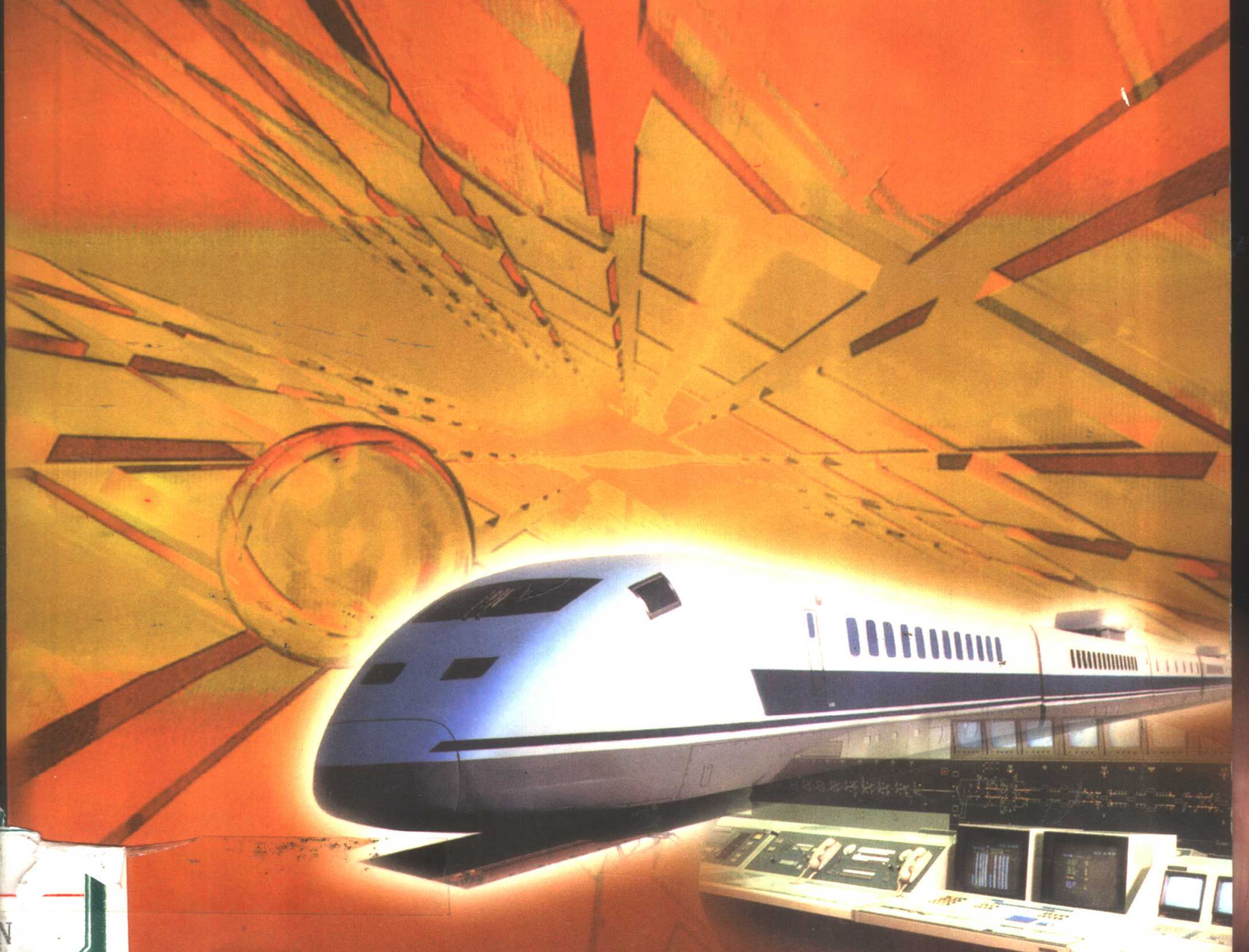
铁道部重点教材
TIEDAOBUZHONGDIANJIAOCAI

高等学校教材

专业英语

（电气工程及自动化）

大连铁道学院 廖 凡 主编
西南交通大学 连级三 主审



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内 容 简 介

本书为铁道部“九五”重点教材之一，是高等学校电气工程及自动化专业的专业英语教材，也可供相关专业的工程技术人员学习参考。

编者针对电气自动化、自动控制、电力牵引传动以及电气化铁道供电等专业的内容与特点选取了 16 篇英语读物，既涉及到电气自动化及相关学科专业的核心领域，又涵盖了较为广泛的专业词汇。每一篇课文中的关键语句与词组均作了注释，并提出一些与课文内容紧密关联的问题，供读者讨论和思考。书末还附有专业词汇表和有关核心期刊，以备参考。

