

**Hydrodynamic power transmission
for shunting and branch line diesel locomotives up to 650 kW**

L 3r4 z and L 3r4 zse turbo reversing transmissions

**Fully hydraulic adaptation of tractive effort, dynamic braking,
increased operating range by range-change gearbox.
Option: constant-speed control.**

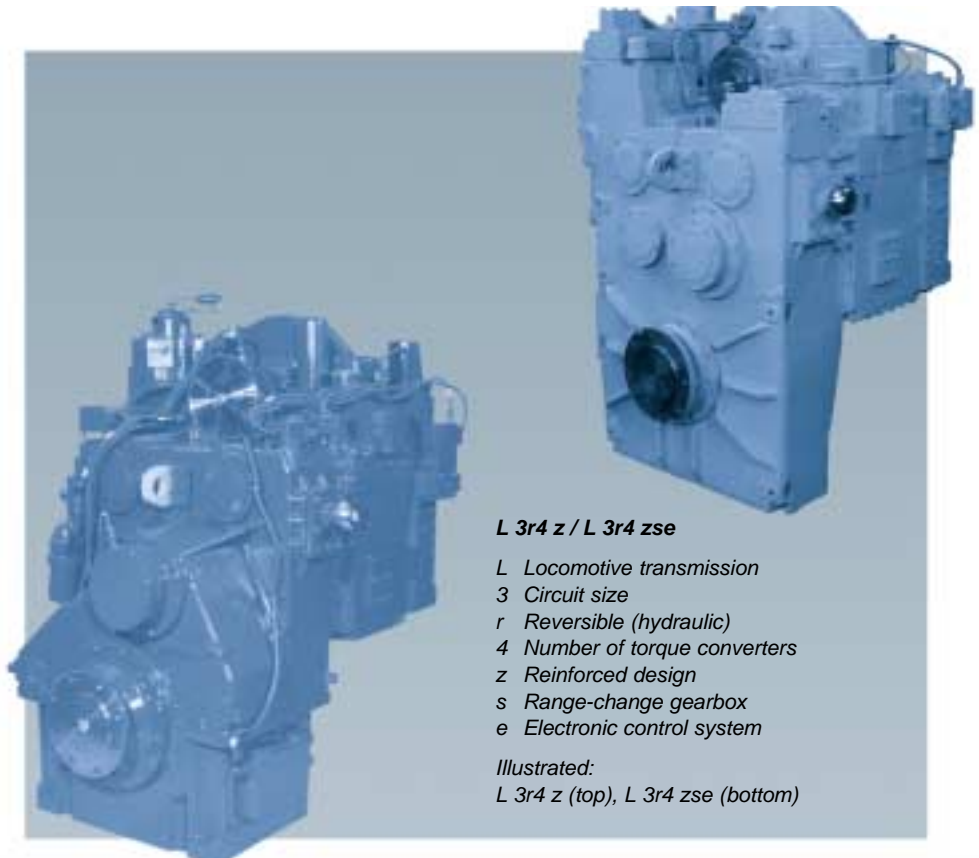
Fully automatic · wear-resistant · reliable

Applications

Voith L 3r4 z and L 3r4 zse turbo reversing transmissions are suitable for diesel locomotives with transmission input powers of up to 650 kW and maximum speeds of up to 60 km/h. If they are fitted with an additional range-change gearbox, the maximum speed can be set up to 100 km/h.

Special features

- Automatic, stepless and jolt-free adaptation of tractive effort to the prevailing resistance.
- No interruption of tractive effort during hydraulic speed changing.
- Isolation of vibrations in the driveline between engine and driving wheels.
- Smooth, virtually wear-free acceleration.
- Universal application of the locomotive for all existing traction duties, both in shunting and in trip service.
- Transport of heavy goods trains with high starting tractive effort in low-speed gear, and light cargo trains in high-speed gear.
- Hydrodynamic change of travelling direction, fast and virtually wear-free. Therefore especially suited for shunting locomotives with frequent directional changes.
- Constant-speed control mode for low locomotive speeds, during loading and unloading and in the hump yard. Changes of the tractive effort occur jolt-free and without jerks.
- Hydrodynamic braking down to complete standstill or turbo reversing without stationary periods by filling the counter-rotating converter during driving.
- Suitable for towing in neutral mode of the transmission when the engine is stationary. For speed limits, please refer to the section "Technical data".



