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## Mechanical and Drive Details

by A.E.Hauser-Gubser

*At present 119 locomotives are on order for the SBB. A further 28 locomotives of similar design will be supplied to the BLS (8) and the Finnish State Railways (20)*

In 1985 the SBB management commissioned a syndicate formed by BBC (later Asea Brown Boveri), of Baden and SLM Winterthur with the development of a new high performance locomotive for the forthcoming Bahn 2000. Only a few performance specifications were initially fixed:

- 1) A multi-purpose locomotive of BoBo formation with converter technology.
- 2) Asynchronous motors.
- 3) Multiple unit control of up to four locomotives with time division multiplex access.
- 4) A top speed of 230 km/h
- 5) Free transverse acceleration of 1.8 m/s<sup>2</sup>.
- 6) Axle load of 20 tonnes.

7) The latest developments in wheelset guiding technology.

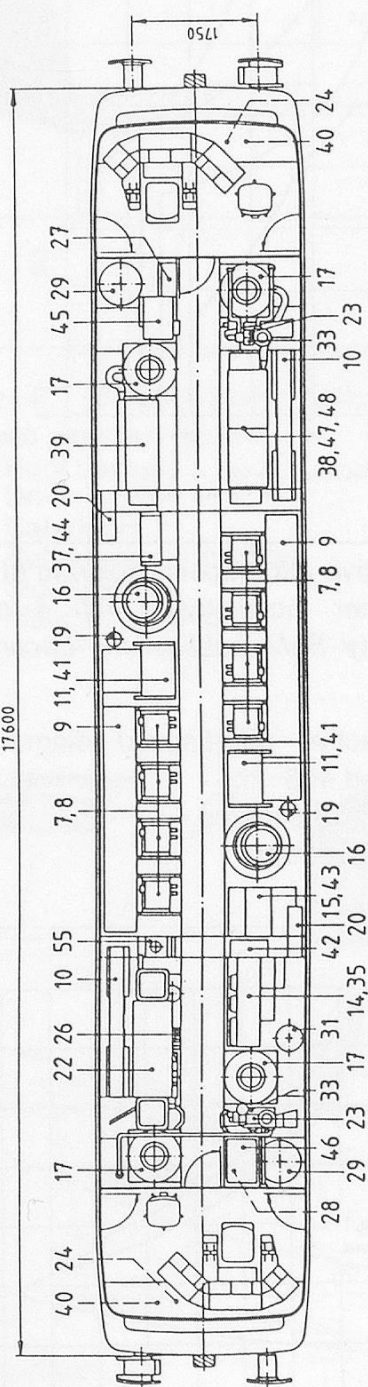
8) Low maintenance costs per km.

In co-operation with the Swiss Federal Railways' technical and workshop services the data presented in Table 1 was worked out. Figure 1 shows the engine and its main components.

In Figure 2 the tractive effort/speed curve of class 460 is compared with those of earlier 4 driving axle locomotives, whilst Figures 3 and 4 show the same curves adjusted for varying gradients with corresponding rolling resistances.

Figure 1: Class 460 locomotive and its main parts *Courtesy ABB*

- |  |   |
|--|---|
| Key  | 30 Store air reservoir                                    |
| 1 Pantographs  | 31 Air regeneration reservoir                             |
| 2 Cut out  | 32 Horns  |
| 3 Main switch  | 33 Hydraulic apparatus for permanent magnetic brake       |
| 4 Primary voltage transformer                          | 35 Loading device for batteries                           |
| 5 Main transformer                                     | 37 Apparatus block for control current system             |
| 6 Container for throttling coils                       | 38 Electronic cabinets 1 and 2                            |
| 7 Four quadrant regulators (line side converters)      | 39 Electronic cabinet 3                                   |
| 8 Power converters                                     | 40 Bus stations, driver's cab (3 each)                    |
| 9 Condensers for intermediate circuit                  | 41 Bus station for converter block                        |
| 10 Suction circuit condensers                          | 42 Bus station for locomotive wiring converters           |
| 11 Apparatus shelf                                     | 43 Bus station for auxiliary equipment                    |
| 12 Asynchronous motor                                  | 44 Bus station for current control block                  |
| 14 Locomotive wiring converters                        | 45 Bus station for pneumatic table 1 (braking calculator) |
| 15 Auxiliary apparatus shelf                           | 46 Bus station for pneumatic table 2                      |
| 16 Cooling equipment for transformer and converters    | 47 Bus station for electronic cabinet 1                   |
| 17 Motor air cooling                                   | 48 Bus station for electronic cabinet 2                   |
| 18 Transformer oil pump                                | 49 Radio aerial   |
| 19 Converter oil pump                                  | 50 Integra safety magnet                                  |
| 20 Transformer expansion vessel                        | 51 Train checking system                                  |
| 22 Condenser aggregate                                 | 53 Main connection  |
| 23 Air pressure protection for air conditioning system | 54 Feeding connection                                     |
| 24 Air conditioning apparatus                          | 55 Heating line   |
| 26 Compressor block and auxiliary compressor           | 56 EP brake line  |
| 27 Control panel 1 for pneumatic apparatus             | 57 UIC standard connection                                |
| 28 Control panel 2 for pneumatic apparatus             | 58 Permanent magnet brake                                 |
| 29 Main air reservoir                                  | 59 Brake shoes  |





