a multi-system train
  - with 15 kV / 16.7 Hz for use on German Rail and Swiss Federal Railway networks
  - with 1.5 kV DC and 25 kV / 50 Hz (in the future) for use on the Netherlands Railways network,
  - with 3 kV DC and 25 kV / 50 Hz for use on Belgian SNCB networks and
  - with 1.5 kV DC and 25 kV / 50 Hz for use on French SNCF networks.

The ICE 3 (multi-system) can cross borders and change line voltage without any problem. Depending on the infrastructure, the system change is performed either while the train is traveling or at standstill. The functions for this operation are integrated in the train control system.

The two transformer cars accommodate the components of the high-voltage AC system that consists of the German Rail pantograph, the surge arrester, and vacuum circuit-breaker with a ground switch for supplying power to the main transformer. The transformer cars are interconnected by a high-voltage roof line. This cable can be open-circuited by disconnectors if a fault occurs.

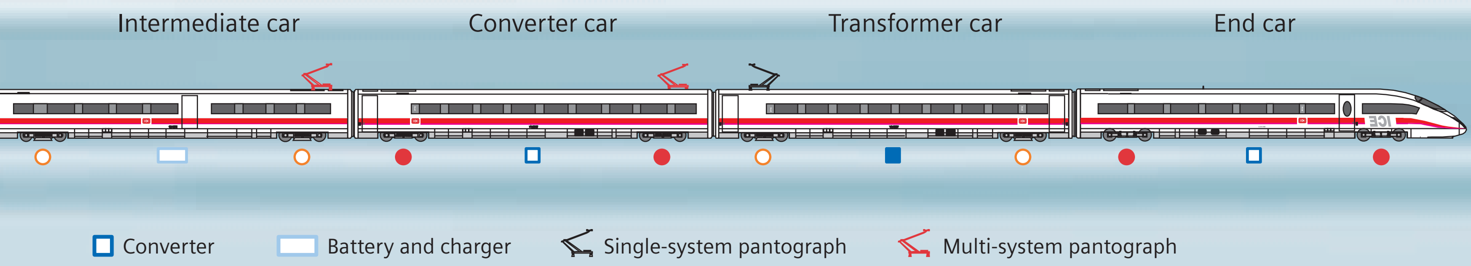
The pantographs for AC operation at 25 kV, and for operation on the Swiss Federal Railways network, are mounted on the intermediate cars. These are also connected to the high-voltage roof line.

The pantographs for DC operation are mounted on the converter sections. The high-voltage DC system is supplied by means of a 25-kV rated disconnector; the high voltage equipment is accommodated in an underfloor DC container.

The main transformer has a steel structure and uses sandwich windings. It is located under floor in the transformer car. Single-system and multi-system transformers are for the most part identical. When changing over from 15 kV to 25 kV, the secondary connections are switched in a disconnector rack located next to the transformer.

In AC operation, four separate secondary windings (switchable between 15 kV and 25 kV) of the main transformer supply the converter in the adjacent converter and end cars, each with their two input converters connected as four-quadrant choppers.

When operating in DC voltage systems, the two traction converters in the converter and end cars are interconnected by chopper reactors and contactors for input voltage selection and operated as DC choppers connected directly to the line via an LC line filter matched to the requirements of the DC systems.



The four-quadrant choppers and the PWM inverter comprise identically designed phase modules. The phase modules are water-cooled, each consisting of 2 GTO thyristors, two back-to-back free-wheeling diodes, the snubber circuit, and the gate drive unit. All the modules are accommodated in an underfloor container. The cooling system is positioned directly next to the converter container.

The traction motors are four-pole, frameless, forced air-cooled, three-phase asynchronous traction motors equipped with a cage rotor. Each motor produces 500 kW of tractive power and has a maximum speed of 6000 rpm.

The single-speed, axle-mounted gear unit has a gear ratio of 2.78:1: its case is made of cast aluminum, with ductile cast iron bearing mounting rings.

ICE 500 bogie

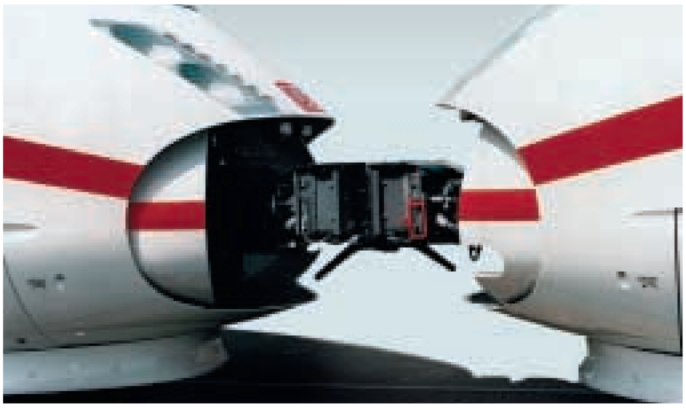
The ICE 3 is fitted with SF 500 bogies that offer maximum ride comfort and have been developed specifically for EMUs running at high speeds up to 330 kph (205 mph). They are a further development of the ICE 2's SF 400 bogie.