L 3r4 z / L 3r4 zse

*L Locomotive transmission
3 Circuit size
r Reversible (hydraulic)
4 Number of torque converters
z Reinforced design
s Range-change gearbox
e Electronic control system*

Illustrated:

L 3r4 z (top), L 3r4 zse (bottom)

- Rapid transmission disengagement in the event of wheel-spin for fast reduction of tractive effort.
- Transmissions with electronic control system offer rail-specific monitoring diagnosis and operating data storage.
- Low service and maintenance requirements, i. e. low life-cycle costs.
- Long-term spare parts supplies.
- Long service life (depending on operation, major overhaul approximately every 30,000 service hours).
- Robust technology, proven for decades with state and private railways.

Principle

L 3r4 z and L 3r4 zse turbo reversing transmissions have two torque converters for each direction of travel,

consisting of pump impeller, turbine wheel and guide wheel (stator).

The transmission of power occurs between impeller and turbine wheel by the mass inertia of the operating fluid in the converter that is being filled. Depending on the driving condition, the stationary guide wheel takes up the difference in torque between impeller and turbine and initiates a stepless and automatic conversion of torque.

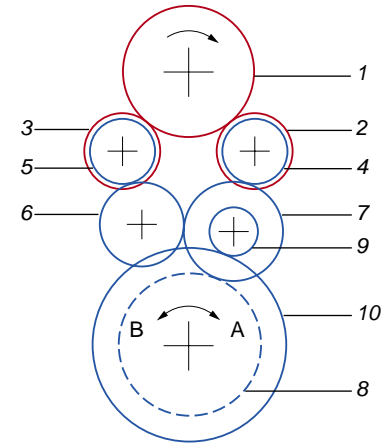
Speed changes and changes in direction of travel occur smoothly, jolt-free and without wear, with the converter circuits being filled and drained.

A range-change gearbox increases the speed range of the locomotive considerably.

Design and operation

Fig. 1 and 2:
Simplified cross section of transmission

- 1,2,3 Step-up gears
- 4,5 Secondary gears
- 6 Intermediate gear
- 7,9 Double reduction gears
- 8 Output gear, high speed range
- 10 Output gear, low speed range
- 11 Output gear (without range-change gear)
- 12 Range-change gearbox
- 13 Output shaft
- 14 Input shaft
- 15 Start-up converter
- 16 Cruising converter
- 17 Filling and control pump



In direction of rotation A = input and output rotate in the same direction (viewed from input flange)

The diesel engine is driving the input shaft 14 of the turbo reversing transmission via a torsionally flexible coupling and a cardan shaft. The primary shafts are driven via the step-up gears 1, 2 and 3, while the hydrodynamic circuits are driven by the pump impeller P connected to the primary shaft.

The pump impellers P transmit power to the turbines T by the mass inertia of the operating fluid. The torque converters 15 and 16 are designed in such a way that they are operating in two consecutive speed ranges efficiently and with identical mechanical ratios. The turbines T are arranged on the secondary shafts and connected via the gears 4, 5, the intermediate gear 6, the double-reduction gears 7, 9 and the output gear 11 (without range-change gearbox) or via the output gear 8 (high-speed range) or the output gear 10 (low-speed range) on the output shaft 13.

The filling pump 17 supplies the torque converter with operating fluid.