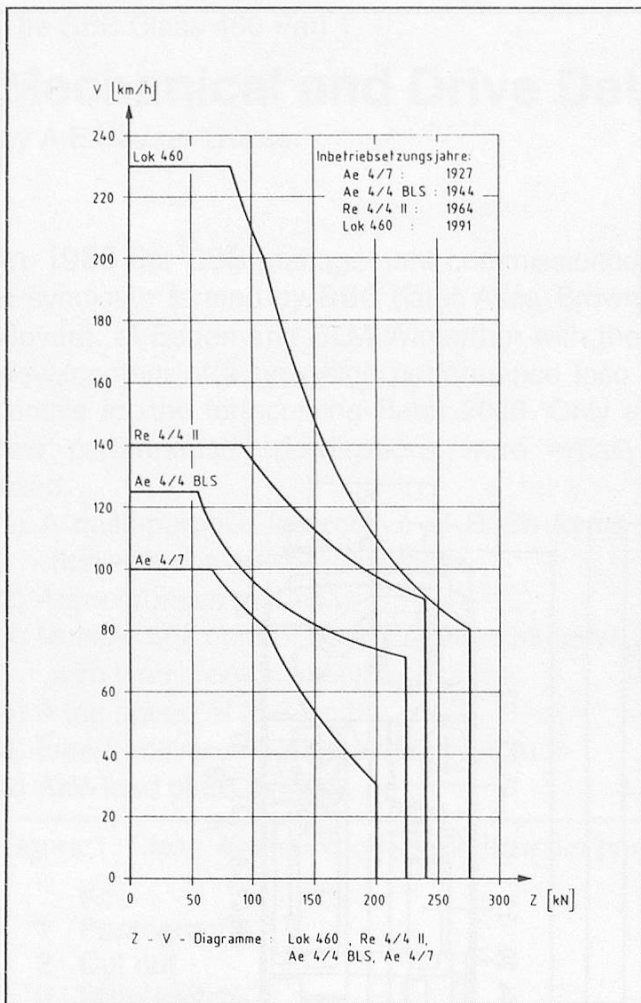


Figure 2: Tractive effort/speed diagram of class 460 and earlier locomotives with 4 driving axles. *Courtesy SLM publication "Locomotive Family 2000"*

Figure 3: Tractive effort/speed diagram for classes 460 and 465  
With rolling resistances -----  
for passenger trains

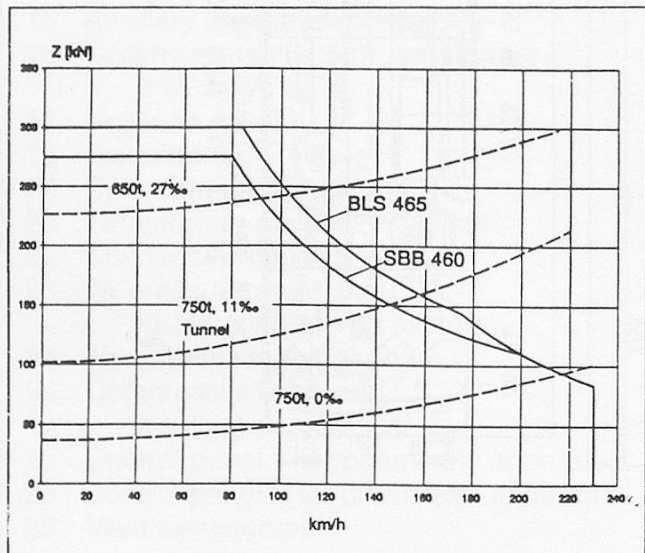


Table 1: Main Technical Data: Class 460

Axle Configuration	Bo Bo
	mm
Length	18500
Height	4310
Width	3000
Bogie wheelbase	2800
Distance between bogie centres	11000
Wheel diameter	1100
	tonnes
Weight in service condition	84
Weight of mechanical part	39
Weight of electrical part	45
Weight of bogie, including drive unit	15.8
	kW
Maximum power output	6100
	kN
Starting tractive effort (0-80 km/h)	275
Tractive effort at 200 km/h	110
Maximum braking force	275
	km/h
Top speed	230
Gear reduction	1:3.6667
Drawbar loads	tonnes
On 2.7% gradient at 82 km/h	650
On 1.1% gradient at 140 km/h	750
On level track at 80 km/h	2000

Figure 4: Tractive effort/speed diagram for classes 460 and 465

With rolling resistances -----  
for freight trains

Figures 3 & 4 courtesy SBB/ABB

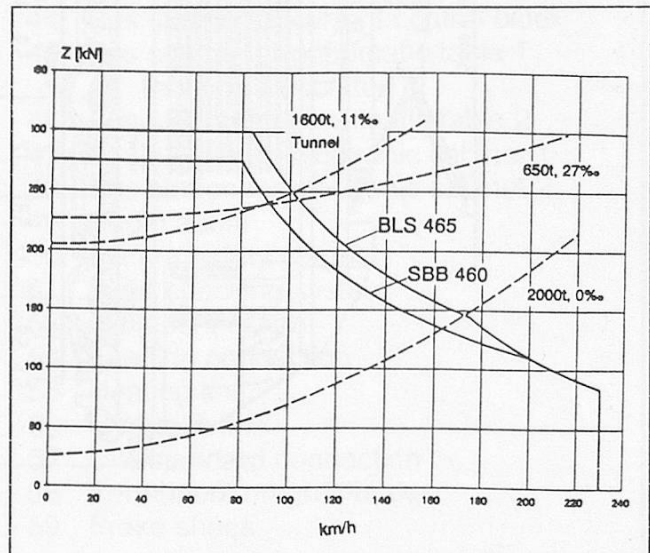


Figure 5: (Right) Body section.

*Courtesy SLM*

- 1 Bottom boom
- 2 Middle floor beam
- 3,4 Corrugated steel side
- 5 Roof flange
- 6 Air filters
- 7 Air pressure compensation room
- 8 Secondary spring recess

## Design Details

### 1: The Locomotive Body

The frame is a welded torsion-free supporting structure built up from the slim and high lower longitudinal member and the buffer beams. The body sides are made from 1.5 mm thick corrugated steel, supported by vertical profiles. To support the roof, part of the sides are provided with buckle-proof steel flanges. In Figure 5 the recess for the secondary springs (left) and the section at the connection of the drawbar between bogie and body (right) are shown.