The ICE 500 bogie is modular in design and can therefore be put together either as

- a powered bogie for the driven axles (with traction and electric brake, including two wheel-mounted brake disks per axle) or as
- a trailing bogie for the non-powered axles (with two axle-mounted brake disks per axle for single-system trains or three axle-mounted brake disks per axle for multi-system trains and two eddy-current braking magnets per bogie).

Complex running calculations carried out for the SF 500 have yielded a design that offers optimum stability and comfort and excellent lateral guidance.

The bogies have been undergone long-duration continuous testing (in the ICE D) and peak load testing (on ICE S).



Nose coupler on ICE 3

Powered bogie on ICE 3

ICE 3 technology – the on-board power system

The on-board power supply system powers the electrical auxiliaries (fans, pumps etc.), the comfort-related loads (air conditioning, heating etc.), and all loads in the galley (microwave oven, ceramic hob etc.).

Our engineers designing this on-board power system had to consider that the auxiliaries and comfort-related loads have to be supplied not only with 15 kV / 16.7 Hz but also with other European railroad supply voltages (25 kV 50 Hz; 3 kV DC; 1.5 kV DC).

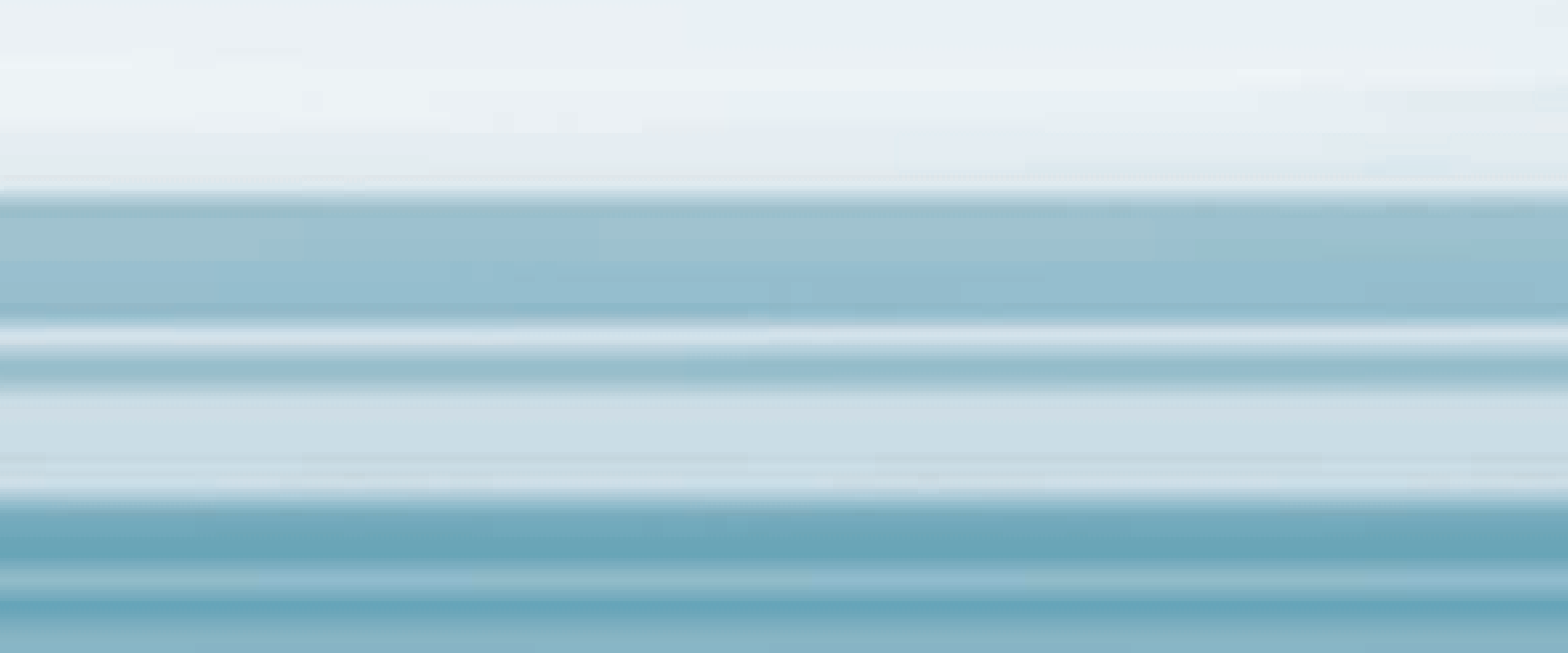
That's why a 670 V DC busbar is used, running through the length of the train. This has weight and space reduction, as well as availability, reliability, and life cycle cost advantages.