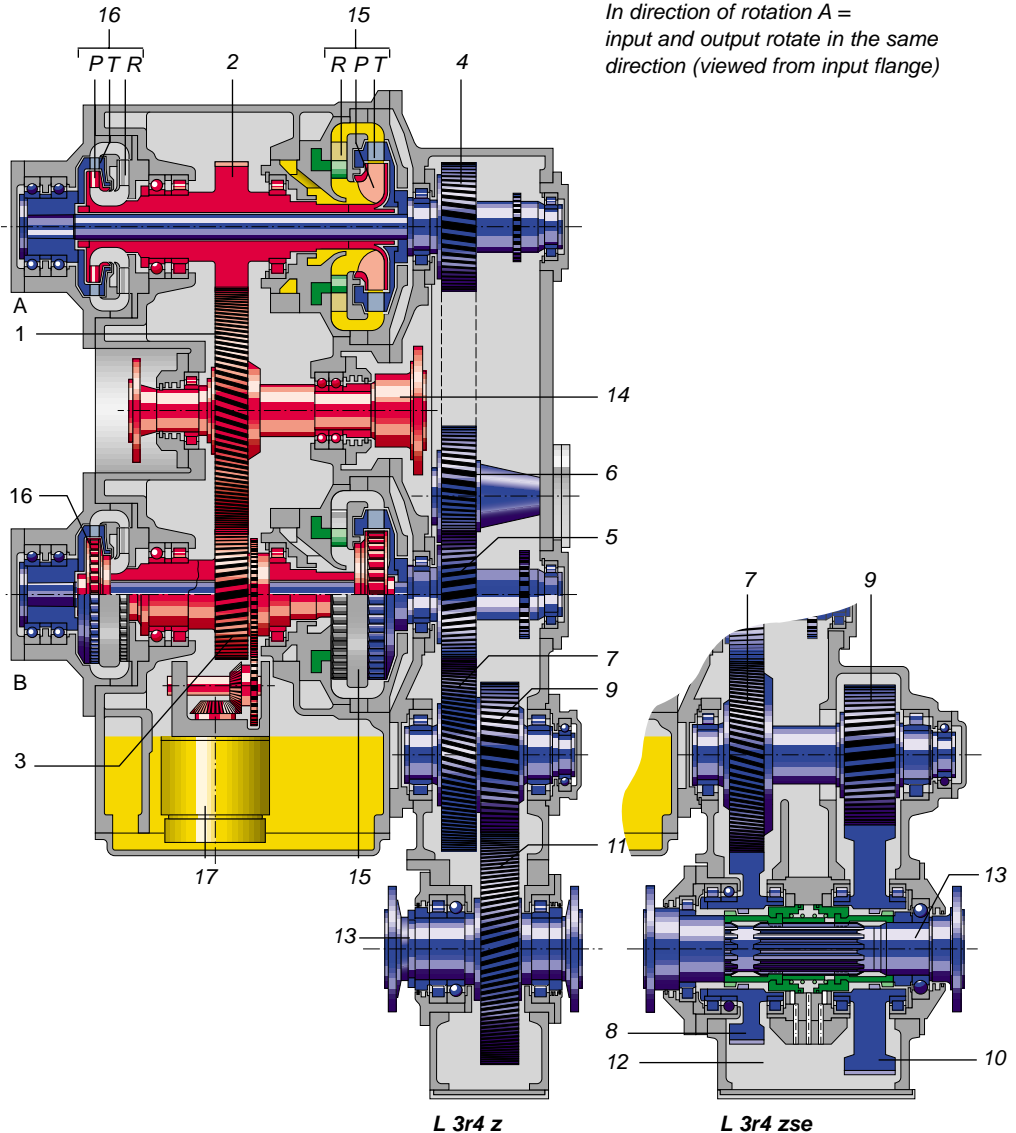
The driving direction of the locomotive is determined by the converter allocated to the driving direction in runner A or B being filled.

As a result of the arrangement of the hydraulic circuits, the change in direction of travel occurs purely hydraulically. Dynamic braking is possible. The start-up converter of the opposite direction of travel is being filled to achieve this.

Range-change gearbox

L 3r4 zse turbo reversing transmissions are fitted with a range-change gearbox 12 which can be activated while the locomotive is at halt.

If the engine is at standstill, the range-change gearbox is automatically moved into neutral position. The locomotive can therefore be towed even at high speed. Limitations due to the locomotive itself need to be observed.