To save weight many of the body parts have been made from synthetic materials. The driver's cabs, for instance, are built up by a five layer sandwich construction of glass reinforced

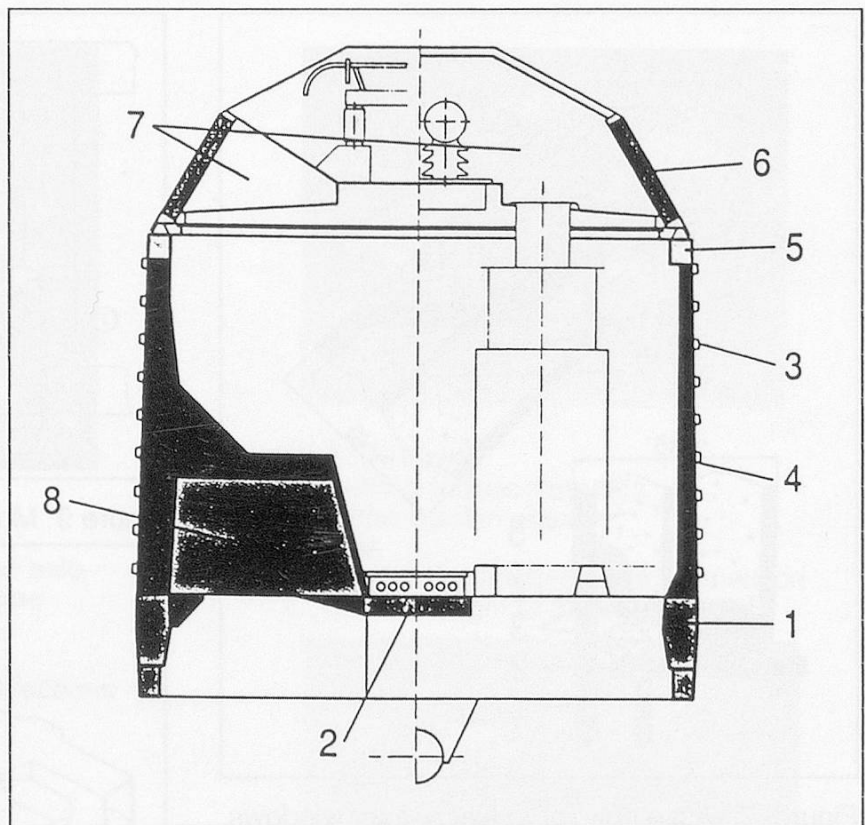
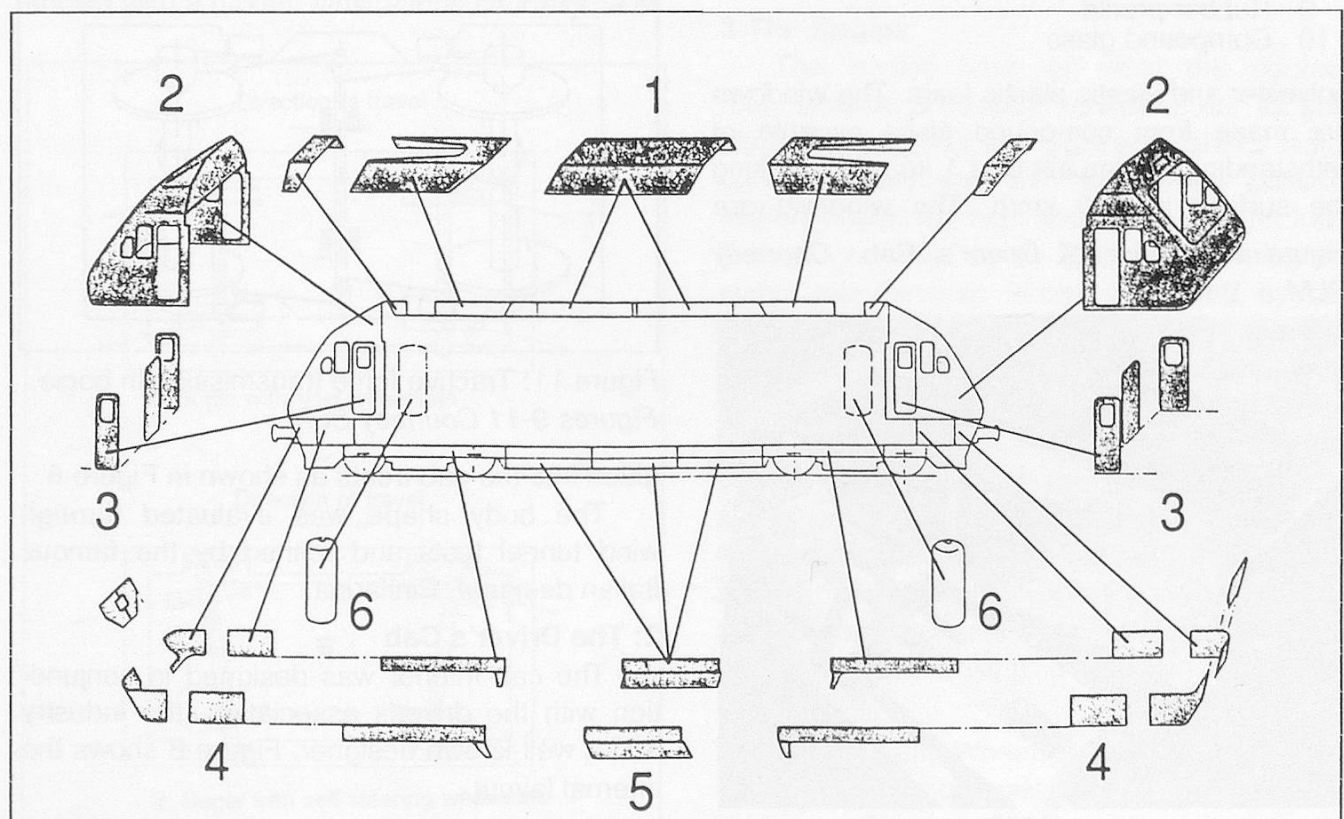


Figure 6: (Below) Body parts of synthetic material. *Courtesy SLM*

- 1 Roof covers
- 2 Driver's cab
- 3 Cab doors
- 4 Bufferbeam sheathing
- 5 Side aprons
- 6 Main air reservoir