The 670 V DC train supply busbar normally feeds 4 cars. In the event of a fault, the train supply busbar is connected by means of a contactor relay.

This 670 V DC train supply bus provides a constant- or variable-frequency three-phase system (with max. 440 V, 60 Hz) which is fed from motor converters through air-cooled, IGBT three-phase inverter modules of various ratings; these modules are installed underfloor in the various cars. The air conditioning converter and main heater in each car are connected directly to the 670 V train supply busbar.

The ICE 3's 670 V DC train supply busbar is supplied in different ways:

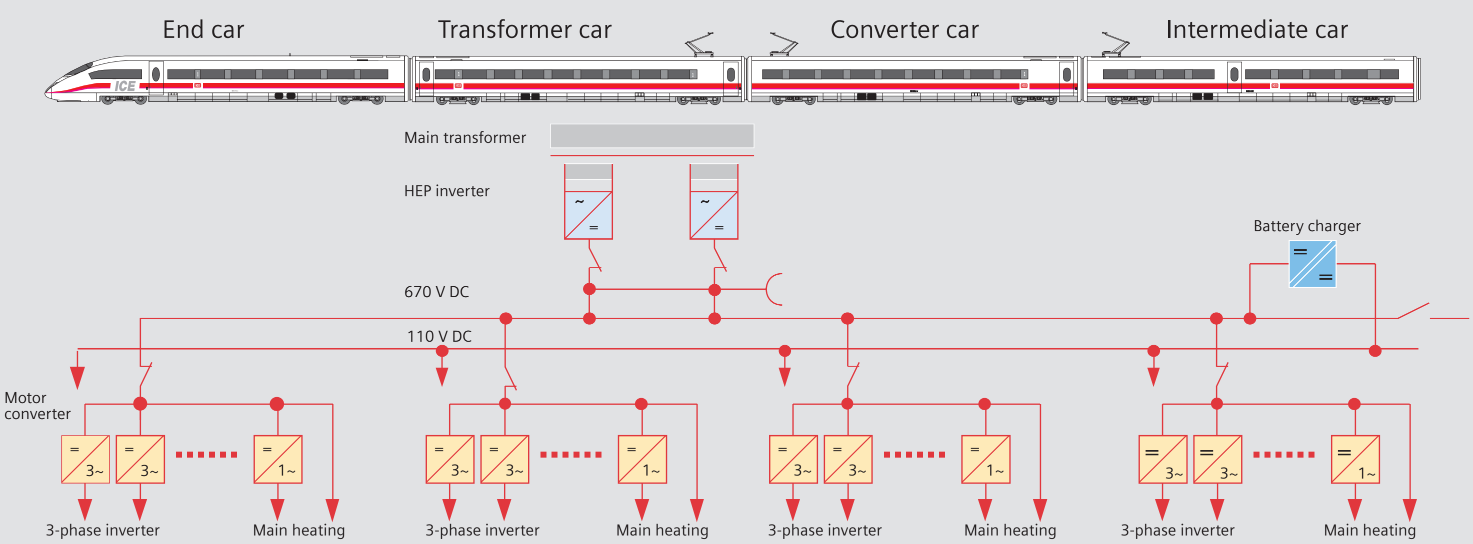
- In AC systems, the on-board power system is supplied with a nominal power of 2 x 250 kVA by the IGBT HEP inverters. These inverters are located under floor in the transformer cars. They are water-cooled, redundantly configured, and connected as four-quadrant choppers. They draw power at two separate auxiliary windings of the main transformer. This means an on-board rating of max. 1000 kVA is installed on the half-train. The maximum requirement for on-board power when the traction auxiliaries and the air conditioning systems are at full power is approximately 800 kVA.