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前　言

国家教委颁布的大学英语教学大纲中，强调大学四年外语学习不断线，并要求使学生达到顺利阅读专业外文期刊的目标，规定了专业英语是一门必修课程。据此，按铁道部原教卫司 1998 年 7 月的编写“九五”重点教材的通知精神，我们编辑了本书。

本书为铁道部重点教材，可作为高等学校电气工程及自动化学科范围（包括电气自动化、自动控制、电力牵引传动、电气化铁道供电等）的专业英语教材。编者按上述专业方向选取了最近出版的英语刊物中有关文章，如我国引进并正运行在主干线上电力机车的设计、结构、特性与控制特点；机车电传动中有关交流传动机车将取代直流传动机车的论述；最新大功率电力电子器件的发展的现状，自动控制领域中最新的 PWM 模式；轮轨机车及磁悬浮列车的极限速度现状；输配电系统中分布式微处理器的应用；铁道电气化供电系统与非正弦系统谐波补偿以及自动控制中有关机器人可靠性；声控 I/O 计算机、计算机自适应控制器、CAD/CAM 现状等等，内容涉及到电气自动化及相关学科的核心领域，从中可了解对某些技术理论问题的观点与论证方法。课文中的专业术语较为广泛，我们除对每一篇课文的关键语句与词组作注释外，在书末附录部分还提供了 New words and expressions，将课文中的专业词汇集中作了注释，供读者阅读时参考。附录中同时列出了与上述专业有关的英文核心期刊，供选择阅读之用。此外，我们还在每课课文之后提出与课文内容紧密关联的一些问题，教师在课堂上与同学可用英语对话讨论，或由同学随堂用简短的英文书面回答所提问题。我们相信，通过本书的学习，将进一步提高同学们的英语综合能力。

本书由大连铁道学院廖凡主编，李东辉和钱建立副主编，西南交通大学连级三教授主审。书中阅读材料分别由大连铁道学院及西南交通大学从事专业英语教学的教师作了编注，其中 1～5 课和 12 课由廖凡同志编注，6、7、16 课由贾俊波同志编注，8、15 课由李东辉同志编注，9～11 课和 13、14

课由张旭秀同志编注。编写过程中还得到了铁道部科教司的支持和大连铁道学院、西南交通大学的大力协助，对以上同志和单位的帮助我们在此表示深深的谢意。 由于编者水平有限，书中错误疏漏之处尚乞同行们指正。

编　者

1999 年 6 月

CONTENTS

TEXT ONE

New Rolling Stock[1] for the Chinese Railway

—Class 8K Eight-Axle Double Electric Locomotives[2]

for the Datong-Qinhuangdao Coal Line

Introduction

Against severe international competition, the 50 c/s Group[3] secured a contract in the spring of 1985 from the China National Machinery Import and Export Corporation for 300 heavy freight locomotives[4]. The vehicles, which are provided with only one driver's cab, are operated mainly as double locomotives and are intended to improve the transportation capacity of Shanxi Province where the major coal-mining areas of the Republic of China are to be found. The backgrounds of this important export contract, as well as the design and electrical equipment of the locomotives are described.

General

Background and Principal Current Projects

During 1984, the enormous Chinese Railway network carried 1123 million passengers, equivalent to approximately 204 billion passengers-killometres. [5] The annual freight traffic is currently around 1 200 million tones, 40% being coal. In 1986, a record amount[6] of coal carried is anticipated, between 880 and 890 million tones. Despite these heavy tonnage there are still electricity bottlenecks[7] in the industrialized regions in the east and south of the country, primarily due to insufficient transport capacity.

Consequently, for several years the People's Republic of China has been making considerable efforts to expand its existing railway network to meet the greater demands of passenger and freight traffic. The electrification of new and existing sections has absolute priority in the 1980s. One of the largest of the current projects is the 630 km long Daqin Line from Datong in the middle of the coal mining area of Shanxi Province to Qinhuangdao, the port on the Bohai Sea. Completion of the Xinxiang to Heze and Yanzhou to Shijiusuo[8] sections has given Shanxi Province access to another new seaport through which the large population centers in the east, primarily Shanghai, can be supplied with its "black gold".

In addition, of course, the new seaports also open up the possibility of exporting, which will enable the current practice of stockpiling, with all its attendant risks, to be further reduced. Other projects in hand are electrification of the existing lines between Zhengzhou and Wuhan (double track, 547 km), Chongqing and Guiyang (single track, 215 km) and Yingtan and Xiamen (single track, 705 km).

The main lines of the Chinese Railways in the north are shown in Figure 1.1.