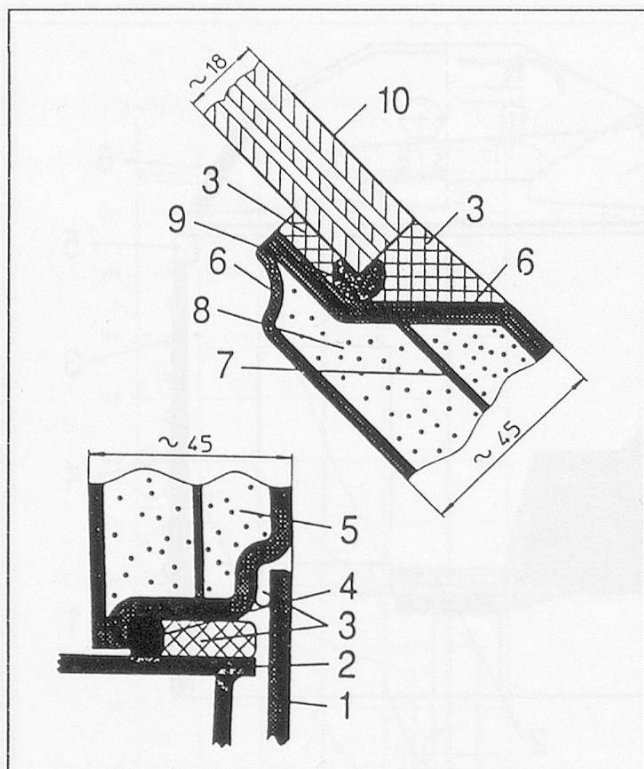


Figure 7: Assembly of driver's cab windows.  
*Courtesy SLM*

- 1 Glass fibre reinforced sheathing
- 2 Steel sheet
- 3 Synthetic glue
- 4 Spacer block
- 5 Sandwich structure
- 6 Glass fibre reinforced cover
- 7 Spacer
- 8 Foam core
- 9 Rubber profile
- 10 Compound glass

polyester and elastic plastic foam. The windows are made from compound glass capable of withstanding the impact of a 1 kg mass striking the surface at 540 km/h. The windows are

Figure 8: Interior of Driver's Cab. *Courtesy SLM*

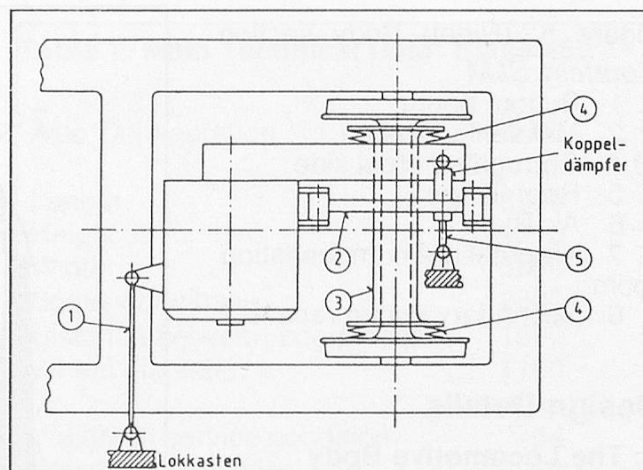
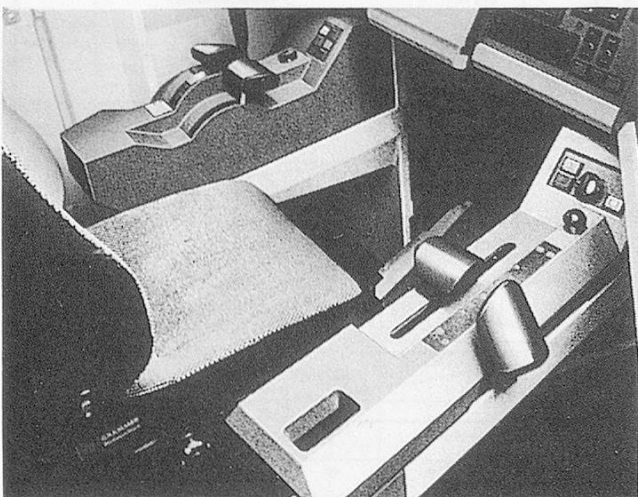


Figure 9: Motor suspension in bogie.

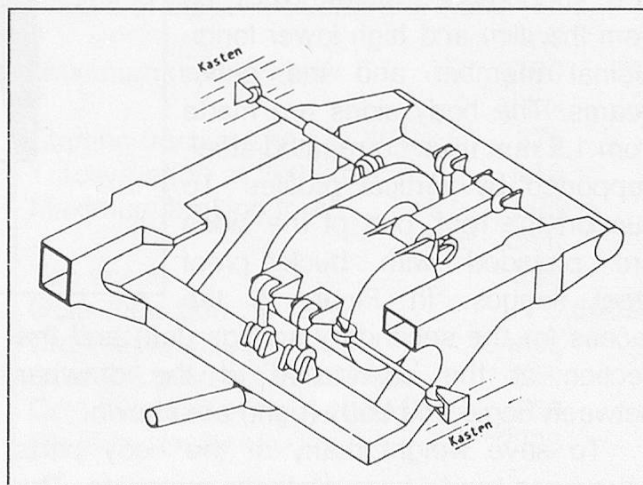


Figure 10: Drive unit support in bogie.

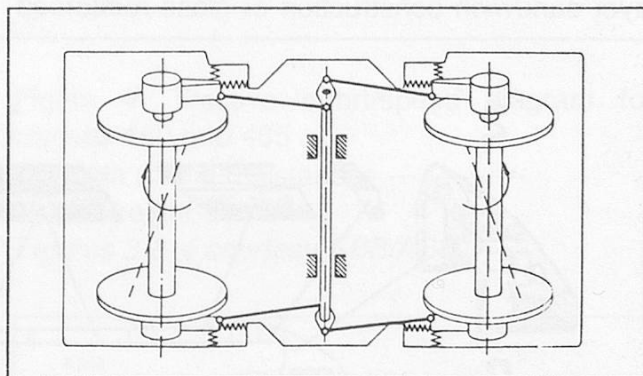


Figure 11: Tractive force transmission in bogie.  
*Figures 9-11 Courtesy SLM*

glued into the cab fronts as shown in Figure 6.

The body shape was evaluated through wind tunnel tests and refined by the famous Italian designer, Pininfarina.

## 2: The Driver's Cab

The cab interior was designed in conjunction with the driver's association, the industry and a well-known designer. Figure 8 shows the internal layout.