- P Pump impeller
- T Turbine
- R Guide vanes (reaction members)

- Red = Primary parts (rotating parts driven by the engine)
- Blue = Secondary parts (rotating parts connected with driving wheels)
- Yellow = Operating fluid (mineral oil)
- Grey = Stationary parts (housing)

Locomotive control system

Locomotives with Voith turbo reversing transmissions are easy to operate. There are two basic systems for the design of the operating elements in the driver's cabin:

Single-lever system

The drive-braking control and the shifting into reverse are combined in one lever. The transmission and engine control system is designed in such a way that the direction of travel can be selected, the transmission activated and the engine engaged by continuous adjustment of the lever. If hydrodynamic braking is required, the driving-braking-reversing lever is shifted into the opposite travel direction.

Two-lever system

The control functions are allocated to two levers. The reversing lever is used for selecting runner A or B. The main controller activates the engine and sets the engine and the braking power. Hydrodynamic braking occurs by shifting the reversing lever into the opposite direction of travel and activating the main controller.

Range-change gearbox

The range-change gearbox has its own lever with positions S and L (high-speed and low-speed range) in the driver's cabin.

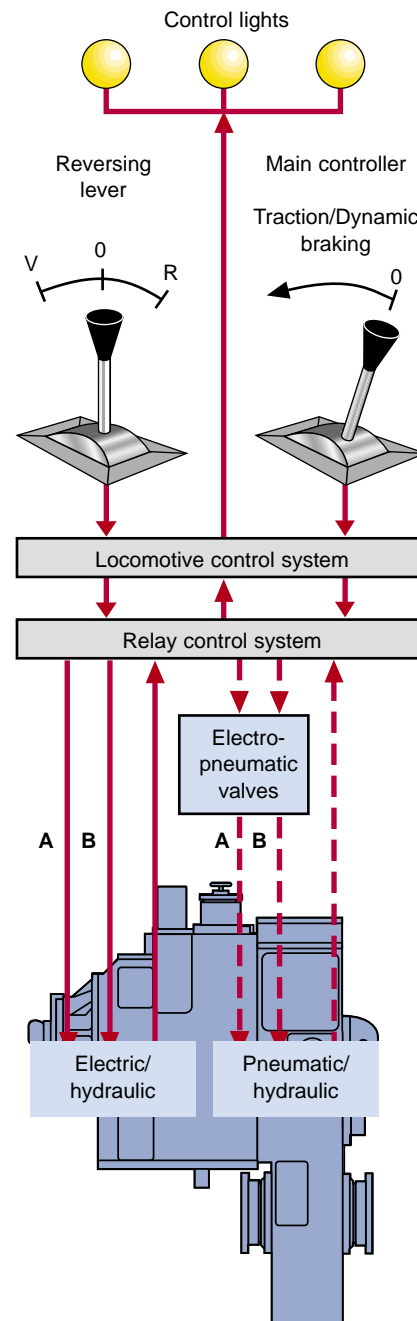
Engine control

Depending on the position of the main controller, in traction the engine speed is continuously increased until it has reached rated speed.

For hydraulic braking, the engine speed is limited to approximately 50 % of the rated speed (higher speeds result in higher primary losses in the transmission).

Transmission control

The example shows a two-lever system for L 3r4 z turbo transmission.



Electronic transmission control system Voith Turbo Control

The example shows a one-lever system with an additional selector for L 3r4 zse turbo reversing transmission.