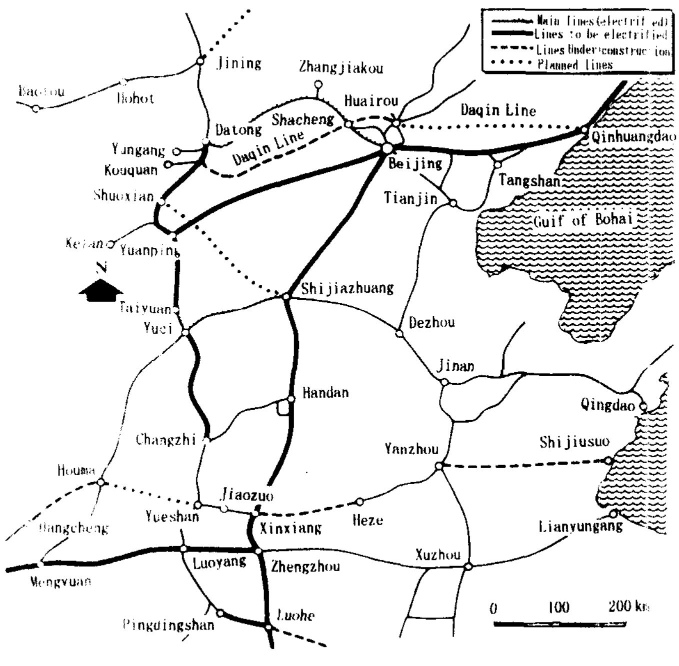


Figure 1.1: The railway network in the north of the People's Republic of China

Acquisition of Electric Locomotives

The Zhuzhou Factory[9] is the only manufacturing facility in China capable of building complete electric locomotives. During the last year it has begun production of a new eight-axle double electric locomotive called the "SS_4", of which up to 200 units per annual are to be built. However, even this number, which is large by European standards, will not be sufficient to satisfy the demand. It will still be necessary to acquire locomotives from overseas, primarily from the West. As Table 1.1 shows, there is already a history of such acquisition going back over 25 years. One of the most recent highlights of the relationship between East and West was in March 1985 when a contract was signed for the supply of 300 four-axle thyristor controlled locomotives from the 50 c/s Group which comprises Messrs. Ateliers de Constructions Electriques de Charleroi (ACEC)[10] of Belgium, AEG[11] Aktiengesellschaft (AEG) of West Germany, Alsthom of France[12], Brown Boveri & Cie Aktiengesellschaft (BBC)[13] of Switzerland, Societe MTE[14] of France and Siemens Aktiengessellschaft of West Germany[15]. Messrs. Schweizerische Locomotive and Masschinenfabrik (SLM)[16] of Switzerland are a temporary associate member of the Group for the duration of the contract. This largest ever export contract for electric locomotives, involving the provision of design expertise for all the main items of mechanical and electrical equipment, is being led by Alsthom. The last two double locomotives are already being built in China at the Zhuzhou Factory with electrical components being incorporated. Delivery began in November 1986 and will be completed by November 1987. This very short dead line has meant the shipping of up to 26 half-units every month and necessitated great commitment and strict delivery of substantial quantities of equipment on the part of all the participants. Table 1.2 shows how the work was shared among the various partners of the Group.

Table 1.1: Locomotives provided by overseas suppliers

Class	6Y2	6G1	6G50	8K	6K	
Supplierl	Alsthom/MTE	Electropatere Rumania	50 c/s Group	50 c/s Group	Kawasaki[17]/ Mitsubishi	USSR
Year	1960	1971	1972	1986/1987	1987	1988
Wheel arrangement	Co' Co'[18]	Co' Co'	Co' Co'	Bo' Bo+Bo' Bo[18]	Bo' Bo' Bo	Bo' Bo+Bo' Bo
Weight [t]	138	126	138	184	138	184
Nominal rating [kW]	4 300	5 400	5 600	6 400	4 800	6 400
Continuous tractive effort [kN]	320	269	360	471	355	
Max. Speed [km/h]	100	110	110	100	100	
No. of locomotives	25	9	40	150	80	100

Table 1.2: Sharing of the major items of the contract work

	Belgium	West Germany	France	Switzerland
Locomotive bodies & assembly[19]			250 Alsthom①	50 BBC/SLM②
Bogies & assembly			600 MTE	
Transformers with motor & filter reactors	75 ACEC	85 Siemens①	75 MTE 65 Alsthom	
Traction motors		300 Siemens 200 AGE	700 Alsthom①	
Gearing		1 200 AEG		
Electronic control gear				300 BBC
Semiconductors & converter accessories			300 MTE	
Manufacture & assembly of main equipment compartment		125 Siemens	135 Alsthom① 40 MTE	
Manufacture & assembly of battery compartment		145 Siemens	115 Alsthom 40 MTE	
Auxiliaries power supplies[20]				300 BBC
Auxiliaries(blowers & motors)[21]		2 400 Siemens		
Capacitors for harmonics & power improvement		8 400 Siemens		