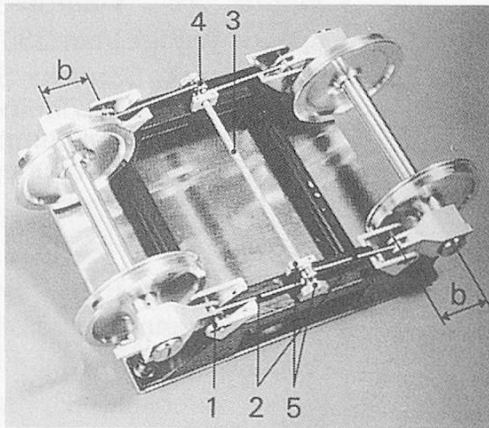


Figure 12 (Above)

- 1 Guidance in longitudinal and transverse direction of the axle housings in the bogie frame
- 2 Guiding bar for wheelset
- 3 Torsion shaft
- 4 Connecting rod in opposite directions
- 5 Bearings for tractive force transmission
- b Lever arm

Figure 14 (Right)

- 1 Flexicoil body springs
- 2 Transversal stops for body movement on curves
- 3 Rubber-metal tilting elements
- 4 Motor/gear block
- 5 Coupling link drive unit/bogie
- 6 Longitudinal link drive unit/bogie

Figures 12-14: Functional principles of bogie shown with a model. *Illustrations courtesy SLM*

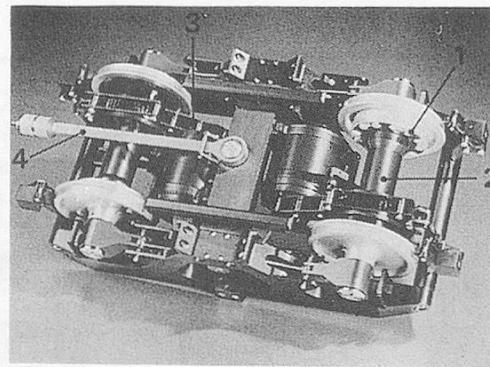
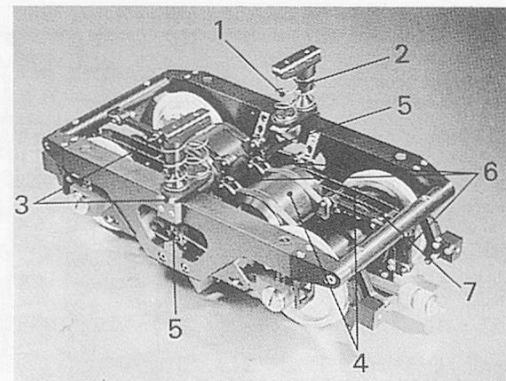


Figure 13 (Above)

- 1 Flexring rubber elements
- 2 Hollow cardan shaft
- 3 Gear
- 4 Drawbar for tractive force connection from bogie to locomotive body



### 3: The Bogies

The bogies have to meet the rigorous requirements of railway service under all conditions. These include negotiating sharp radius curves readily and with the lowest possible friction; sustaining high speeds on straight track and on gradients up to 2.7%; overcoming the static and dynamic forces generated by bad track; displaying excellent rolling qualities regardless of the position of the locomotive in the train. Extensive scientific research and development studies carried out by SLM proved the application of the principle of radial self-steering, using the guiding effect of the wheel/rail interface to be not only the best but also a very simple solution. Nevertheless several constructional steps had to be taken.

Firstly, the driving unit (motor and gear

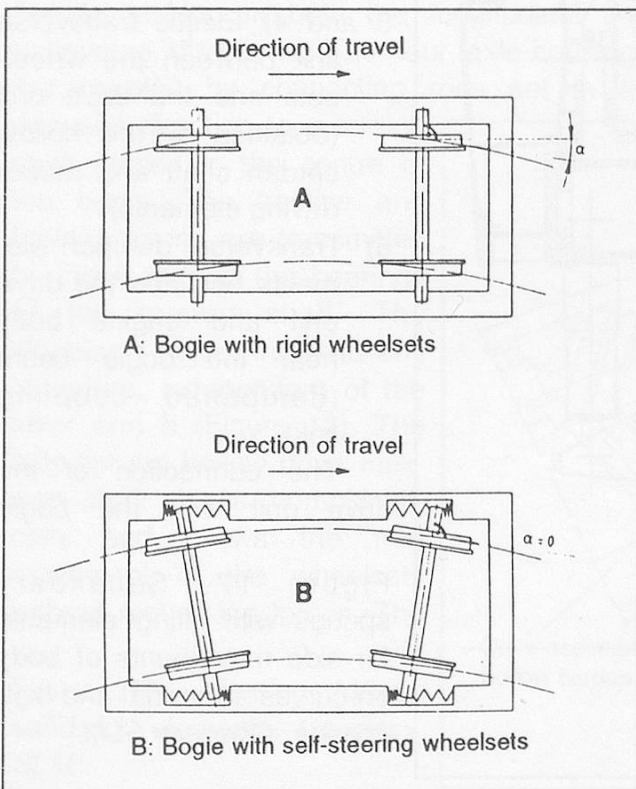


Figure 15: (Left) Wheelset adaptation of class 460 on curves contrasted with rigid wheeset guidance. *Courtesy SLM*