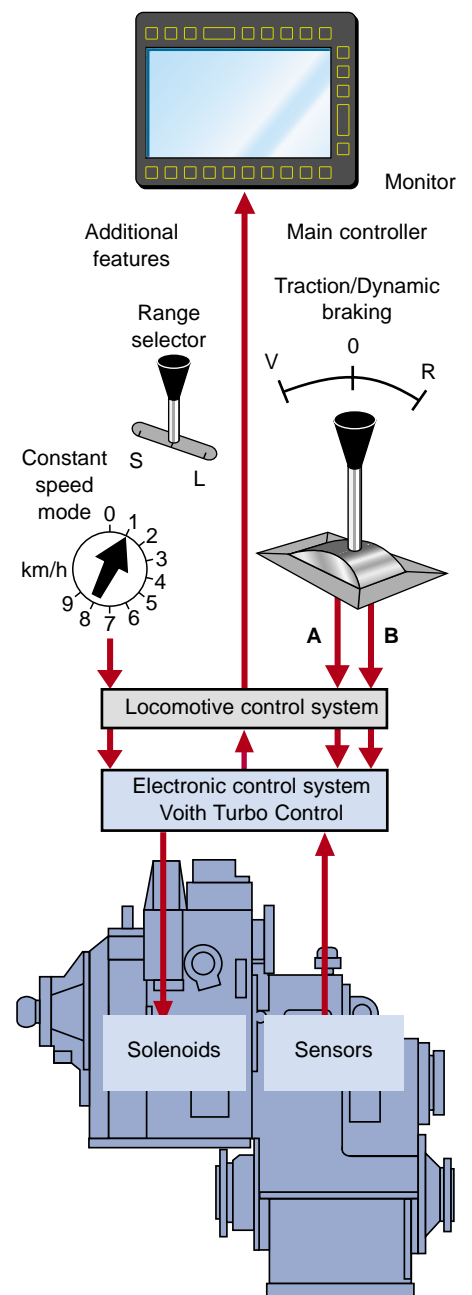




Fig. 3:
Voith micro-processor control as 19" plug-in unit in control panel.

Transmission control

The L 3r4 z transmission can be controlled electrically or pneumatically. The locomotive control system is usually designed in such a way that it automatically recognises the operating conditions driving and braking for the engine control.

The L 3r4 zse transmission is supplied with the electronic control system Voith Turbo Control. This version can be supplied with additional features. An example is the constant-speed mode which can be provided via a selector lever and relevant interfaces.

Electronic control with Voith Turbo Control

This modular micro-processor control system has been especially designed for turbo transmissions. The control electronics which are accommodated in the control panels of the driver's cabin accept the commands given by the driver and process them together with the signals of the transmission sensors. They are then forwarded to the electro-hydraulic solenoids (Aktorik) at the turbo transmission.

The solenoid valves take on the speed-shifting function of the converter circuits during traction and braking, as well as for the range-change gearbox. Input and output speed, oil temperature, the position of the range-change gearbox and the position of the main control pistons are recorded by the transmission sensors. If, for example, the maximum oil temperature is exceeded, the relevant converter is automatically drained and the engine put to idling.

The electronic transmission control comprises a diagnosis and operating data storage system. Stored data can be read via a laptop computer.

Additional features

Maximum load control, wheel-spin protection

The demands made on the tractive behaviour of a modern locomotive include the full utilisation of its adhesive weight and avoidance of wheel-spin, even if there is a high surplus of tractive effort.

The prerequisite for this is maximum load control in conjunction with wheel-spin protection. The maximum load control limits the tractive effort to approximately $\mu_0 = 0.30 - 0.33$ and forms part of the locomotive and engine control system.

The objective of the wheel-spin protection is to detect and eliminate wheel-spin at the earliest possible stage and to reduce the tractive effort instantly. In addition to the engine control, a rapid-transmission-disengagement device can ensure that the tractive effort is reduced at an even faster rate.

Constant-speed mode

The electronic transmission control system offers the possibility of maintaining a constant speed in the tractive and braking range e. g. between 4 to 20 km/h. With low tractive or braking efforts, the required effort is controlled at constant engine speed (e. g. 50 % of the rated speed) by balancing the two partially-filled start-up converters. As a result, the locomotive speed is kept constant. If a higher tractive effort is required, the engine speed is included in the constant speed mode control. In order to allow proper controlling, the tractive or braking effort requirements need to be below the maximum tractive effort (see diagram). Controlled speeds below 4 km/h need to be defined precisely with a view to the:

- dynamic behaviour of the trainset
- condition of the track
- tractive and braking effort requirements.