Notes: ①Responsible for design
②Associate member

Locomotive Design and Principal Data

Locomotive Design

The double locomotives are intended for heavy main-line services on the mountains coal lines in the north of China. They had to be capable of accelerating a 4 000-tone train from rest to speed of 48 km/h on a gradient of 0.9% the hauled load on the level was the same. Ambient conditions to be taken into account included temperature from -40 to +40 ℃ and a maximum altitude of 2 200 m. The specified values of total efficiency and psophometric interference current at rated load were 0.83 and 7 A respactivelly.[22] Suitable filters had to be incorporated for the suppression of harmonics and for improving the power factor (specified value $\lambda = 0.9$).

Principal Data

The principal data of the double locomotive is as follows:

wheel arrangement[23]	Bo'Bo' + Bo'Bo'
Gauge	1 435 mm
Catenary supply	19~29 kV, 50 Hz
Length over central buffer couplings	36 228 mm
Distance between bogie centers	9 694 mm
Bogie wheelbase	2 780 mm
Height with lowered pantographs	4 600 mm
Maximum width	3 048 mm
Wheel diameter (new)	1 250 mm
Gear ratio	4.055 : 1
Total weight	184 t
Continuous rating	6 400 kW at 48 km/h
Continuous tractive effort	471 kN
Starting tractive effort	628 kN
Regenerative braking rating at wheels	5 300 kW
Braking effort with regenerative braking	382.5 kN at 50 km/h
Max. speed	100 km/h

Tractive Effort/Speed and Braking Effort/Speed Diagrams

The tractive effort/speed diagram shown in Figure 1.2 was predetermined by the loads to be hauled. The tractive effort needed to haul a 4 000 tone-train up a gradient of 0.9% corresponds to the continuous rating of the double locomotive. Although the tractive effort can be varied steplessly, there are in fact 11 guide steps for driving and braking on the master controller. Each step corresponds to 200 A or 10 km/h. Depending on the hauled load and the topography, each step produces a specific speed, which amounts to "characteristic" control[24]. A sensitive anti-slip device ensures safe transmission of the tractive effort during starting and continuous operation, producing an adhesion of approximately 35%.

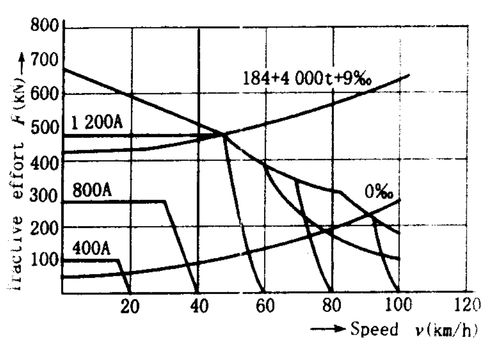


Figure 1.2: Tractive effort/speed diagram

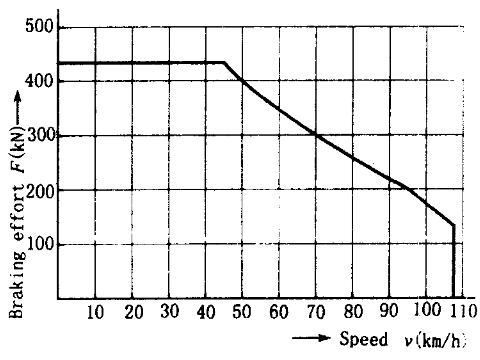


Figure 1.3: Braking effort/speed diagram

Whereas all except two of the earlier locomotives supplied were equipped with dynamic braking, a powerful, line supply-dependent regenerative braking system was specified for the new locomotives.[25] The braking effort/speed diagram is shown in Figure 1.3. In the speed range from 0 to 45 km/h there is a constant braking effort of 382.5 kN available. Between 45 and approximately 95 km/h the braking effort is kept constant. The 5 300 kW attainable at the wheels makes an important contribution to energy recovery on the mountainous coal lines.