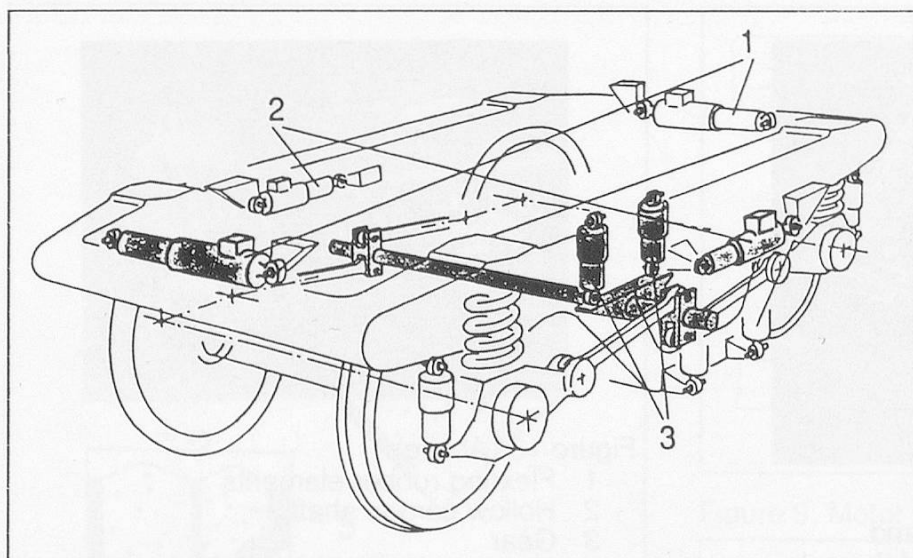


Figure 16: Dampers for speeds higher than 230 km/h or bad track. *Courtesy SLM*

- 1 Transversal damper
- 2 Longitudinal damper
- 3 Damper for connecting rods

housing) had to be dynamically disconnected from the bogie in the horizontal transverse direction. By careful selection of the position and the characteristics of the dampening and springing components, a decisive improvement in the stability was achieved (Figure 9). The flexible elements are:

- 1) A rigid transverse link between the body and the motor+gear housing in the centre of the bogie (rubber cushioned transverse link).
- 2) A soft transverse and torsional link between bogie and drive unit near the bogie beams (longitudinal link with broad rubber elements).
- 3 and 4) Elastic transverse link between the wheelsets and the drive unit (obtained by the hollow cardan shaft and rubber driving elements).
- 5) Transverse damper elements between the drive unit and engine body near the bogie beam (dampened coupling link).

The connection of the drive unit with the bogie

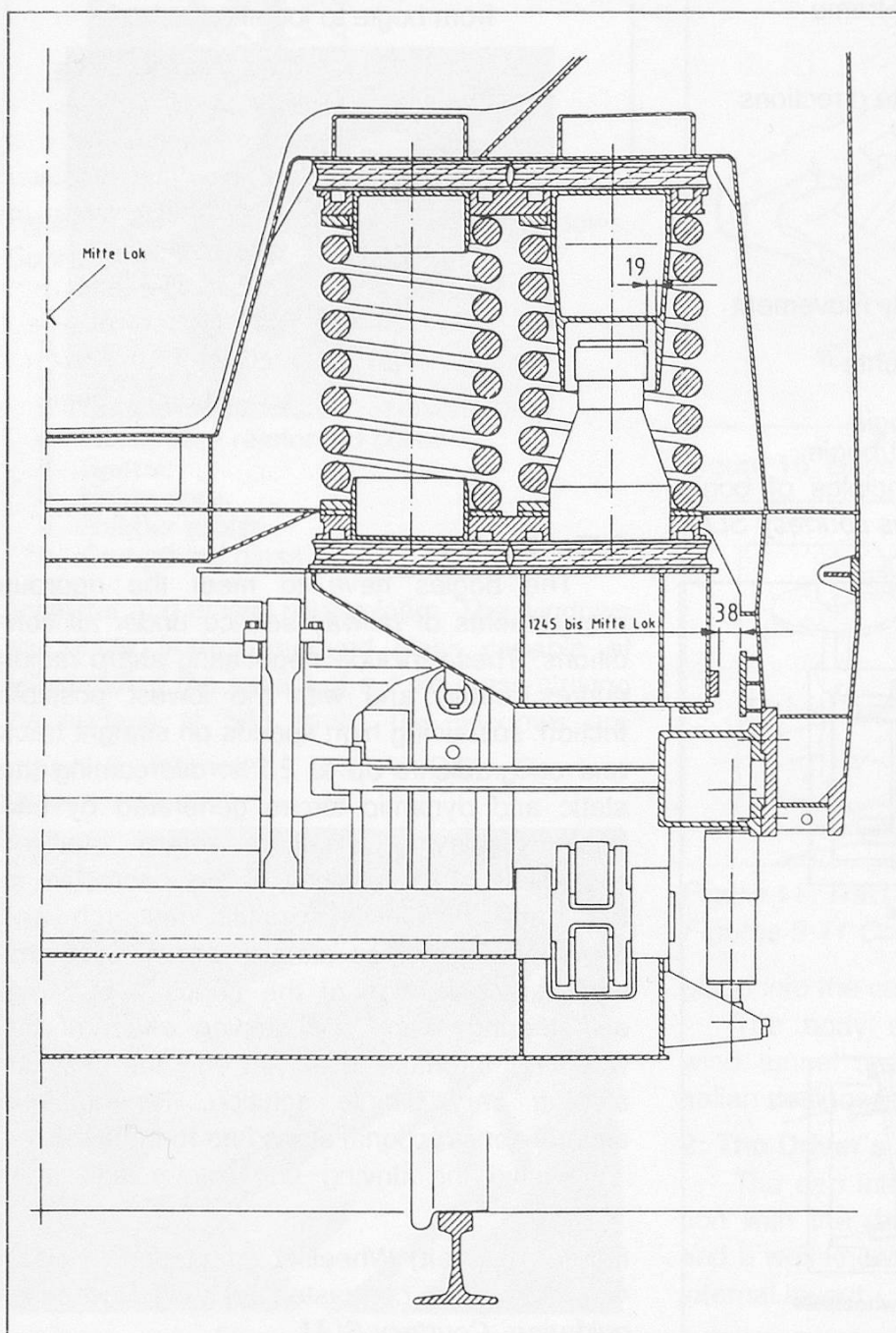


Figure 17: Secondary springs with tilting elements for side movements of body on curves at normal and high speeds. *Courtesy SLM*