• In DC systems, the on-board power system is powered from the DC link of the traction converters. The variable DC voltage of the traction DC link is adapted to the constant voltage of the 670 V train supply bus by modulating the pulse width of a phase module from the traction converter. The traction and on-board power system circuits are switched between 15 kV and 25 kV and AC and DC by two 6-pole contactors for input voltage selection.

The on-board power system also includes the 110 V battery busbar, which likewise runs the length of the train, and powers the car lighting, electronic control units (such as the traction control unit (TCU), brake control unit (BCU), central control unit (CCU) and door control unit), and conventional circuitry level.

Connected to this battery busbar in each of the two trailer cars are two 280 Ah lead battery packs. Each battery pack is provided with its own water-cooled battery charger. Each charger is rated at 60 kW and is powered from the 670 V train supply busbar. In energy recovery mode, each charger can feed 30 kW from the battery into the 670 V train supply bus. This guarantees a continued supply to essential traction auxiliaries to allow eddy-current braking and continued operation of, say, the air conditioning system in the event of a line voltage failure.



Onboard power system in the ICE 3 (power input, AC operation)

ICE 3 technology – the brakes concept

The ICE 3 is equipped with 3 different, largely independently acting brake systems:

- a regenerative brake with regenerative feedback in the powered cars,
- an eddy-current brake in the non-powered cars,
- an air brake in all cars.

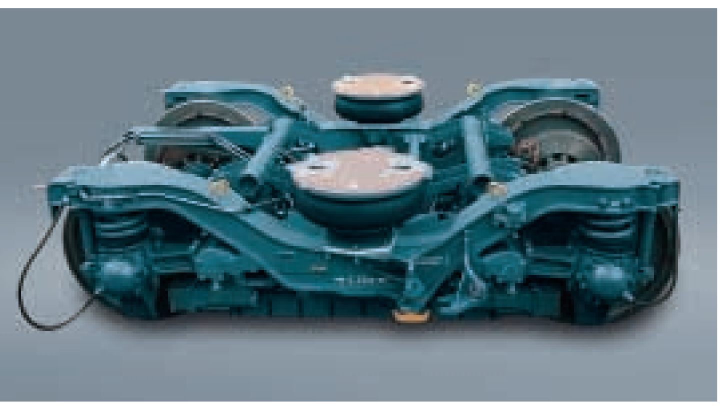
The regenerative brake, a type of brake that recovers energy from electrical braking, has a maximum braking power of 8200 kW.

The second, wear-free brake system is a linear eddy-current brake. The braking effort is generated by braking magnets located in the trailing bogies. Energy is supplied from the traction circuit and this supply is maintained by regenerative operation of the traction motors when there is no line voltage.

Four series-connected eddy-current braking magnets are excited by the traction converter by means of a step-down chopper.

The third brake system installed in the ICE 3 is an air brake as specified by the UIC. The driven axles are equipped with wheel-mounted brake disks for each wheel. The trailing wheelsets are fitted with 2 axle-mounted brake disks in single-system trains and 3 in multi-system trains. The use of steel brake disks and sintered-metal brake linings manufactured using Isobar technology allows the train to be braked from top speed using only the air brake in the event of a fault.

The various brake systems are controlled by a new characteristic-map control system that is designed for optimum wear and use of energy and can be deployed both in half-trains and extended trainsets.



ICE 3 trailing bogie with eddy-current braking magnet

ICE 3 technology – the air-cycle HVAC system

ICE 3 trainsets are the first rail vehicles to be equipped with air-cycle heating, ventilation, and air conditioning (HVAC) systems which use air as their cooling medium. This replaces the conventional cooling media which are so damaging to the environment. This technology, which is already successfully used in aircrafts, has been adapted and tested for use in ICE 3.

In a closed circuit, air is compressed in 2 stages, intercooled with ambient air in a heat exchanger and then expanded in a turbine; during this process, the temperature of the process air is reduced to around 2 °C.