Power Circuitry

The traction motor voltage is controlled steplessly by thyristors. In the simplified power schematic for one half locomotive unit shown in Figure 1.4 it can be seen how the symmetrical transformer feeds the converters for each bogie through pairs of its four traction windings. The converter comprises fullycontrolled and semi-controlled bridges[26] connected in series. Connected to the latter are the field-weakening thyristors which permit stepless field control of the traction motors in the field-weakening range. During normal driving the fullycontrolled bridge is operated as a semi-controlled bridge. The motor fields are reversed in order to reverse the direction of travel. For each bogie there is a stabilizing resistor which can be switched in parallel with the series-connected traction motors[27] during braking.

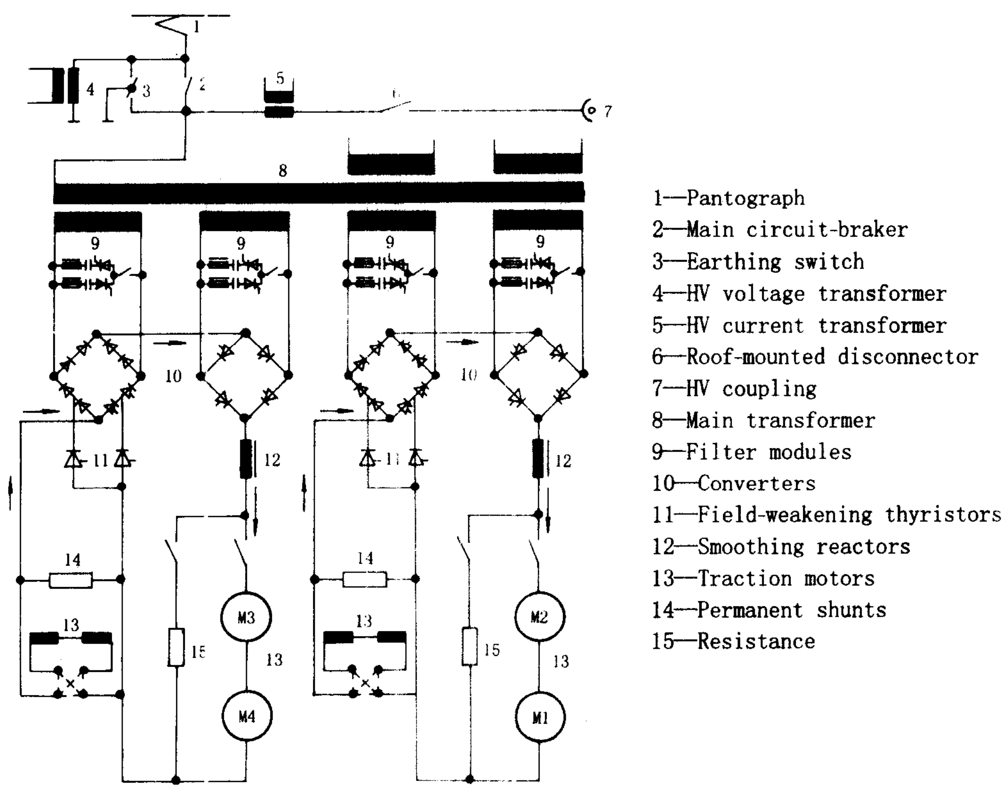


Figure 1.4: Simplified main circuit

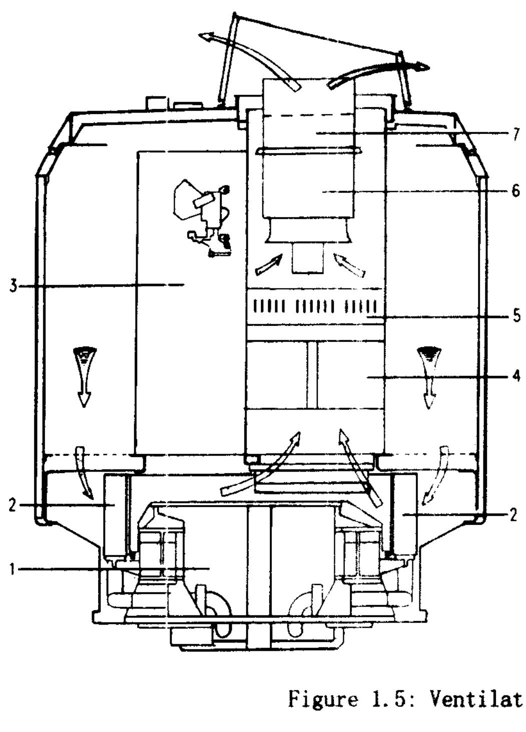
Equipment Layout and Ventilation System

Equipment Layout

The internal arrangement of the equipment provides two side gangways, each accessible from one of the two driving cab doors. Several cross gangways link the two gangways. The position of the main equipment unit above the main transformer in the center of the machinery compartment governs the arrangement of the remainder of the equipment. The battery unit on one side and the air-conditioning unit on the other are immediately behind the rear bulkhead of the cab. Next in line is a traction motor blower, parts of the pneumatic system and space for the signal cubicle to be provided by the customer. On the opposite side of the main equipment unit are the pneumatic system rack, the second traction motor blower and the main air compressor. Separated from these by a cross gangway are the two cleaning filter units and fans mounted on the sides of the vehicle. The wide center gangway between these two filter units leads to a door at the end of the machinery compartment giving access to the other half of the double locomotive. Gangway bellows similar to those on express trains permit safe and comfortable movement from one half of the locomotive to the other.