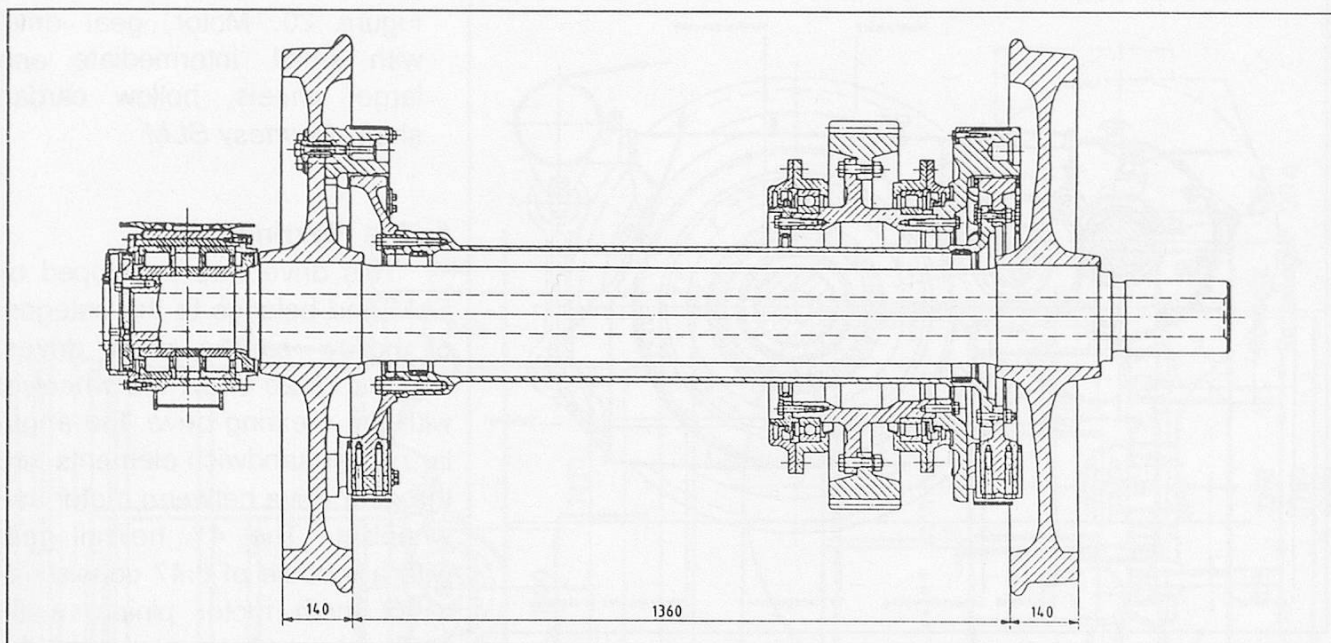


Figure 18: Flexring drive on wheelset. *Courtesy SLM*

frame is therefore firm in the vertical and longitudinal direction but flexible in the transverse direction. The 3D drawing Figure 10, illustrates the method of support of the drive unit in the bogie frames.

Secondly, the usual assistance of the longitudinal tractive force transmission between wheelset and bogie frame by means of the drive unit was abandoned for kinematic reasons. The wheelsets are now guided in a very flexible fashion in both the longitudinal and transverse directions. The four axle-housings are coupled by connecting rods set in an opposite direction to a torsion shaft placed in the centre of the bogie. The tractive and braking forces are transmitted by these rods to the bearings of the torsion shaft. The wheelsets adjust freely to any curvature, independent of the lever arm  $b$  (Figure 12). The fully sprung hollow drive Flexring shaft works homokinetically and allows the free movement of the wheelsets without restraining forces. The

drawbar for the transmission of the tractive forces between the bogie and locomotive body is placed below the bogie, giving rise to very low axle-load variations during rolling within the bogie. The body springing is cushioned by the transverse and tiltable rubber elements (see Figures 11-14). A perfect adjustment of wheelset to curvature is thus produced, as shown in Figure 15 where the self-steering bogie is compared to a conventional rigid guidance system. The stability characteristics are furthermore adaptable to badly laid track or speeds in excess of 230 km/h by mounting damping elements to prevent rolling motion (Figure 16).

The new bogies are lighter than those of former locomotives. Whereas a bogie for the