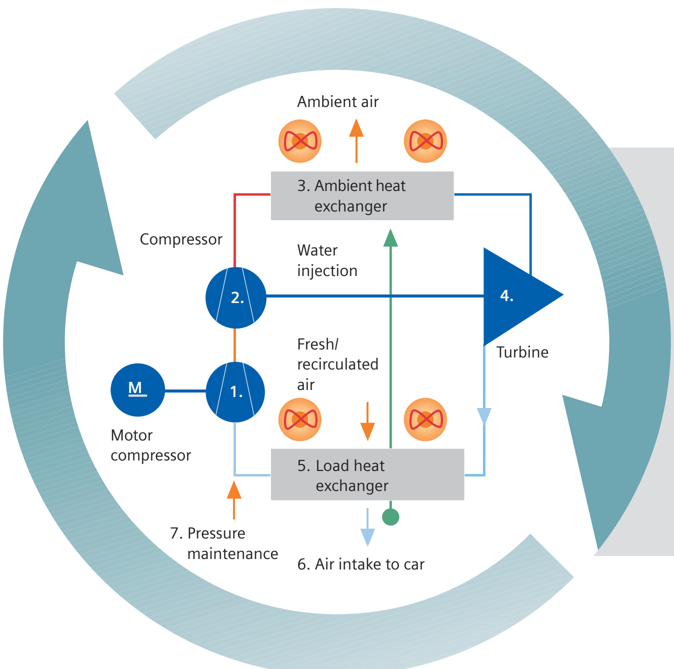
This cold air exchanges its "coldness" with the fresh air fed into the car in a further heat exchanger.

After passing through this heat exchanger, the process air is fed back to the first compression stage, where the process starts again. The moisture (air humidity) in the outside/recirculating and process air is used to boost efficiency (evaporation).

The units that make up the cooling circuit are installed in a compact A/C system in the roof area of the car.

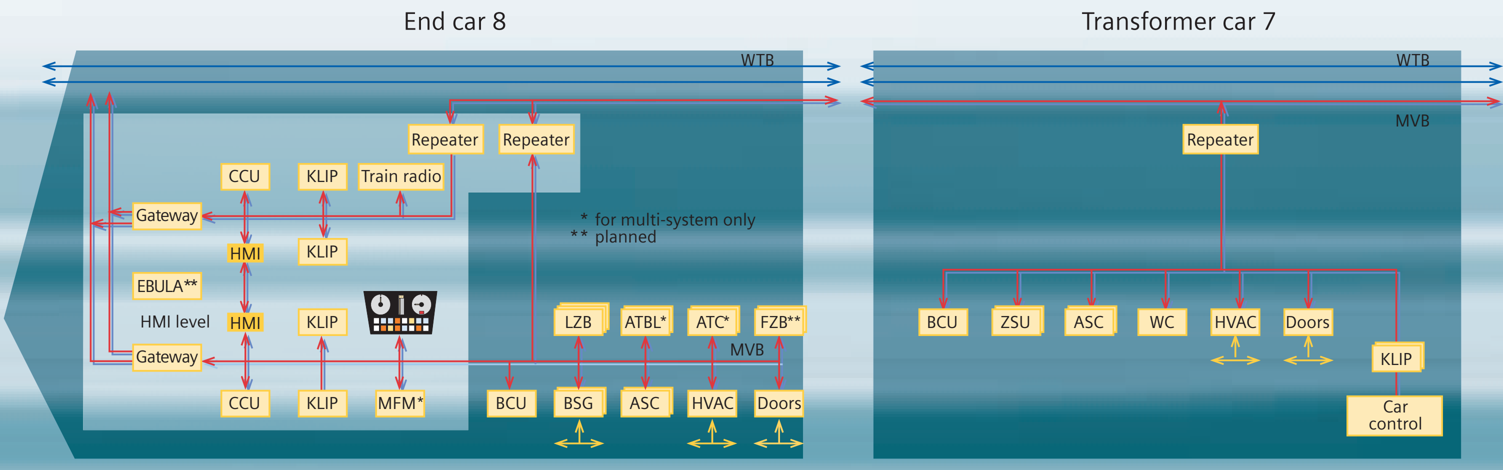
The cooling circuit is not operative when the HVAC system is in heating mode. The heating function is performed by an electrical heating in the A/C system and additional reheaters and recirculating-air heaters in the car. The air conditioned in the A/C system is fed via branch ducts in the ceiling and side walls to the air inlets.

In addition to the great environmental impact benefit, the air-cycle HVAC also helps to cut life cycle costs thanks to the reduced scope and cost of maintenance work and its reduced weight. The labor costs involved in exchanging components are considerably lower than for conventional systems, since there is no time-consuming draining and refilling of the refrigerant circuit.



1. Compression of process air in motor compressor
2. Second compression in cold unit compressor (driven by turbine)
3. Cooling of process air by heat exchange with ambient air and condensation of water precipitated at load heat exchanger
4. Expansion of process air in turbine and further cooling (energy released drives turbine)
5. Cold process air cools mixed air (fresh/recirculated air) by heat exchange and evaporation of free water in process air
6. Conditioned air enters car through air inlet
7. Compressor to compensate for air consumption of water injection and internal losses

Cooling process in air-cycle HVAC



Block diagram of the control structure of a tractive unit

ICE 3 technology – onboard control and train protection systems

The central control unit
The heart of the onboard control system of the ICE 3 is the central control unit (CCU), a SIBAS® computer developed specifically for the requirements of railroad systems. It is a redundant system, i.e. 2 CCUs are installed in each end car. If one CCU develops a fault of some kind or fails, switchover to the other CCU is automatic.