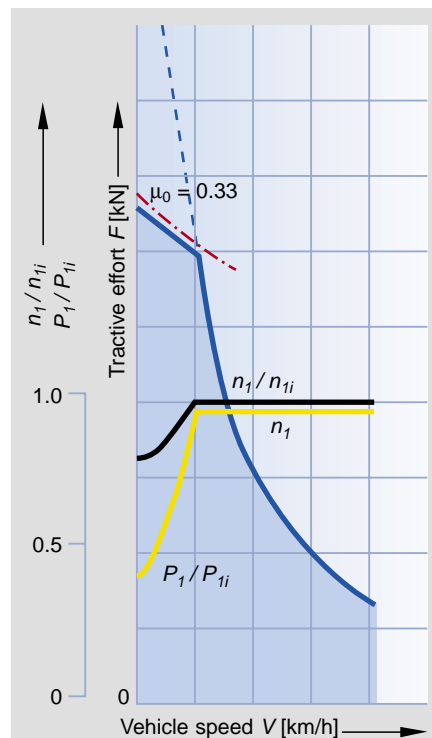


Fig. 4: Maximum load control

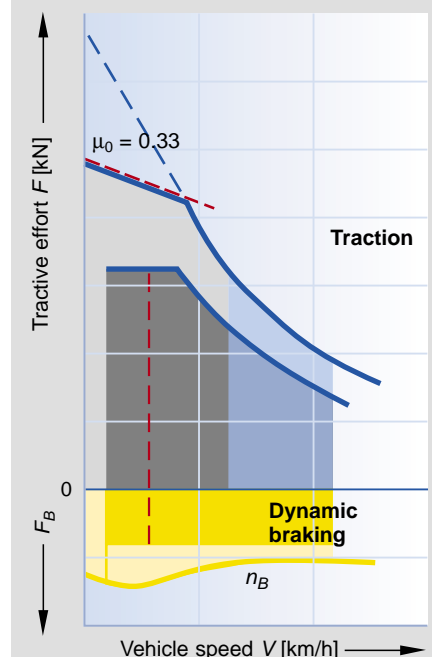


Fig. 5: Constant speed mode

Tractive and braking effort characteristics

Turbo reversing transmissions are expected to transmit the engine power within a large speed range with a minimum of losses. In an ideal situation, the tractive effort forms a hyperbolic curve as the locomotive speed increases. As shown in the tractive effort diagram (right), the achieved tractive effort characteristic – with only two hydraulic converters and only one speed-shift – comes close to the ideal tractive effort hyperbola.

A range-change gearbox on the output side offers two speed ranges – low-speed or shunting range (L) with high start-up tractive effort and high-speed or trip range (S) for higher top speeds (see diagram on the right).

Hydrodynamic braking and reversing

Dynamic braking is possible within the limitations of the cooling system dimensioned to the traction requirements and the storage capacity of the drive system. If a defined braking effort (continuous braking) is required, the oil cooling capacity need to be checked. Since hydrodynamic braking occurs by activating the converter in the opposite direction of travel, the locomotive can be braked and accelerated into the opposite direction (turbo reversing).

If the operating instructions do not allow turbo reversing, the locomotive wheels need to be at a complete halt (forced standstill). The locomotive control deactivates the transmission and reengages the mechanical brakes. The locomotives can be started only if the main controller is put into neutral and a new traction command has been placed.