Ventilation System

The total airflow of approximately 21 m^3/s is drawn by the various blowers from the machinery compartment through inertial filters. There are three separate ventilation subsystems for the traction motor, transformers and main equipment unit. The latter is shown diagrammatically in Figure 1.5. About 11.5 m^3/s of air is drawn in through the two oil coolers mounted on the sides of the transformer directly beneath



1—Main transformer
2—Transformer oil cooler
3—Main equipment compartment
4—Auxiliary converter with DC link components
5—Converter tier including thyristors for field weakening and power factor improvement
6—Blower
7—Stabilizing and shunt resistors

Figure 1.5: Ventilation system

the discharges in the side gangway. The four blowers above the rectifier draw cooling air through the auxiliary converters and the semiconductor subassemblies and discharge it back to the outside through the resistors above.

The air from the traction motors can be discharged back into the machinery compartment through exhaust ducts, the exhaust apertures in the end shields have then to be covered. Both filter units are kept clean by their own small suction fans, the dust collected is blown to atmosphere. The use of inertial filters is on account of the harsh operating conditions, i.e. large amounts of coal dust when loading and meeting other trains, and sand-laden air in desert regions. [28]

Electrical Equipment

Roof-Mounted High Voltage Equipment

Each of the two half-units of the double locomotives is equipped with a standard single-arm pantograph which is connected directly to the pneumatically-operated main circuit-breaker. The link between the main circuit-breaker and the automatic HV articulated coupling[29] at the end of the vehicle is provided by a roof conductor mounted on 25 kV insulators and incorporating a pneumatically-operated disconnector. This customer-specified arrangement allows not only independent operation of the two half-units comprising the double locomotive (e.g. for hauling passenger trains) but also the facility for the second half-unit providing the feed should there be a fault near the pantograph and main circuit-breaker. [30] Usually, the double locomotive always uses the rear pantograph.

The connection between the main transformer and the HV terminals of the transformer is provided by an HV cable and plug connector whose roof end terminates in a roof insulator. In parallel with the main transformer there is also an earthing switch, with which all the HV equipment can be earthed, and an HV instrument transformer.

Main Transformer and Reactors

The main transformer is a special design, similar to that used in French Railways locomotives suitable for underfloor mounting between the bogies and combined ventilation with the main equipment unit directly above. The oil tank, the air-guiding cover, the coolers mounted on the sides of the cover and their pumps form a very compact unit.

Apart from the core and oil assembly of the transformer, the oil tank also contains the double reactors of the filter modules. The transformer is of the two-limb type due to the requirement for maximum magnetic decoupling of the traction systems. Insuldur paper insulation is used for the cylindrical winding of the transformer and polyester fleece for the disc coils of the reactors. The two oil pumps work together to circulate the oil through ducts in the cylindrical windings. In the case of the reactor windings, on the other hand, the oil simply circulates round the outside.

The main transformer is illustrated in Figure 1.6. It has been designed for the following performance at 25 kV rated voltage (Table 1.3).

Table 1.3: Principal data of the transformer

Winding	Power	No-load voltage	Rated current
Traction	4×1 224 kVA	4×1 020 V	4×1 200 A
Brake excitation	2×90.5 kVA	2×69.5 V	2×1 300 A
Auxiliaries 1	197 kVA	857.7 V	230 A
Auxiliaries 2	33 kVA	185.5 V	178 A

The impedance voltage with one or two traction systems short-circuited is 16.5%, with a secondary winding short-circuited it is 15%. The traction-motor double reactor adjacent to the core and coil assembly has designed for an inductance of 6 mH with a continuous current of 1 250 A. At saturation, the inductance falls to 4.2 mH. Apart from primary-side protection, the transformer also incorporates the following protection and monitoring devices; contactmaking thermometer with switching points at -25 and +90 ℃, oil flow monitor, oil level indicator, dehydrating breather and pressure relief valve.