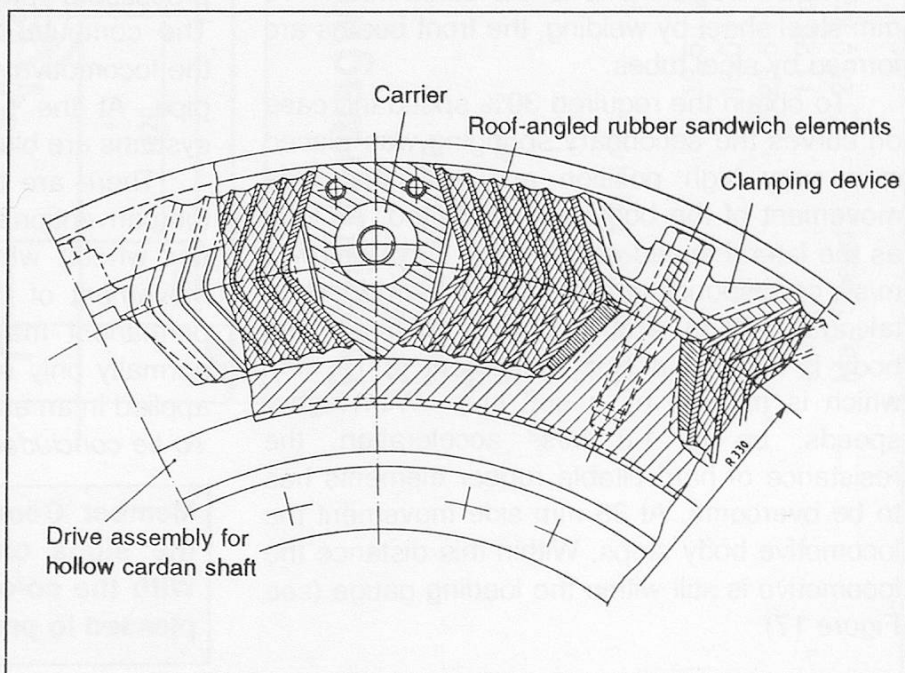


Figure 19: Flexring drive, sandwich elements. *Courtesy SLM*

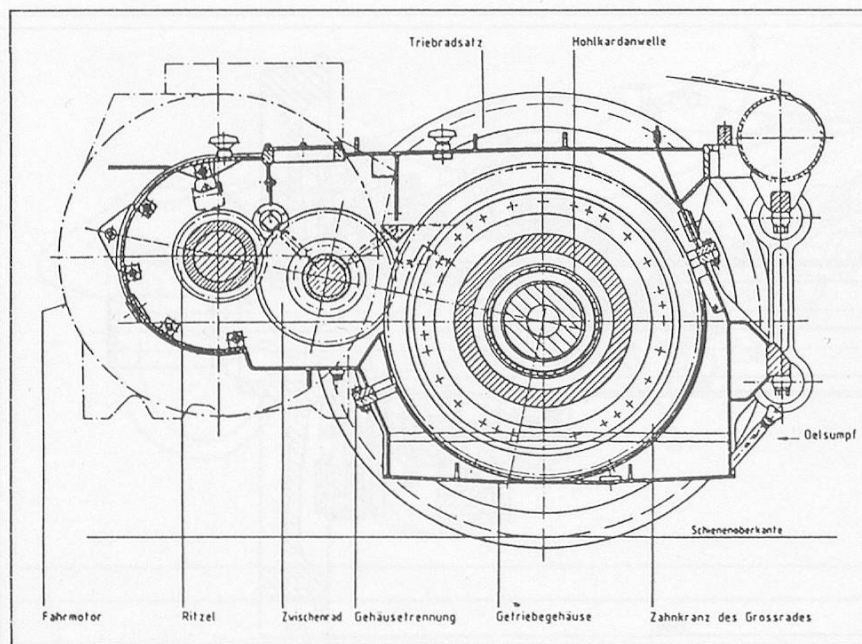


Figure 20: Motor, gear drive with small, intermediate and large wheels, hollow cardan shaft. *Courtesy SLM*

#### 4: The Flexring Drive

This drive was developed by SLM and belongs to the category of hollow cardan shaft drives. Figures 18-20 show the wheelset with the Flexring drive, the angular rubber sandwich elements and the gear drive between motor and wheelset. The 4° helical gear with a module of 6.47 consists of a 33 tooth motor pinion, a 50 tooth intermediate gear and the

Re4/4<sup>II</sup> or Re4/4<sup>III</sup> classes weigh, with drive units, some 20 tonnes, the class 460 bogie only weighs 15.8 tonnes, a saving of 21%. This is due to the use of asynchronous motors, which are about 65% lighter but 400 Kw more powerful, and the low weight of the mechanical brakes. The unsprung weight of the wheelset has been dramatically reduced, it is now less than 1 tonne against the former 1.5 tonne. The axles are hollow, with a bore of 80 mm dia., and are equipped with monobloc wheels, 1100 mm dia when new. By employing the glueing method for fixing the tyres, which provides greater safety than the shrinking process, is has been possible to use very slim wheel hubs. The hollow bogie frame is fabricated from 7-10 mm steel sheet by welding, the front beams are formed by steel tubes.

To obtain the required 30% speed increase on curves the secondary springing was placed in a very high position and a limited side movement of the body was permitted. As long as the lateral speed acceleration stays below 1 m/s<sup>2</sup>, corresponding to the forces exerted when taking a 300 m radius curve at 80 km/h, the body is allowed a side movement of 19 mm, which is marked by a soft stop. With higher speeds, up to 1.8 m/s<sup>2</sup> acceleration, the resistance of hard tiltable rubber elements has to be overcome. At 38 mm side movement the locomotive body stops. Within this distance the locomotive is still within the loading gauge (see Figure 17).

121 tooth main gear. The overall reduction is 1:3.6667.

#### 5: The Brakes

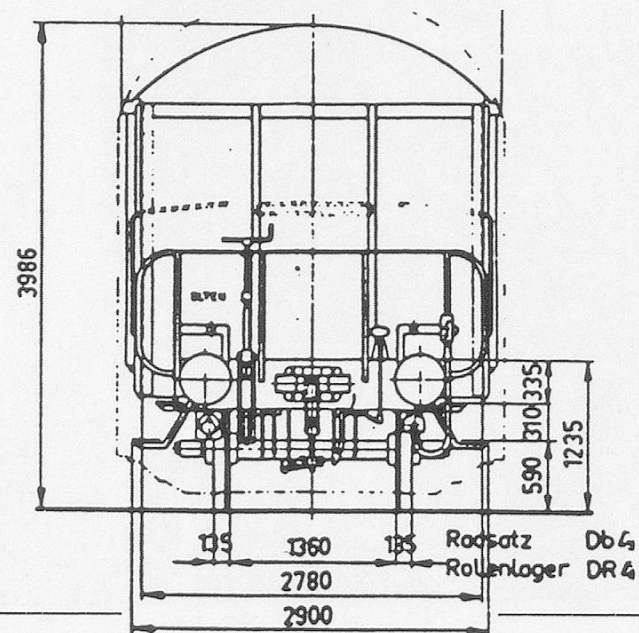
To recover energy, reduce the wear on the wheel treads and mechanical brakes as far as possible and to prevent noise emission, the electric regenerative brake has absolute priority for all braking operations. On long, steep descents with heavy trains this brake recovers up to 40% of the energy consumed and is capable of bringing the entire locomotive and train almost to a standstill. Instead of the classic brake applicator valves, "fly by wire" slide levers are used, which transmit their position electronically to the MICAS 2S micro-processors with integrated braking computers. The computer regulates the electric brake of the locomotive and the air pressure in the train pipe. At the same time the various braking systems are blended.

There are two mechanical brakes. One is the conventional shoe brake (one 2-shoe brake per wheel) which automatically follows each movement of the wheelsets. The other is the permanent magnetic brake. Both brakes are normally only used at low speeds, but can be applied in an emergency.

*To be concluded*

**Member George Hoekstra has translated the signs on the BLS Adventure Trail. With the co-operation of the BLS, we are pleased to present it with this issue.**





Scale 1:87

**Built 1959-66**

50 85 033 101-140

Series9-66

50 85 033 101-140

Tare . . . . .	13.5 t
Load . . . . .	15.0 t
Total . . . . .	28.5 t
Length . . . . .	11.26 m
Max Speed . . . . .	125.0 km/h