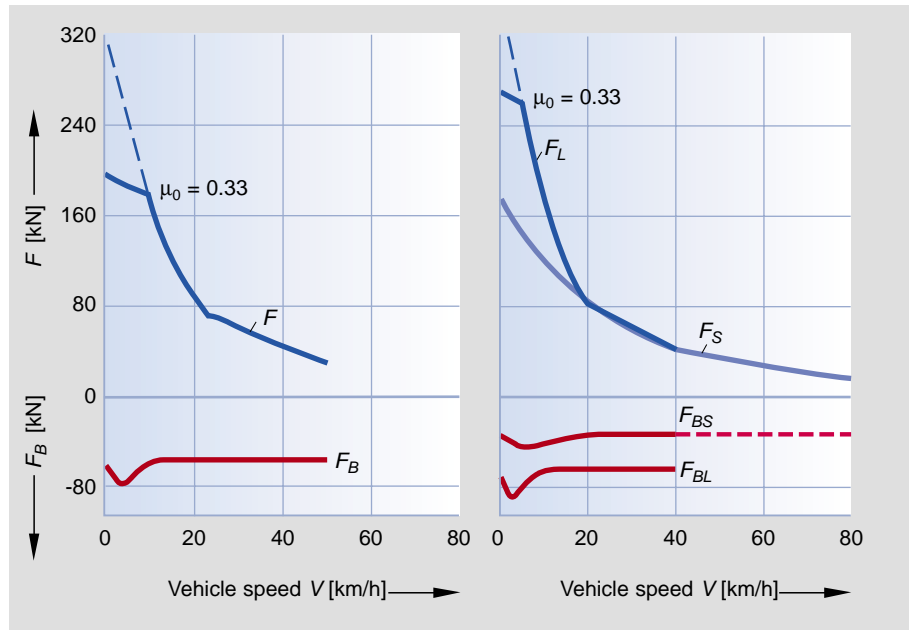


Fig. 6: **Traction F (low-speed gear) and braking effort F_B** of a L 3r4 turbo reversing transmission in a 3-axle multi-purpose locomotive, weight 60 t, max. speed 50 km/h, transmission input power $P_1 = 650$ kW.

Fig. 7: **Traction effort F_L (low speed gear), F_S (high speed gear) and braking effort F_B** L 3r4 zse turbo reversing transmission with range-change gearbox for a multi-purpose locomotive, weight 80 t, max. speed 40/80 km/h.

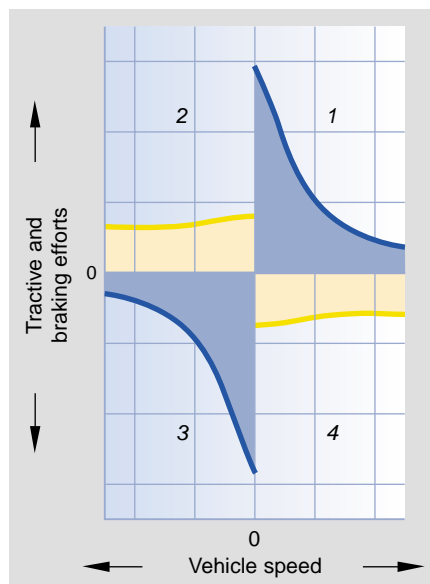


Fig. 8: **Four-quadrant chart**
 1 Traction – Direction A
 2 Dynamic braking – Direction B
 3 Traction – Direction B
 4 Dynamic braking – Direction A

Technical data	L 3r4 z	L 3r4 zse
Transmission input power $P_{1 \max}$	650 kW	650 kW
Transmission input speed n_1	see performance chart	
Transmission output speed n_2	variable with different gear sets	$n_2 = 2840 \text{ min}^{-1}$ (with maximum input)
Oil filling without pipes and heat exchanger	100 l	100 l
Transmission control	electric-hydraulic or pneumatic-hydraulic	electronic-hydraulic
Distance input/output	830 mm	840 mm
Mass	2100 kg	2800 kg
Towing speed***	80 % (100 %**) V_{\max}	125 % V_{\max}^*
Rapid transmission disengagement to avoid wheel-spin	additional electro-hydraulic feature	via electronic control
Constant-speed mode	via locomotive control	Voith Turbo Control and engine control system
Diagnosis and operating data	via locomotive control	Voith Turbo Control

* Duration limited to 10 hours, afterwards engine needs to be restarted.

** For towing periods < 15 min.

*** The indicated towing speeds only apply to the turbo transmission. Cardan shafts and driving characteristics of the locomotive need to be checked separately.

Fig. 9:
Performance chart

P_1 = Transmission input power
 n_1 = Transmission input speed

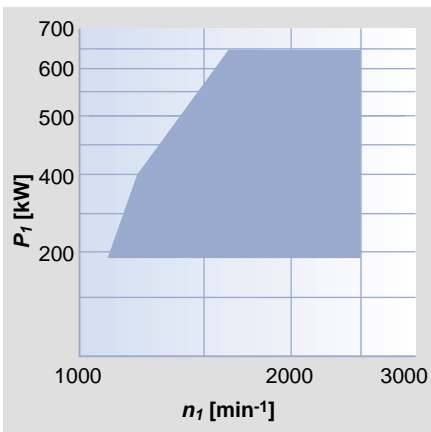


Fig. 10:
Dimensions
in mm