The heat losses are dissipated through two steel finned-tube coolers mounted on each side of the transformer cover. The coolers are made of stainless steel and each of the two elements is sized for dissipating proximately 100 kW with a cooling air flow of m^3/s and a constant temperature of 42 ℃. The oil is circulated by two pumps mounted on the side of the tank. The whole transformer unit ready to install weighs approximately 12.74 t, the core and coil assemblies of the transformer, smoothing reactors and filter reactors[31] weighing 3 850, 3 245 and 1 580 kg respectively.

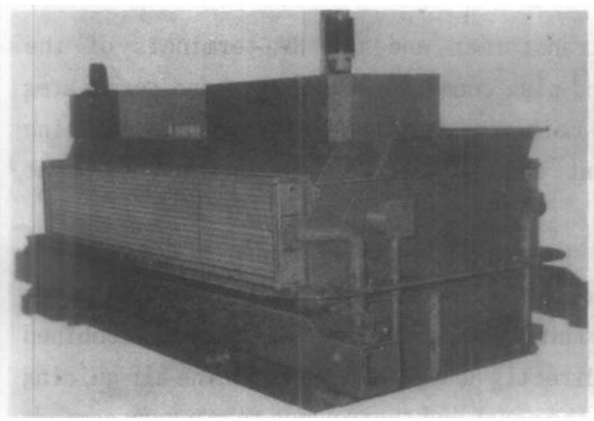


Figure 1.6: Main transformer

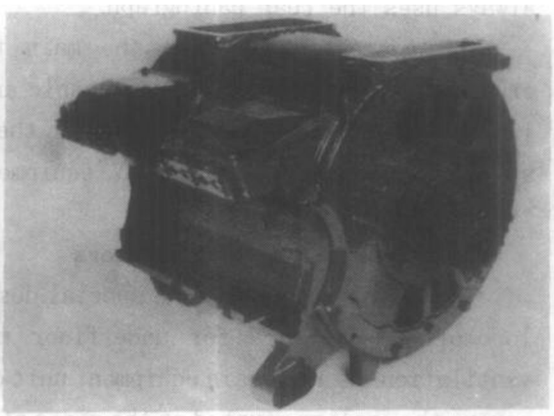


Figure 1.7: Traction motor

Traction Motors and Drive

The pulsating-current, half-voltage traction motor (Figure 1.7) is a six-pole uncompensated series machine.[32] Basically, it is a modified version of the motor already used successfully in the Class 6G50 locomotives. The most important changes are the use of a roller-type nose bearing and Class C insulation for the windings (max. permitted armature/field temperature rise: 180/200 K). The performance data of the half-voltage motor at a rated voltage of 865 V and with a cooling airflow rate of 2.16 m^3/s is as follows (Table 1.4):

Table 1.4: Motor performance data

	Continuous	60 min	N(max)
Motor current [A]	1 250	1 290	660
Output at motor shaft [kW]	1 000	1 035	537
Torque [Nm]	9 550	10 000	2 490
Speed [r/min]	1 000	975	2 060
Effective field ratio [%]	96	96	56
Insulation	Class C		
Weight without pinion and without nose bearing	3 450 kg		

The cast steel frame forms part of the magnetic circuit. The interior is hexagonal and the conventionally-made main poles and commutating poles are bolted to the six flat surfaces. A rotatable brush holder yoke carries six brush holders each having four brush boxes for the reinforced split-type carbon brushes. One end of the motor frame is machined for mounting the nose bearing housing. The roller-type nose bearing replaces the plain bearing type[33] on the original motor. The drive is transmitted through a pair of straight-cut spur gears. The gear wheels run in oil in a split gearbox made of cast aluminum.

Converters

The semiconductors held between heat sinks are mounted on insulating boards and interconnected according to their particular use. As can be seen in Figure 1.5, the converter tiers are inserted in the ventilated part of the main equipment unit; apertures in the tiers underneath the various heat sink tags ensure the necessary airflow. A converter system for feeding the series-connected motors of one bogie comprises the following (Table 1.5):

Table 1.5: Semiconductors in each converter

	Fully-controlled bridge	Semi-controlled bridge	Field-weakening device
Thyristors	8(2 200 V, 1 700 A)	4(2 200 V, 1 700 A)	2(2 200 V, 1 700 A)
Diodes		4(2 200 V, 2 500 A)	

Power Factor Improvement

Filters are connected in paralleled with each of the four traction secondary windings in order to suppress harmonics and to improve the power factor. Each filter circuit comprises two series-connected thyristors (3 400 V, 7 500 A) in antiparallel connection[34] and the two associated LC filters. The specification of the filter modules is as follows (Table 1.6):

Table 1.6: Specification of the filter modules

	3rd harmonic	5th harmonic
L [mH]	1.2×(1±3.5%)	1.3×(1±3.5%)
C [μF]	900	300
I_{rms}[36] [A]	660	350
f [Hz]	150	250

The double reactors providing inductance are housed in the transformer-tank. The capacitors are of the foil type[35] with the windings for 150 and 50 μF in a common steel housing.