The TCN standard
The 116 system control units installed in the ICE 3 are integrated by means of a train communication network (TCN) bus system. This international standard makes it possible to equip vehicles deployed in international and cross-border traffic with the same bus. It has entailed international standardization of data exchange between programmable controllers in rail vehicles, providing the basis for coupling of open systems.

The TCN system basically consists of the wire train bus (WTB) and the multifunctional vehicle bus (MVB). In case of the ICE 3, 4 cars make up a traction unit connected by what is known as an "MVB segment". The MVB segments of the ICE 3 are connected to the WTB via gateways. The various system control units are connected via the MVB. The WTB is used to carry both the data between the two traction units and the data between 2 coupled multiple units.

The consistently redundant configuration of the TCN system considerably increases the availability of the data communication routes. Further advantages are to be found in the significant savings in hardware, installation space, weight and life cycle costs (LCC). Reducing the number of interfaces and subsystems has increased data transparency and shortened data transfer times.

Process visualization on displays
Two displays integrated into the driver's console provide the driver with extensive information about the status of the ICE 3's numerous systems. These displays also allow the driver to execute a large number of switching operations, some of which are menu-driven. In addition to this comprehensive process visualization, the computers behind these two displays contain the diagnostics system COBRA® (COBRA = Central On-Board Railway Assistant). This constantly provides the driver with a relevant overview of all operating peculiarities and faults. Diagnostics messages are radioed ahead to the maintenance workshops.

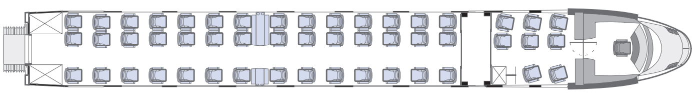
Train protection systems
To protect and control the train, the ICE 3 is equipped with a number of different automatic train protection (ATP) systems because railway operators have already invested in separately developed train protection systems.

The ICE 3 is equipped with the following ATP systems:

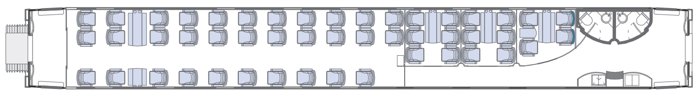
- For the single-system trains, the successful LZB 80 continuous inductive ATC system with intermittent ATC function (formerly German Rail's Indusi system). This continuous trackside-to-train transmission system provides numerous functions from train control through continuously controlled rail operation with cab signaling.

Interior layout

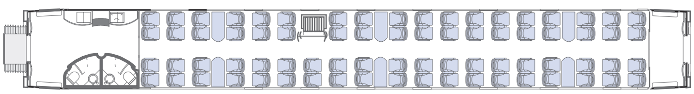
Example: ICE 3 single-system train (series 2)



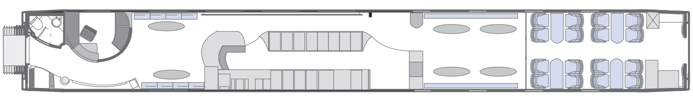
A *End car, 1st class, with lounge and open saloon*



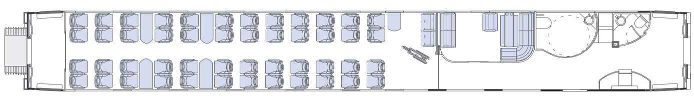
B *Transformer car, 1st class, with open saloon and compartments*



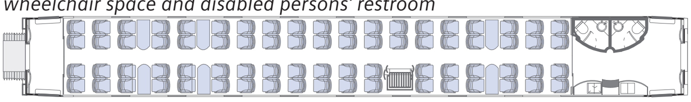
C *Converter car, 2nd class, with open saloon*



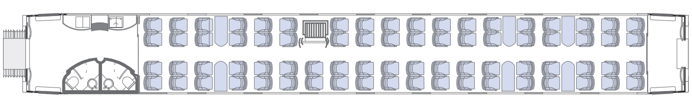
D *Intermediate car, 2nd class, with 2 bistros*



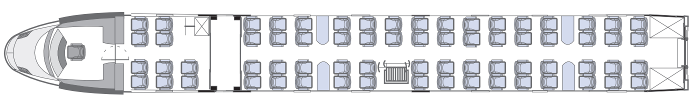
E *Intermediate car, 2nd class, with multi-function compartment, wheelchair space and disabled persons' restroom*