Main Equipment and Battery Compartments

Main Equipment Compartments As with the Class BB 15 000 SNCF[37] locomotives, the various items of equipment for the main and auxiliary circuits are concentrated in a single equipment compartment. It has dimensions of 5 750 mm×1 700 mm×2 320 mm and weighs approximately 8 200 kg. The use of a central, preassembled compartment arranged directly above the main transformer has particular benefits for the final assembly of the locomotives. Short, pre-cut conductors can be fitted to the bushings of the transformer before it is installed and be connected up immediately later on when the equipment compartment is installed. The numerous control system connections are made by means of coded multiple couplings. As Figure 1.5 partly shows, the equipment compartment is divided into two halves, one half containing all equipment needing ventilation and the other half all the switch gear for the main and auxiliary circuits.

To the right and left of the ventilated equipment are two sections for housing the 24 filter capacitors. At one end of the equipment compartment there is the electronic equipment cubicle and space for low-voltage switch gear, i.e. primarily relays.

Battery Compartment As the name suggests, the major part of this equipment compartment is reserved for battery racks. The Chinese-made racks for four cells each are placed in trays of stainless steel which rest on Teflon strips and, during maintenance, can be pulled completely out of the compartment on to a support attached on the outside. When pushed home, trays and racks are held in position by adjustable straps clipped into position. In addition to the switchgear, the compartment also houses all the main components of the 110 V system, such as the battery charger, headlamp inverter and the inverters for the radiotelephone and signalling system power packs. A separate section houses the auxiliary air compressor and its electrical and pneumatic accessories. The battery sections contain thermostatically-controlled heating elements for controlling the temperature.

Electronic Equipment

All the control electronics for the converters, field-weakening thyristors, power factor improvement thyristors and the static converters for the auxiliary power supply are carried on two identical subracks. The subracks and plug connectors are housed in a steel cubicle which is installed in a recess of the main equipment compartment. The double Europa format subassemblies[38] carry the compartments of the various electronic circuits. The converters for each bogie of each half-unit of the locomotive are controlled by separate, independent electronics comprising:

- power supply (conditioned from vehicle battery)
- input and output stages
- vehicle control
- converter control
- pulse generation and output stage

The circuitry, i.e. control of the converters for all bogies, is such as to obtain the maximum possible redundancy. Setpoint issue is via the main potentiometer on the master controller. For shunting duties, the converter can also be controlled by means of the auxiliary potentiometer fitted near the side window of the driving cab. In the event of a complete electronic malfunction on the manned half of the locomotive, there is also provision for driving of the locomotive or locomotives to be continued from the manned cab. The last two double locomotives will have non-standard electronics employing MC techniques.[39]

Auxiliaries

Auxiliaries Power Supply Two identical static converters provide the auxiliaries power supply. Each converter has two outputs, one providing a fixed voltage/frequency and the other a variable voltage/frequency. This allows various auxiliaries, e.g. according to bogie, to be assigned to a particular converter so that, in the event of a malfunction, operation can be maintained with at least 50% of the locomotive's power.

The variable output of the converters can be used for varying the blower speeds according to the traction motor load in order to save energy and reduce noise. Each converter comprises a semi-controlled bridge fed from the auxiliaries winding of the transformer and two inverters connected through a DC link. GTO thyristors are used for the converters to give simple power and control circuitry and a compact, weight-saving arrangement.

Principal data:	
Input voltage	$857\times(1^{+20\%}_{-25\%})$ V
DC link voltage	500 V
DC link current	170 A
Output 1:	
Voltage	95～380 V variable (3 phase)
Frequency	12.5～50 Hz
Rated output	50 kVA
Short-time output	90 kVA
Output 2:	
Voltage	380 V, 50 Hz constant (3 phase)
Rated output	50 kVA (90 kVA)

Auxiliary equipment All auxiliaries are driven by standard AC motors having higher specification winding insulation to cope with converter-fed operation. According to which converter the particular item of equipment is assigned, the drive motors are started either direct-on-line (air compressor, oil pumps) or steplessly (blowers). The equipment includes:

- 1 main air compressor, 3 000 L/min at 10 bar with 26.3 kW, 1 430 r/min drive motor
- 2 oil pumps, each 500 L/min at 800 mbar with 2.2 kW, 2 950 r/min drive motor