F *Converter car, 2nd class, open saloon*

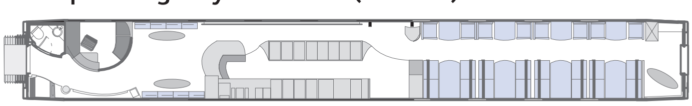


G *Transformer car, 2nd class, open saloon*



H *End car, 2nd class, with lounge and open saloon*

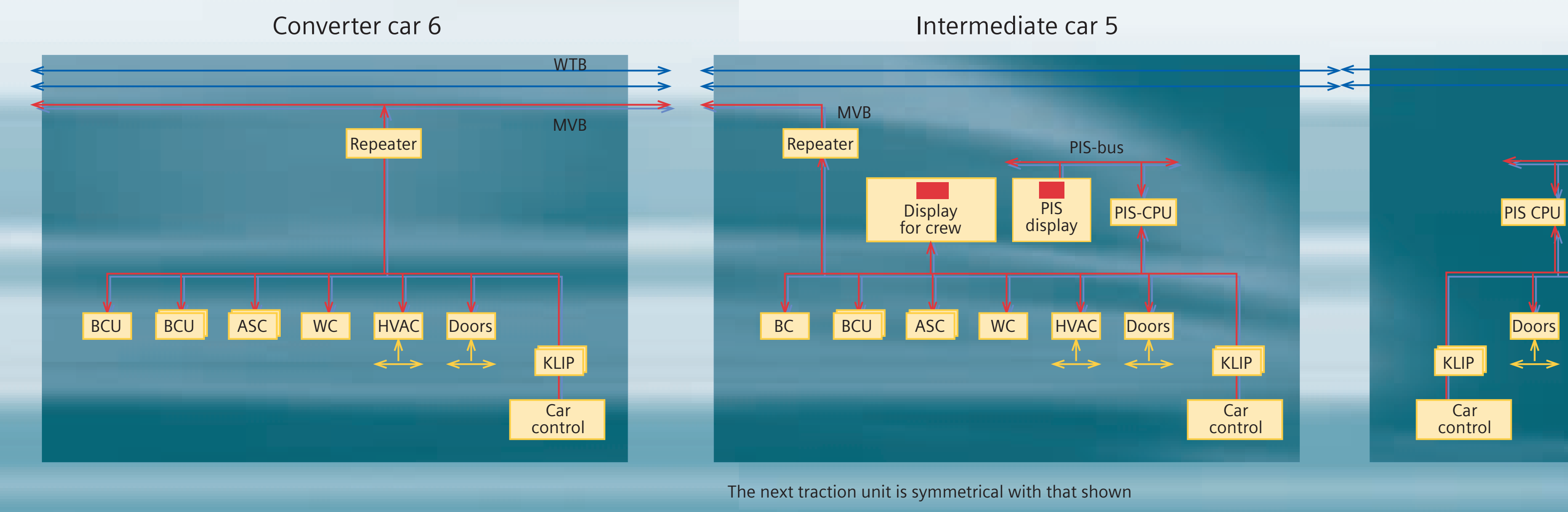
Example: Single-system train (series 1) with restaurant



Main features of restaurant concept: restaurant car replaces car D, 1st class car B replaces car C

Single-system train (series 2) with bistro	Seats
1st class	
– lounge	8
– open saloon	74
– compartment	16
1st class total	98
2nd class	
– lounge	10
– open saloon	344
– compartment	–
– multi-function compartment	6
wheelchair space	(1)
folding seats	(2)
2nd class total	360
restroom	9
disabled persons' restroom	1
personnel restroom	1
total number of seats	458

Single-system train (series 1) with restaurant	Seats
1st class	
– lounge	8
– open saloon	105
– compartment	28
1st class total	141
2nd class	
– lounge	10
– open saloon	234
– compartment	–
– toddler compartment	6
wheelchair space	(1)
folding seats	(2)
2nd class total	250
1st and 2nd class total	391
restroom	9
disabled persons' restroom	1
personnel restroom	1
restaurant	24
total number of seats incl. restaurant	415

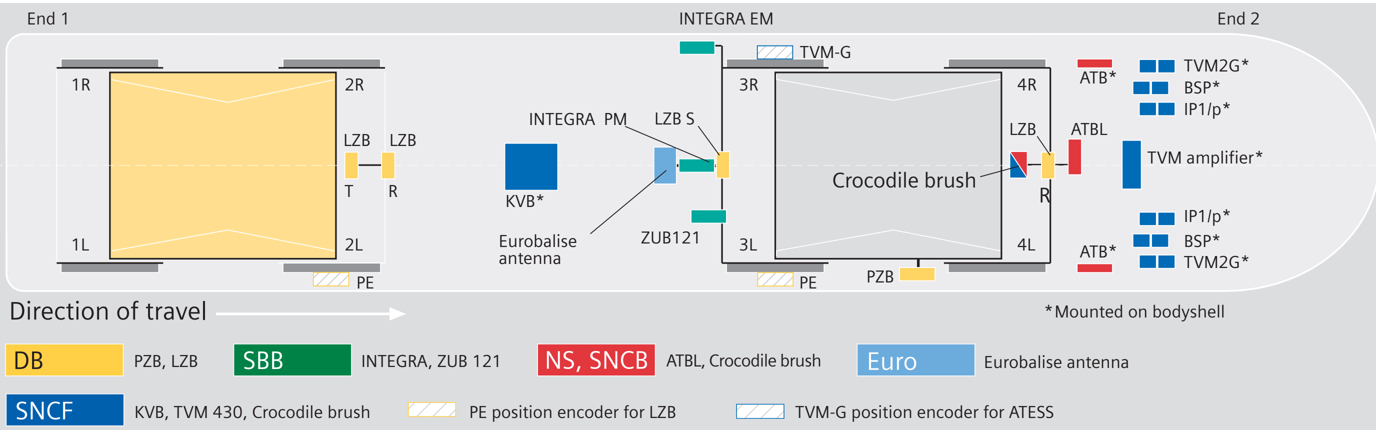


- On multi-system trains, the LZB is supplemented by the following national ATP systems to ensure safe operation in European networks:
  - Integra Signum and ZUB 262 for SBB (Switzerland)
  - ATBL for NS (Netherlands) and SNCB (Belgium)
  - optional: TVM and KVB for SNCF (France).

One unit of each of these ATP systems is installed in each end car of a half-train.

Antennas and magnets
All the ATP systems require antennas or magnets under the end cars, for the most part, on or close to the first bogie (see center figure). An antenna for the Eurobalise automatic train control and communications system has been installed to prepare for future European train protection systems which will provide vehicle tracking and other functions. These systems are there to ensure safe and reliable signaling for the ICE 3 in Europe.

Interoperability
Smooth and trouble-free operation across the system boundaries of the national railway networks is essential to ensure the success of European high-speed rail travel. The ATP systems, in particular, and their integration into the ICE 3's onboard control system, with reliable data exchange via the MVB, enable safe and reliable crossing of national borders without time-consuming stops. Wherever the necessary trackside infrastructure exists, the ICE 3 can already cross the borders between Germany, the Netherlands, Belgium, Switzerland, and Austria in accordance with the spirit of future interoperable, cross-border traffic.



Antennas and magnets of the ATP systems are mounted under the end cars

Technical data

	Single-system train (series 1)	Multi-system train (series 1)	Single-system train (series 2)
Track gauge [mm]	1435	1435	1435
Train length (8-car) [m]	200	200	200
Car length			
– end car [mm]	25675	25675	25675
– intermediate car [mm]	24775	24775	24775
Dist. betw. bogie centers [mm]	17375	17375	17375
Car width [mm]	2950	2950	2950
Car height [mm]	3890	3890	3890
Top speed			
– AC voltage [kph]	330	330	330
– DC voltage [kph]	–	220	–
Traction voltage			
– AC voltage	15 kV / 16.7 Hz –	15 kV / 16.7 Hz 25 kV / 50 Hz	15 kV / 16.7 Hz
– DC voltage		1.5 kV 3.0 kV	
Tractive effort			
– AC voltage [kW]	8000	8000	8000
– DC voltage [kW]	–	4300	–
Tractive effort at start-up [kN]	300	300	300
Braking systems	Regenerative brake, linear eddy-current brake, air brake with steel brake disks	Regenerative brake, linear eddy-current brake, air brake with steel brake disks	Regenerative brake, linear eddy-current brake, air brake with steel brake disks
Max. axle load [t]	< 17	< 17	< 17
Tare weight [t]	410	436	410*
No. of seats (bistro/restaurant concept)	441 / 415	431 / 404	458
– 1st class	98 / 141	93 / 136	98
– 2nd class	343 / 250	338 / 244	360
– restaurant	– / 24	– / 24	–

*design target

Reg. No. 58893

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